MEASURING PLANT LEVEL PRODUCTIVITY

By

A. GHOBADIAN, B.Sc., M.Sc.

VOL II

A thesis submitted to the
Loughborough University of Technology
In partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Engineering Production
Loughborough University of Technology
April 1982

CONTENTS

ABSTRACT

Changes in productivity levels are increasingly recognised as a major influence on a wide array of macro- and micro-economic problems. Despite the importance attached to changes in productivity amplitudes, a wide-spread confusion exists as to the definition, nature, methods of measurement and effects of productivity adjustments.

At macro-level, there have been some outstanding efforts over the years to define and quantify the mechanics of productivity. However, there has been less activity at company level. Most of the literature has been limited to developing partial labour productivity and to a lesser extent machine utilization measures. These are totally inadequate as they reflect the joint effects of a variety of factors including the substitution of one factor for another.

The object of this research is to clarify the definition, nature and effects of productivity adjustments at company level. It examines productivity measurement techniques and their applicability to companies engaged in batch production. It also demonstrates some improvements to the theoretical foundations of existing techniques and applies methods not traditionally used for productivity assessments. Finally, it provides detailed definitions and statistical techniques for measurement of inputs and outputs of an enterprise.

The techniques used were "Total Factor", "Added Value", "Productivity Analysis", "Productivity Costing" and "Production Functions". These were selected because they reflect conceptions closely related to technological and engineering concepts of productivity.

The thesis initially examines the general concepts of evaluation of effectiveness and productivity. A comprehensive literature survey is provided in Chapter 4. From Chapters 5 to 13 we examine the theories of the techniques mentioned above and demonstrate their applications with the aid of two major industrial case studies. Manufacture in both companies was organised along orthodox batch modes. In Company A, production characteristics were close to "Flow Line" while in Company B, operations tended towards those of a "Jobbing" shop. Chapter 14 is concerned with the statistical examination of the data collected.

The original contributions made by this study are:

(1) A comprehensive application of existing techniques to measurement of productivity of batch producers.

(2) Augmentation of the theoretical foundation of these techniques.

(3) Provision of formal definitions and statistical techniques for the measurement of heterogeneous outputs and inputs. Also, the introduction of some unique measurement techniques.

(4) Use of "Production Functions" for measurement of productivity at plant level.

(5) Correlation and regression analysis of empirical data, which shows total productivity to be a function of all partial productivities and that it is a misconception to treat labour productivity as the sole measure of efficiency of a company; and

(6) Two comprehensive computer programs which simulate and optimise the operations of a company in terms of its productivity performance.

LIST OF TABLES

VOLUME 2

Page

CHAPTER 10

LIST OF FIGURES

VOLUME 2

CHAPTER 11

Page

CHAPTER 12

CHAPTER 13

CHAPTER NINE

PRODUCTIVITY ANALYSIS: CONCEPT AND THEORY

9.1 Introduction

In this chapter we describe in some detail the theoretical foundation of the "Productivity Analysis" technique. Gold (Refs. 1, 2, 4, 5), the main protagonist of this approach, constructed a framework consisting of three tiers representing a shift in performance measure from (physical input / physical output) to (financial input / physical output) to (financial input / financial output) at successively higher levels of aggregation within the firm.

Gold's analysis at (physical input / physical output) and (financial input / physical output) levels is solely concerned with direct inputs: a considerable shortcoming. Indirect inputs are an integral part of production, in the modern and complex industrial systems and should be included in any analysis of productivity.

To overcome this shortcoming, the author has amended Gold's framework to include an analysis of indirect input productivities at physical level, as well as the financial physical level. This enables the analyst to determine the effect of variation of indirect inputs on unit cost and consequently on the rate of return on investment.

Also, various approaches to index numbers formulations are discribed in this chapter, as well as the measurement techniques used.

9.2 Physical Relationships, Direct Inputs

Production usually involves integrating the contributions of many kinds of materials and purchased supplies, a variety of labour skills, numerous types of capital facilities and equipment and a wide array of technical and managerial efforts in order to fabricate a range of products. Appraisals of the efficiency of this entire complex of activities must obviously encompass all of the inputs and outputs.

In order to meet the requirements of practical decision-making by management, productivity analysis must be transformed so as to cover the following (Refs. 1, 4, 5, 6):

(1) changes in the level of each category of input requirements per unit of output, including materials, facilities, investment and indirect personnel, as well as direct labour;

(2) changes in the proportions in which inputs are combined, both in order to take account of substitutions (e.g., buying more highly-fabricated components instead of making them, or replacing labour with machinery) and also in order to differentiate between changes in the productivity of major as against minor inputs;

(3) differences between the productivity of inputs when they are fully utilized and when their contributions are reduced by idleness (e.g., as in the case of under-utilized equipment); and

(4) variations in all components of this "network of productivity relationships" as viewed simultaneously by managers capable of adjusting relationships among them in the interests of improving aggregate performance relative to specified criteria.

One means of meeting these needs is the network of productivity relationships which covers the direct inputs (Ref. 1). As shown in Figure 9.1, the network of productivity relationships has six links. Three cover the input requirements per unit of output not only for labour, but also for materials and for fixed capital. The productivity of net fixed investment is determined by comparison with productive capacity rather than output to permit differentiating between the productive contributions available from capital goods and the extent to which they may be under-utilized because of market pressures. Thus,

$$\frac{\text{Output}}{\text{Fixed Investment}} \equiv \frac{\text{Capacity}}{\text{Fixed Investment}} \times \frac{\text{Output}}{\text{Capacity}}$$

(Apparent productivity of fixed investment) (Potential productivity of fixed investment) (Utilization rate)

The remaining three links cover the proportions in which these are combined, e.g., the extent to which more highly-processed materials or additional facilities may be substituted for the labour. Because of the possibility noted above that capital facilities may be under-utilized in computing actual factor proportions; net fixed investment is adjusted for the utilization rate.

By presenting productivity relationships as a network of interactions, this approach emphasizes that a change in any component, such as output per man-hour, may be merely the passive result of changes initiated elsewhere in the network because all six components must be brought back into balance with one another after an initiating impact in any component. For example, the partial displacement of labour by additional machines would represent an initiating impact on the ratio of man-hours to actively utilized facilities and would lead to the increased output per man-hour, even if the remaining labour continued to work at unchanged tasks and at an unchanged pace. But the adjustment process would not yet be completed. The increase in output per man-hour would require either a reduction in man-hours if output remained at the earlier level, or an increase in materials inputs to permit the maintenance of total man-hours by increasing output in proportions to gain in output per man-hour. In either case, the ratio of man-hours to materials input would decline; thus completing the adjustment cycle on the assumption that the replacement of labour by additional machines involved no change in material requirements per unit of output or in the ratio of capacity to fixed investment. In short, it is necessary to identify the source of the innovational impact instead of assuming that it was necessarily engendered within any component registering a change.

The productivity network approach also draws attention to the possibility, and the significance, of concomitant changes in the productivity of materials and capital inputs. It would seem appropriate, therefore, in appraising how a particular firm or sector of industry compares with foreign competitors to supplement the generally-dominant concern with output per man-hour with analysis of each of the other five components of the productivity network. Indeed, it is quite conceivable that differences in the productivity of capital could be substantially greater than those of the output per man-hour. Such a finding would then engender new lines of enquiry seeking to determine the relative contributions to this outcome of such factors as more advanced technology, larger-scale operations, newer facilities, and lower facilities construction cost per unit of productive capacity.

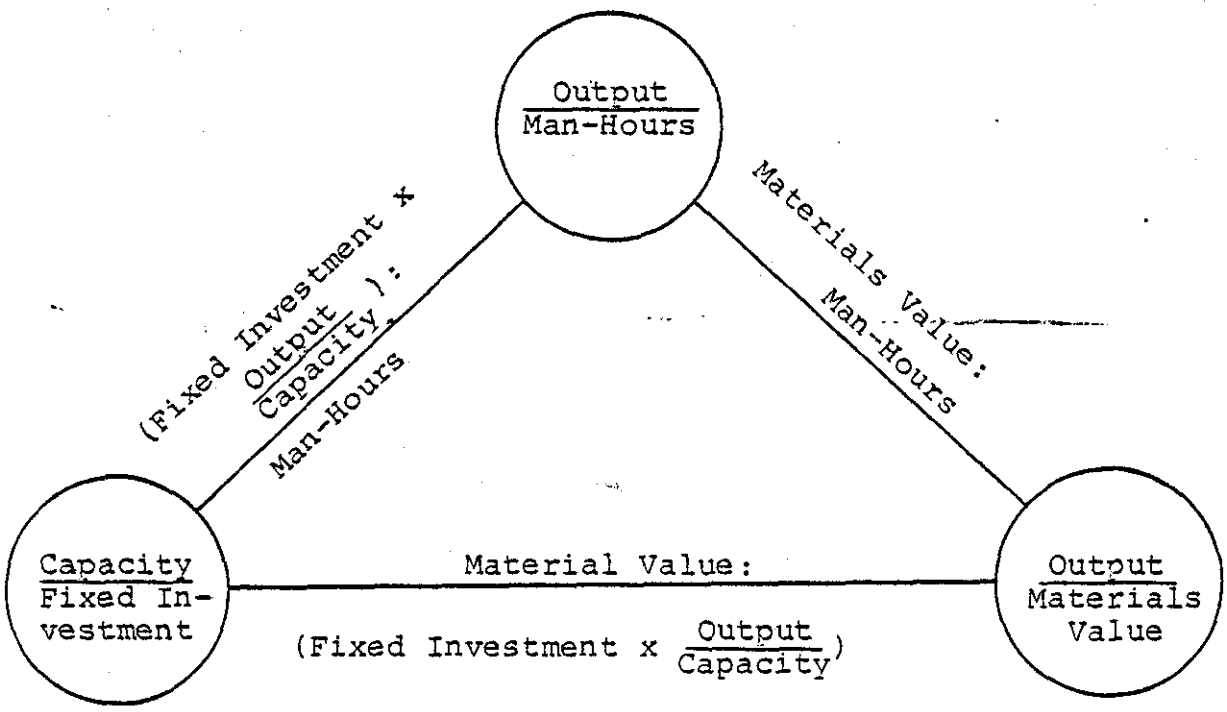


Figure 9.1 The Network of Productivity Relationships among Direct Input Factors

9.3 Physical Relationships, Indirect Inputs

Gold's approach to productivity analysis (Refs. 1, 2, 4, 5, 6) has one very important weakness, in so far as it excludes the indirect input productivities. These are inputs which are not directly connected with the production processes, such as indirect labour (who are usually compensated monthly), working capital which includes items such as stocks and debtors, and finally, inputs which do not appear in the final products; such as, indirect materials, utilities, etc.

In modern and complex industrial systems, indirect inputs are an integral part of production, and should be included in any attempt concerning the analysis of the productivity; as they profoundly affect the total productivity of a system and its unit costs.

As shown in Figure 9.2, the network of indirect productivity relationships has four links. Three cover the input requirements per unit of output for indirect labour, other inputs (as defined in Chapter 5), and working capital. The remaining link covers the proportion in which indirect labour and other inputs combine.

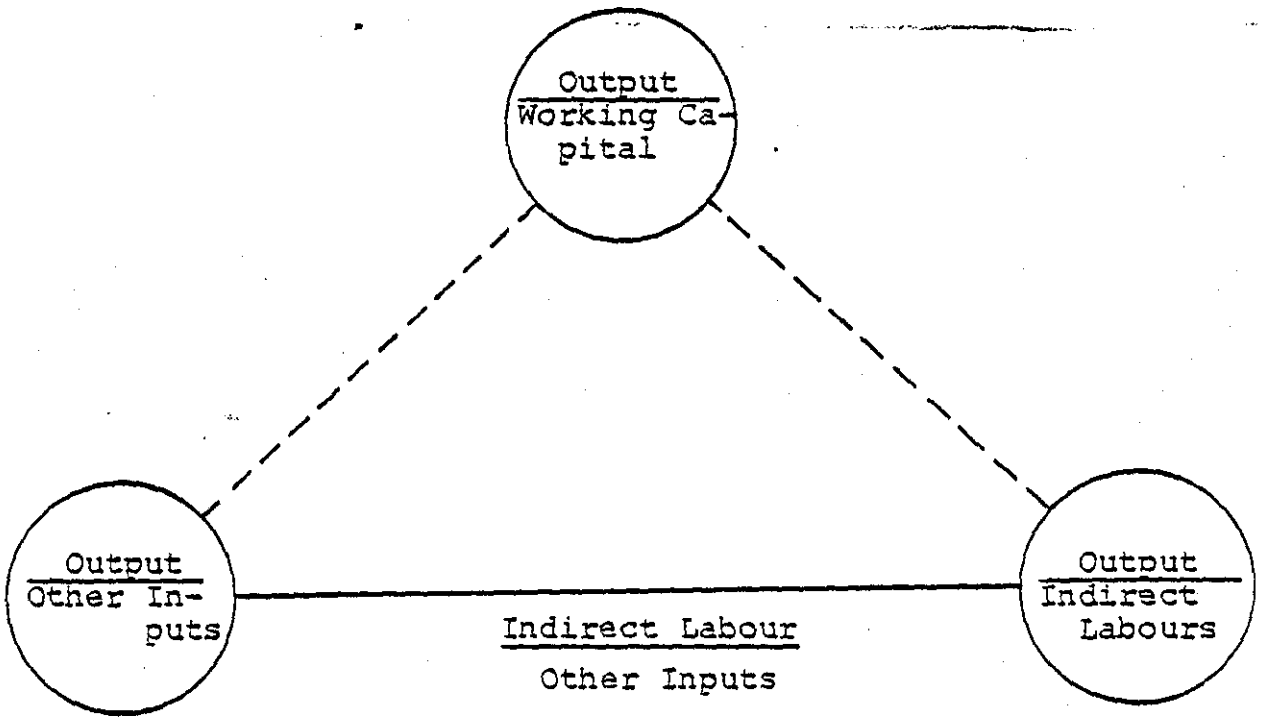


Figure 9.2 The Network of Productivity Relationships among Indirect Input Factors

The inclusion of indirect labour input (salaried) employees in analysing productivity is becoming progressively more important, as more and more employees are being compensated monthly.

The other inputs usually include the expenditure for office automation and use of computers. Generally speaking, the cost of office automation is treated as current expenditure rather than fixed investment. In view of increasing "new technology" being introduced to replace the clerical functions performed by labour, measurement of other inputs productivity and the extent which indirect labour is replaced by various computer hard- and software, and the effect of these changes on the unit cost are of paramount importance.

Working capital has a direct influence on the productivity of a manufacturing system. Management has often to face a dilemma of how much stock to carry. The answer depends on factors such as capacity utilization, state of the market, cost of capital, etc. There is no easily-recognisable linkage between the working capital and indirect labour and other inputs. However, computerisation of stock control procedures could lead to a more effective stock management, which in turn could influence the working capital productivity and to that extent there is a linkage between these two input factors. Furthermore, computerisation of stock control system could result in the reduction of clerks employed in documentation of stock, and hence, in an indirect manner: a linkage between working capital and an indirect labour input factor.

9.4 The Rôle of Productivity Networks

The analytical approach to productivity measurement described in the two previous sections involved four successive stages: the first expanded the analysis to cover each of the three basic categories of direct inputs (labour: man-hours, purchased materials and fixed investment); the second encompassed the proportions in which these direct

inputs are combined as well as their individual input quantities relative to output; the third also allowed for variations in the degree of utilisation of relatively fixed inputs (e.g., machinery), and the fourth extended the analysis to indirect inputs (e.g., salaried employees, other inputs and working capital). But this still leaves productivity measures crystallised at the level of relationships between aggregates -- between the total value of each input and total output (or capacity) -- implying that productivity analysis has no concern with what happens inside "the black box" into which inputs are absorbed and out of which products flow.

Effective management, however, requires penetration beneath aggregate productivity relationships to the behaviour of the components which comprise them (Ref. 2) -- entering into what we call "point efficiency" or interior sectoral studies. Thus, aggregate output might be decomposed into the output of each product line and separate networks of input-output measures developed for each, as is demonstrated in the following chapter. Alternatively, the entire production process might be divided into successive operations or departments with input-output relationships developed for each. And subdividing each stage by product, or subdividing each product by stage of production, would yield input-output relationships for still smaller cellular components of the activity system.

Such approaches would provide progressively more explicit guides to detecting the loci of all significant changes in input-output relationships and then probing attendant causes and effects over a wider sector of associated operations (Ref. 12). Thus, adjustments in aggregates could be traced back to their roots and the effects of localized innovations could be traced through the aggregate relationships. In addition, productivity measures might be developed having coverage of activities which would conform with established organizational grouping, thus integrating such measures into the structure of administrative controls.

9.5 Cost Structure

Management cannot evaluate the net benefits of a past innovation solely on the basis of data specifying resulting adjustments in each of the six components of the network of direct productivity relationships and four components of the network of indirect productivity relationships (Refs. 9, 10). Nor can management choose between alternative innovations on the basis of estimated effects on each of these components. Estimates of such relationships are critical elements in appraising their economic implications, but the analysis must be extended to include the latter if it is to serve as a sound basis for managerial decisions. A first step in this direction would involve exploring the cost effects of changes in unit input requirements and factor proportions by superimposing the "structure of costs" on to the "network of productivity relationships" as shown in Figure 9.3 (Ref. 9).

The effect of changes in output per man-hour on unit wage cost depends, of course, on concomitant changes in wage rates. Similarly, the effect of changes in unit material requirements on unit material cost depends on accompanying changes in the price of such materials. The consequence of changes in the productivity of fixed investment on the costs of such investments per unit of output depends on the annual rate of charges on such investment as well as on the rate of utilization of capacity. The effect of changes in indirect labour productivity depends on changes in salary rates. And the effect of changes in output per other inputs on unit's other cost depends on the rate of changes of these costs, etc. Algebraically, these may be expressed as follows:

$$\frac{\text{Wage-Cost}}{\text{Output}} \equiv \frac{\text{Man-hour}}{\text{Output}} \times \frac{\text{Wages}}{\text{Man-hours}}$$

$$\frac{\text{Materials Cost}}{\text{Output}} \equiv \frac{\text{Materials Volume}}{\text{Output}} \times \text{Material Price}$$

$$\frac{\text{Fixed Investment Charges}}{\text{Output}} \equiv \frac{\text{Fixed Investment Charges}}{\text{Fixed Investment}} \times \frac{\text{Fixed Investment}}{\text{Capacity} \times \frac{\text{Output}}{\text{Capacity}}}$$

$$\frac{\text{Salaries - Cost}}{\text{Output}} \equiv \frac{\text{Number of Salaried Staff}}{\text{Output}} \times \text{Average Salary Rate}$$

$$\frac{\text{Other Inputs Cost}}{\text{Output}} \equiv \frac{\text{Volume of Other Inputs}}{\text{Output}} \times \frac{\text{Other Inputs Cost}}{\text{Vol. of Other Inputs}}$$

$$\frac{\text{Cost of Financing Inventory}}{\text{Output}} \equiv \frac{\text{Working Capital}}{\text{Output}} \times \text{Weighted Cost of Capital}$$

What is being emphasized in this framework, however, is the necessity of considering interactions between productivity adjustments and factor prices instead of continuing to make the simplifying assumptions that the latter remains unchanged.

In turn, the effect of a change in unit wage costs on total unit costs depends on the proportion of total costs accounted for by wages as well as on the accompanying change in other unit costs weighted by their respective share of ~~total~~ costs. Hence, changes of total unit cost from period 1 to period 2, compared with period 1, is given by (Refs. 1, 6):

$$\Delta\left(\frac{\text{Total Costs}}{\text{Output}}\right)_{2,1} \equiv \left[\Delta\left(\frac{\text{Wage Costs}}{\text{Output}}\right)_{2,1}\left(\frac{\text{Wage Cost}}{\text{Total Cost}}\right)_1\right] + \left[\Delta\left(\frac{\text{Material Cost}}{\text{Output}}\right)_{2,1}\left(\frac{\text{Material Cost}}{\text{Total Cost}}\right)_1\right] + \left[\Delta\left(\frac{\text{Salaries Cost}}{\text{Output}}\right)_{2,1}\left(\frac{\text{Salaries Cost}}{\text{Total Cost}}\right)_1\right] + \left[\Delta\left(\frac{\text{Other Costs}}{\text{Output}}\right)_{2,1}\left(\frac{\text{Other Costs}}{\text{Total Costs}}\right)_1\right] \quad (9.1)$$

Integration of the productivity and cost structure networks thus relate changes in "apparent" input productivities and factor proportions through factor prices to each of the

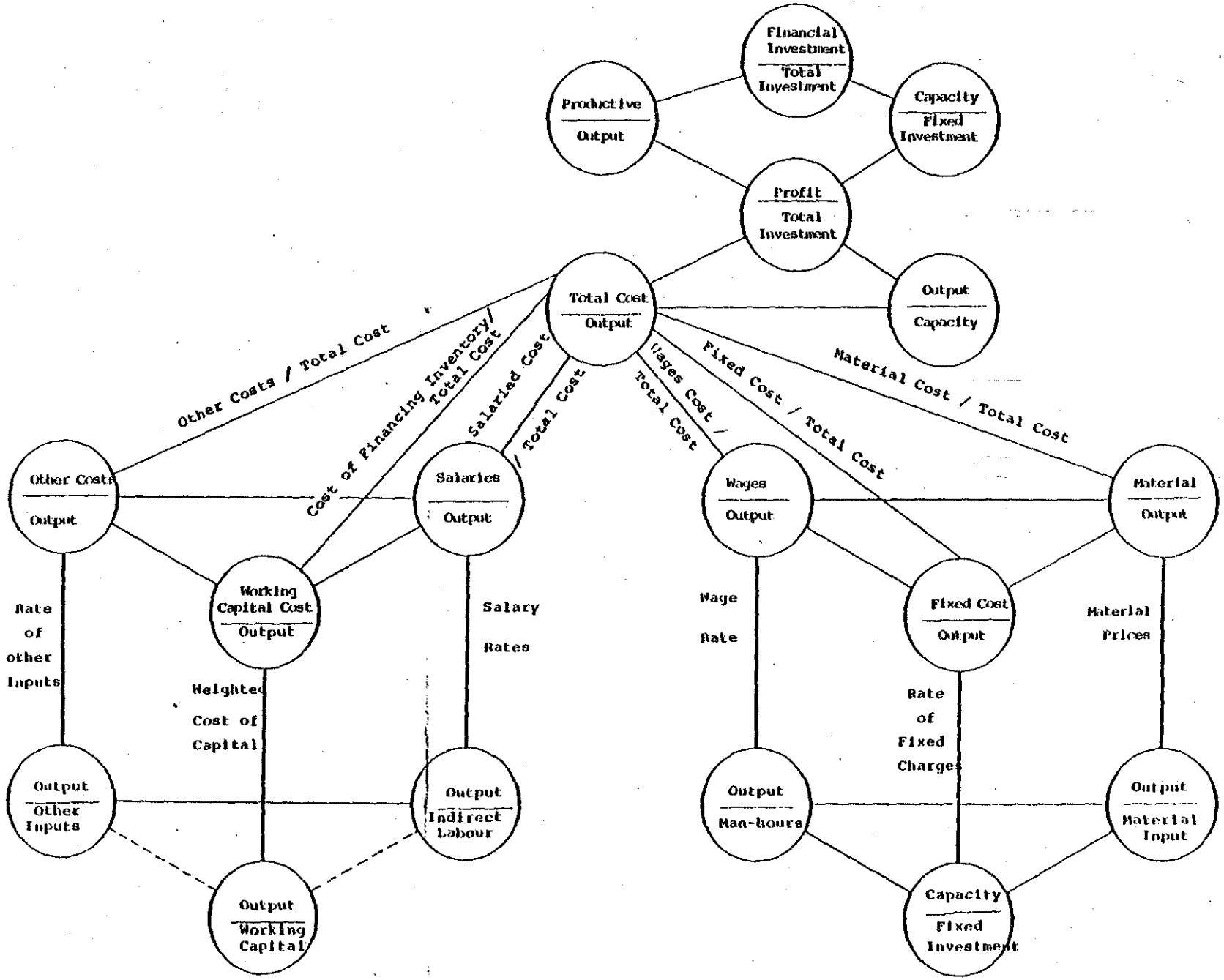


Fig 9.3 Productivity Network, Cost Structure and Managerial Control Ratios

unit costs; and it also relates changes in individual unit costs through cost proportions to total unit costs. Hence, it identifies the additional kinds of information required to evaluate the prospective effects on total unit costs of given patterns of past or anticipated changes in the network of productivity relationships.

9.6 Managerial Control Ratios

From a micro-economic point of view, no firm is dominated by the objective of maximizing a physical output relative to physical inputs. Similarly, managerial decisions in private industry obviously cannot be based on the minimization of total unit cost in view of the overriding importance of the rate of profit on investment (Refs. 7, 8). Consequently, the managerial evaluations of productivity adjustments must reach beyond their probable effects on total unit costs to consider additional possible side effects influencing the rate of profit on investment (Ref. 11).

Figure 9.4 shows business activity as a four-stage process consisting of inflows of financial resources from investors and lenders, the conversion of these into physical inputs, the transformation of such inputs into physical outputs, and the conversion of physical goods and services through sales into financial outflows, which are allocated to lenders and investors, and fed back into the business (Ref. 6). Investors and lenders virtually monopolize the upper, or financial, level of these flows -- substituting for the actual conversions into physical resources and eventually back into financial flows (see broken line).

Efforts to dig beneath the final measure of business performance represented by the rate of profit on investment have long been dominated by various sets of financial ratios. The reason for this is the nature of the involvement of the suppliers of the funds with the firm, as shown in Figure 9.4. As is evident, their interests are encompassed by the financial level of flows, and therefore financial evaluations dominate the annual reports of corporate performance from which these ratios are determined.

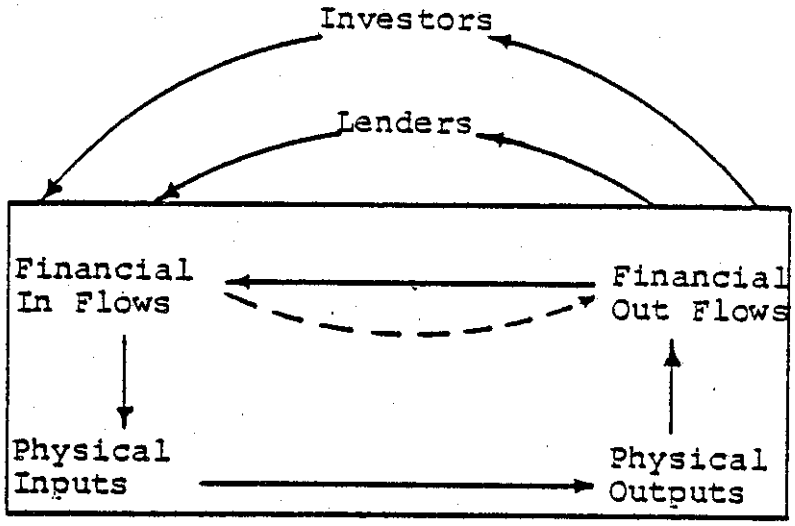


Figure 9.4 Physical and Financial Resource Flows within the Firm

Although committed to certain of the same objectives as investors, operating management's primary responsibilities centre around the adjustments of the level and composition of the physical inputs and outputs through which financial inflows are converted into larger financial returns (Ref. 6). Thus, as indicated in Figure 9.4, management requires criteria of performance relating financial outlays to physical input quantities, physical output quantities to physical input quantities, and the financial value of outputs to their physical volume. Such measures parallel the sequential process starting with the conversion of investment funds into physical input flows through the price and quantity commitments of procurement and hiring staff in material, capital goods and labour markets. These are transformed into a flow of products through production and assembly operations. And such physical output is converted into a revenue flow through sales efforts leading to price and quantity commitments in product markets.

In addition, management needs sufficient elaboration of this network at various levels of activity to differentiate between short-term and longer-term determinants of aggregate performance, and between internally-controlled and externally-

imposed adjustments. Finally, management requires the extension of such an integrated structure of performance criteria to lower levels of organisational activity progressively (Ref. 6).

The resulting framework would help to trace changes in aggregate levels of performance back through intervening linkages to the initiating units. It would guide efforts to explore the likely ramifications of prospective changes in specified operations. Moreover, it would assist planning by specifying the magnitudes of component adjustments necessary to achieve proposed aggregate advances, and by highlighting the interactions likely to be triggered by prospective innovations.

Based on the assumption that management's primary measure of aggregate performance is the rate of profit on investment, the areas of decision-making which affect this objective may be identified by proceeding through the five simple stages of analysis reviewed below (Refs. 1, 9, 10, 11, 12). The ratio of profit (before tax) to total investment may be regarded as determined by the ratio of profit to physical output and by the ratio of output to total investment:

$$\frac{\text{Profit}}{\text{Total Investment}} \equiv \frac{\text{Profit}}{\text{Output}} \times \frac{\text{Output}}{\text{Total Investment}} \qquad 9.2$$

But profit per unit of output is determined by the difference between the average gross receipts per unit of output (i.e., average realised price) and average total costs per unit of output:

$$\frac{\text{Profit}}{\text{Output}} \equiv \underbrace{\frac{\text{Product Value}}{\text{Output}}}_{\text{(Average Price)}} - \underbrace{\frac{\text{Total Costs}}{\text{Output}}}_{\text{(Average Unit Cost)}} \qquad 9.3$$

In seeking the determinants of changes in the ratio of output to total investment (the final ratio in [9.2]), one may follow the process whereby the latter is linked to the former. Specifically, part of total investment is allocated to facilities and equipment which determine productive

capacity and it is the latter which determines output potentials. Hence, changes in the ratio of output to total investment may be regarded as determined by the ratios of output to productive capacity, of productive capacity to fixed investment, and of fixed investment to total investment:

$$\frac{\text{Output}}{\text{Total Investment}} \equiv \underbrace{\frac{\text{Output}}{\text{Capacity}}}_{\text{(Utilisation Rate)}} \times \underbrace{\frac{\text{Capacity}}{\text{Fixed Investment}}}_{\text{(Productivity of Fixed Investment)}} \times \underbrace{\frac{\text{Fixed Investment}}{\text{Total Investment}}}_{\text{(Internal Allocation of Capital)}} \qquad 9.4$$

Thus changes in the ratio of profit to total investment may be attributed to five areas of performance: product prices (Total Product Value/Output); unit costs (Total Costs/Output); utilisation of facilities (Output/Capacity); productivity of facilities and equipment (Capacity/Fixed Investment); and the allocation of investment resources between capital goods and working capital (Fixed Investment/Total Investment):

$$\frac{\text{Profit}}{\text{Total Investment}} \equiv \left(\frac{\text{Product Value}}{\text{Output}} - \frac{\text{Total Costs}}{\text{Output}}\right) \times \frac{\text{Output}}{\text{Capacity}} \times \frac{\text{Capacity}}{\text{Fixed Investment}} \times \frac{\text{Fixed Investment}}{\text{Total Investment}} \qquad 9.5$$

Moreover, a shift in focus to the ratio of profit to equity investment would add a sixth area of decision-making concerned with the structure of financing:

$$\frac{\text{Profit}}{\text{Equity Investment}} \equiv \frac{\text{Profit}}{\text{Total Investment}} \div \frac{\text{Equity Investment}}{\text{Total Investment}} \qquad 9.6$$

These six managerial control ratios provide a useful basis for planning and performance evaluation, for they represent a blend of physical and financial aspects of resource flows, of short- and long-term perspectives, and of the stock and

flow components of the system. Specifically, since capacity, and fixed and total investment tend to change very much more slowly than the sales (or value of product), costs and output, the first three ratios in 9.5 would tend to determine short-term changes in profit/total investment. Long-term changes in the latter would be traceable, in turn, not only to the remaining two control ratios, but also to persistent trends in the first three. Both the physical and financial aspects of stock and flows are accordingly encompassed.

As is shown in the following chapter, applications of this network of managerial control ratios to the performance records of particular firms or plants can reveal which of the strategic areas of decision-making contributed most or least to observed adjustments in the rate of profits on investment. Moreover, if the analysis is applied to records covering a long period, the findings may be expected to reveal any persistent trends in the sources of upwards and downwards pressures on the rate of returns, and also to spotlight the sectors most likely to shift between exercising favourable and unfavourable effects.

This analytical framework, as is shown in the following chapter, may also be used in forward planning to help analyse either the probable effects of expected changes on the rate of return or the alternative combination of adjustments needed to achieve specified profits.

9.6.1 Comparison of managerial control ratios and financial ratios

The traditional array of financial ratios centre around total sales, total costs and total profits from the income statement, and around fixed investment, working capital, total investment and net worth from the balance sheet. However, differences may be observed in the detailed subdivisions of costs and investments (Refs. 13, 14, 15). In evaluating general performance, the ratios used most commonly relate profit and sales to total and equity investment;

profit and costs to sales; and working capital and net worth to total investment. Models used by well-known industrial corporations for top management control purposes follow closely parallel lines. Du Pont emphasises Profit/Sales, Sales/Total Investment and Profit/Total Investment as well as the composition of the cost of sales, of working capital and total investment (Ref. 15). Monsanto concentrates on Profits/Investment, Net Income/Investment, Sales/Property, and the ratio of selling expense, operating expense and cost of goods sold to sales (Ref. 16). Armstrong Cork and West Virginia Pulp and Paper methods reflect essentially similar patterns (Ref. 17).

Comparisons reveal that the managerial control ratios cover most of the basic variables entering into these financial ratios and would cover most of their key relationships as well, if -- as shown in Figure 9.5 -- the network of managerial control ratios was elaborated to include the following three intermediate relationships:

$$(1) \quad \frac{\text{Profit}}{\text{Total Investment}} \equiv \frac{\text{Profit}}{\text{Sales}} \times \frac{\text{Sales}}{\text{Total Investment}}$$

$$(2) \quad \frac{\text{Profit}}{\text{Sales}} \equiv \frac{\text{Profit}}{\text{Output}} \div \frac{\text{Sales}}{\text{Output}}$$

$$(3) \quad \frac{\text{Sales}}{\text{Total Investment}} \equiv \frac{\text{Sales}}{\text{Output}} \times \frac{\text{Output}}{\text{Total Investment}}$$

Hence:

$$(4) \quad \frac{\text{Profit}}{\text{Total Investment}} \equiv \frac{\text{Profit}}{\text{Output}} \times \frac{\text{Output}}{\text{Total Investment}}$$

In addition, the managerial control ratios include consideration of changes in prices, output, capacity, facilities utilisation and investment requirements per unit of capacity -- and delineate their interactions with one another and with solely financial aspects of operations in shaping adjustments in measures of aggregate performance. These additional bases for managerial control obviously cannot be

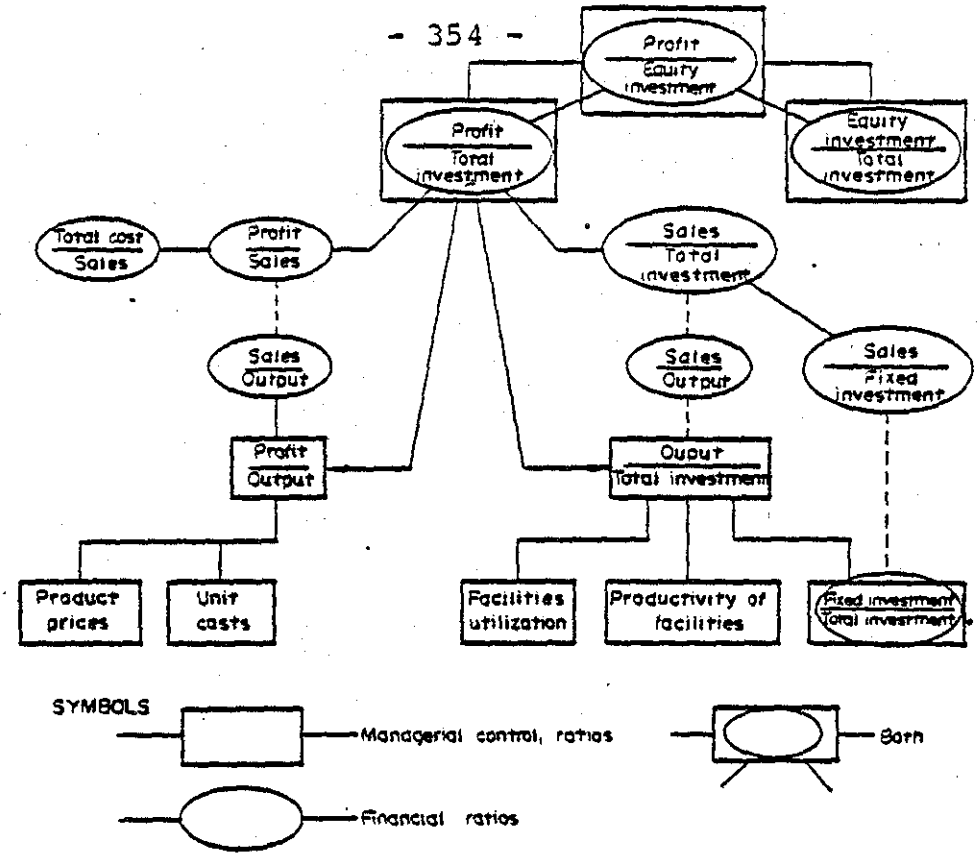


Figure 9.5 Comparison of Managerial Control and Financial Ratios

used in place of the financial ratios. But it seems reasonable to suppose that, in most industrial situations, management would secure additional, practically useful guides to control with a system of managerial control ratios supplementing pure income, outflow and investment relationships, with a variety of measures designed to represent the physical side of production and to bridge the gap between the physical and financial aspects of operations.

9.6.2 Elaborations of the network of managerial control ratios

Managerial control ratios also lend themselves to further disaggregation, identifying performance criteria for successively more specialised sectors of activity and permitting appraisal of the relative dominance of such results by internally-controlled and by external forces (Ref. 11), as shown in Figure 9.6.

For example, changes in Product Value/Output, or the average price received for all products are traceable to adjustments not only in the price of each product, but also in the

relative volumes of different products sold -- the former often being more responsive to direct management controls than the latter. Thus, an increase in each product price may be accompanied by a decrease in the average price received for all products, if sales of the lower-priced products increase relative to sales of the higher-priced products. Similarly, changes in the average total cost per unit of output (Total Costs/Output) are determined not only by current changes in unit material, unit wage and each of the other component unit costs, but also by their respective proportions of total costs, as was discussed in Section 9.5. In turn, changes in each of these unit cost categories may be attributed to changes in the factor price and in the amount of that input required per unit of output, with the latter probably more responsive to direct managerial controls than the former.

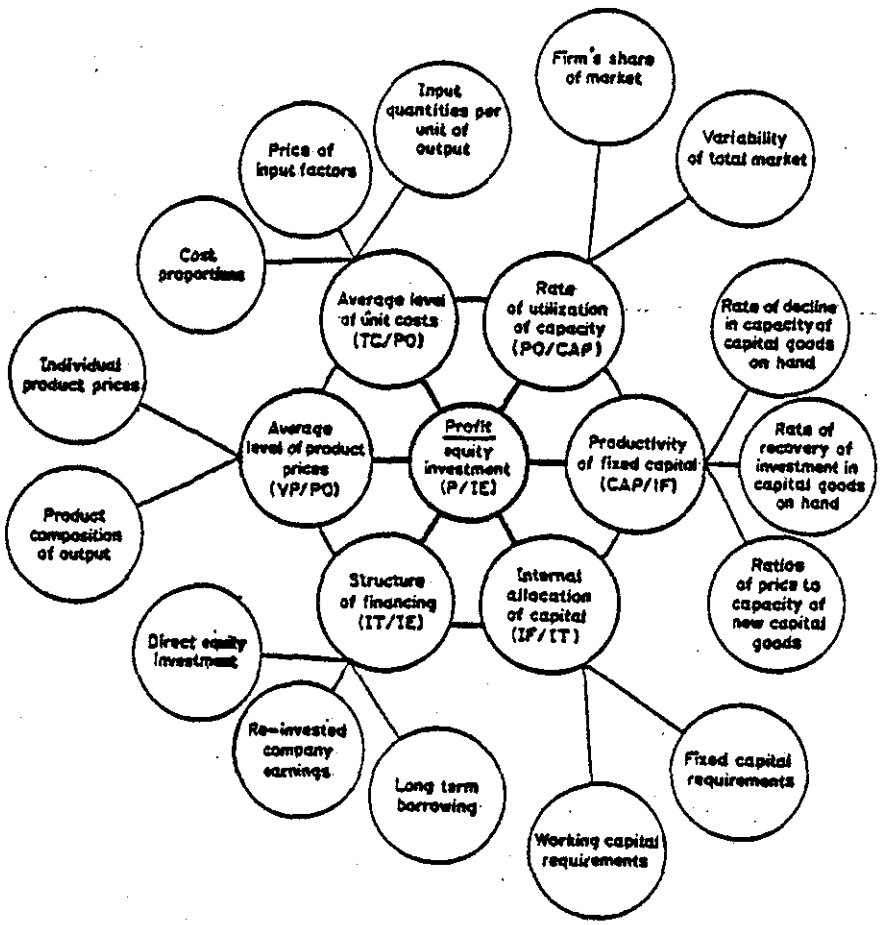


Figure 9.6 Simplified Model of Primary Managerial Control Ratios and of Factors Affecting Them

Continuing with this process of unravelling complex performance measures into their components, changes in Output/Capacity may be traced to two sets of factors. The firm's output adjustments may be due to changes in the total market for such products and in the firm's share of that total. Capacity adjustments may be due to technological advances, to wear, to obsolescence of the facilities and equipment, and to changes in the stock due to acquisitions and retirements.

Following this line of reasoning, changes in Capacity/Fixed Investment reflect adjustments in capacity relative to changes in net fixed investment resulting from depreciation and obsolescence changes as well as payments for newly-acquired additions to the stock. Changes in Fixed Investment/ Total Investment reflect managerial estimates of the relative need for productive capacity and for working capital to promote and finance capacity and utilisation.

Finally, managerial control ratios also encourage analysis of the continuous interaction of physical and financial aspects of operations in shaping aggregate performance adjustments in any sector. The successive linking of control ratios (each having one term identical with the ratio on either side) means that adjustments in output, capacity or fixed investment play inverse rôles in adjacent ratios and thus cancel each other out, unless the initiating adjustment exercises differential effects on the two variables with which it interacts in these ratios. Thus, increases or decreases in capacity can affect Profit/ Total Investment only if they induce differential changes in output and fixed investment, with which capacity is linked in the third and fourth control ratios (Equation 9.5). Any resulting changes in output and in fixed investment must then be traced through remaining control ratios to assess the final effects of the capacity adjustment on Profit/Total Investment. In fact, application of these managerial control ratios reveal the relative contributions of the six strategic decision-making areas to observed adjustments in Profit/Total Investment.

9.7 "Productivity Network", "Cost Structure" and "Managerial Control Ratios"

As is shown in Figure 9.3, "managerial control ratios" may be integrated with the "network of productivity relationships" and with the "structure of cost relationships" to provide a unified framework for systematically exploring the complex of interactions linking changes in factor inputs and factor prices to unit costs and cost proportions and to the other determinants of changes in the rate of profits on investment.

This structure in fact demonstrates a shift in performance measures from (Physical Input/Physical Output) to (Financial Input/Physical Output), to (Financial Input/Financial Output) at successively higher levels of aggregation within the firm.

This framework, as is demonstrated in the following chapter, may be used in analysing past performance; in developing integrated plans for achieving specified future targets; or in appraising alternative innovations, even when their initial impacts focus on different parts of the system.

9.8 Changes in Profitability Components -- the ~~r-Model~~

The managerial control ratios presented in Section 9.6 may be expressed as follows:

$$\frac{\text{Profit}}{\text{Total Investment}} = \left(\frac{\text{Product Value}}{\text{Output}} - \frac{\text{Total Costs}}{\text{Output}}\right)\left(\frac{\text{Output}}{\text{Capacity}}\right) \times \left(\frac{\text{Capacity}}{\text{Total Investment}}\right) \qquad 9.7$$

or, $r = (p - c)ez$

$= aez$

where, r = return on total investment = Profit/Total Investment

p = unit price for the output

c = unit cost for the output

a = $p - c$ = unit profit for the output

e = Output/Capacity = capacity utilisation of the plant

$$z = \frac{\text{Capacity}}{\text{Total Investment}} = \left(\frac{\text{Capacity}}{\text{Fixed Investment}}\right) \times \left(\frac{\text{Fixed Investment}}{\text{Total Investment}}\right)$$

This is a simplified version of Equation (9.5), derived by combining the terms representing the productivity of fixed investment and the internal allocation of investment into a single "z factor", which then expresses the amount of capacity provided per unit of total investment. Equation (9.7), which for the sake of convenience is called the r model, reduces the return on total investment r to a dependence on three factors: the unit profit of the output, the capacity utilisation of the plant, and z factor (Ref. 6).

If at a given time the rate of return is given by $r = aez$ and if after a certain time period the rate of return becomes $\Gamma + \delta_r$, it may be expressed as:

$$r + \delta_r = (a + \delta_a)(e + \delta_e)(z + \delta_z) \qquad (9.8)$$

where δ_a, δ_e and δ_z are the corresponding incremental changes in a, e and z, respectively, during that period. The difference between (9.8) and (9.7) gives the incremental change δ_r as follows:

$$\delta_r = ez\delta_a + az\delta_e + ae\delta_z + z\delta_a\delta_e + a\delta_e\delta_z + e\delta_a\delta_z + \delta_a\delta_e\delta_z$$

Dividing the left-hand side by r and the right-hand side by aez and substituting the following:

$r^* = \delta_r/r$ = change in "r" relative to the original value of "r"

$a^* = \delta_a/a$ = change in "a" relative to the original value of "a"

$e^* = \delta_e/e$ = change in "e" relative to the original value of "e"

$z^* = \delta_z/z$ = change in "z" relative to the original value of "z"

we get:

$$r^* = a^* + e^* + z^* + a^*e^* + e^*z^* + z^*a^* + a^*e^*z^* \quad (9.9)$$

Where the relative changes of a*, e* and z* are small (say, below 0.1%), the last four terms in (9.9) may be ignored, reducing (9.9) to:

$$r^* = a^* + e^* + z^* \quad (9.10)$$

Equations (9.9) and (9.10) indicate how a relative change in the rate of return can be attributed to relative changes in the three factors in question and to the interactions between them. When (9.10) holds, the overall relative change in r is the sum of the relative changes in a, e and z. The last four terms in (9.9) represent residuals due to the combined effect of these factors, over and above their identified individual effects (the interaction of all three factors given by the last term in (9.9) is of third-order effect). Thus, if one wants to identify the total effect of a change in "a", then from (9.9) it would be (ignoring the last term a*e*z*):

$$a^*(1 + e^* + z^*)$$

The first term here describes the direct contribution of a*, the second term in the brackets represents the relative effect of the interaction of e* on this contribution, and the third term is the relative effect of z*. In special cases, simpler expressions are obtained. For example, when e and z remain constant over a period of time we find that r* = a*, namely the change in the rate of return is attributable to a change in the unit profit.

It is important to note that Equation (9.9) does not identify the original cause or causes that subsequently lead to a series of changes in the system and thereby to changes in the values of the three components a, e and z; it merely provides a decomposition of the relative change in the rate of return into its several constituent parts, so that their relative contributions can be better appreciated.

The application of this model is demonstrated in the following chapter.

9.9 Measurement -- Problems and Methods

The definition and problems involved in measurement of some of the factors presented in "productivity analysis framework", Figure 9.3, were in fact discussed in previous chapters dealing with total and value added productivity.

In this section we reflect on previous arguments, and we discuss the measurement of factors introduced in this chapter.

9.9.1 Measurement of output levels

As has already been stated, management requires measures of total output reaching beyond purely physical dimensions -- such as the number, weight or value of various products -- so as to aggregate the output of small and large, simple and complex products in terms of their economic significance. This can be done by weighting the output of each product in the base and in the comparison period by its price in the base period. Hence, any change in the resulting total value of all products between the two periods must be attributable to changes in physical output -- for the other determinant of total value, product prices, remains identical in the two periods. By, thus, measuring the relative contributions to output of different products in terms of their relative economic values, or by the cost of all resources absorbed into each plus its overlay of profits, this approach represents an "economically-oriented concept of physical output" (Ref. 6).

Such measures clearly facilitate managerial evaluations of operations by aggregating streams of physically differentiated products into unified total output flows. Another advantage of these methods is that they can accommodate the introduction and growth of new products as well as the decline and elimination of older products. These methods are also subject to serious limitations and

problems of interpretation (Ref. 3). First, resulting measures of output changes may obviously differ substantially from those obtained by using the technological criteria of engineers, or the weight and value criteria of freight handlers, or the service criteria of consumers. Second, the use of relative prices as measures of relative physical outputs per unit of product is clearly vulnerable both to the extent that relative profit margins differ among products (as is frequently the case) and to the extent that the ratios of value added to cost of purchased materials differ among the products.

Various types of quantity indexes are discussed more fully in the next section.

9.9.2 Measurement of input levels

Comparable problems occur in measuring inputs. The first question is, Which dimensions of each input category should be measured?; What is paid for?; or, What is used?; or, What productive contribution is derived? Labour inputs, for example, might be measured in terms of numbers employed, man-hours paid for, man-hours worked, energy expanded, skills applied, hazards borne and work completed which meets quality standards. Similarly, capital inputs might be measured in terms of investments made; the number or volume of equipment and facilities obtained; attendant productive capacity provided; capital charges during a period and actual output attributable to the operation of capital goods. Such choices have to be made partly because some of these dimensions are less amenable to effective measurement than others and partly because given purposes emphasise some dimensions over the remainder. It is important to recognise that the various dimensions need not vary in unison and hence that measurement of one may engender only misleading inferences concerning the movement of others.

The aggregation needs and difficulties are much greater in input measurements. These arise from large varieties of materials and supplies, skill classifications and different

types of equipment and facilities, required in the operation of industrial systems.

Various measurement techniques discussed in previous chapters are also applicable here. However, for the purpose of this analysis, various quantity indexes were computed. These indexes are similar in formulation to the output indexes and are discussed more fully in Section 9.10.

9.9.3 Productive capacity

Precise measurement of productive capacity is extremely difficult, particularly in the case of batch manufacturing enterprises, where circumstances and batch types change continuously. However, it is possible to develop useful estimates of practical capacity, especially under the following conditions (Ref. 1):

(1) If the measurement is focused on individual plants rather than on the economy at large or on major segments of it;

(2) If the measurement is focused on practically sustainable capacity at present rather than on some theoretical maximum under temporary conditions or in the future;

(3) If the estimate is made on the assumption that product design and quality, operating processes, and the general character of input remain unchanged; that the customary number of shifts and normally acceptable length of work day and work week are retained; and that appropriate standard allowances are made for breakdowns, reparis and maintenance;

(4) If it is assumed that sufficient labour, materials and other inputs are available to service the full utilisation of present capital facilities;

(5) If it is assumed that product and factor price adjustments are such as to press for efficient utilisation of all serviceable resources; and

(6) If it is assumed that standard mix of products is stable over time.

If the above limitations hold, then it is possible to estimate the practically sustainable capacity with moderate margins of uncertainty.

Assumptions concerning availability of labour, materials and other inputs needed to attain the productive potential of given capital facilities are generally considered reasonable in the case of studies limited to individual plants and firms. But this is less tenable for wider sectors of the economy, because simultaneous increases in demand for resources from many quarters may exceed the currently-available supply.

Even at the plant or departmental level the determination of capacity is subject to interpretation and problems of measurement. Take, for example, the special case of a single product routed through a series of machines in a plant; the capacity of each machine may be defined as the maximum physical quantity that can be processed during a time interval at given operating conditions, and the capacity of the whole plant would then be determined by the "bottleneck", namely, by the lowest rate of production along the sequence.

Such a definition assumes that agreement can be reached as to what is meant by "given operating conditions", and indeed that such conditions remain static. But changes under these conditions may well occur. It may be possible, for example, to speed up the rate of production of the constraining machine (and thereby to increase the capacity of the plant as a whole), perhaps at the expense of a higher rate of wear of the machine, or by involving higher maintenance costs. The rate of production may even depend at times on the quality and the cost of the input, and in turn it may affect the quality of the output. Thus, there could be several possible "states" of operating conditions, each state corresponding to a certain machine or plant

capacity, and this may occur even in the relatively simple one-product case.

Consider now the multi-product plant and the question of what is precisely meant by the capacity of this plant. Presumably, it is the set of all product-mixes that the designer and the plant manager expect the plant to produce per unit time, given the availability of material, labour and whatever other inputs necessary. In a labour-dominated process such a definition is not adequate, since capacity is then entirely dependent on the manpower level. Even in a capital-dominated process, capacity will depend on various factors, as mentioned earlier, such as the number of shifts worked, product mix, perhaps even on the quality of raw material.

Accepting the above definition and limitations inherent in estimating capacity, particularly in the case of batch manufacturing firms. Two estimating techniques are suggested by Gold (Ref. 1). These are: an estimate of total amount which can be produced of any given product, assuming some specified allocation of plant facilities to such an output; or, an estimate of composite productive capacity covering some specified mix of products. The latter requires resort to techniques similar to those used in measuring physical output adjustments — essentially involving combination of a productive capacity for each product through the use of relative prices as weights. The result cannot be stated in terms of physical units or in terms of absolute capacity, but only as a measure of changes in capacity relative to some specified base year. Such quasi-physical measures, however, may be used to encompass the total output potential of virtually all plants producing reasonably standardised products, whether such product lines are few or many in number; and capacity utilisation rates are determined by comparing the calculated aggregate physical output of a given product-mix with the capacity calculated for that same product-mix, using the same price weights for the output and capacity calculations.

Sustainable capacity could also be estimated by determining the standard mix of products, analysing cycle of operations and calculating machine times required for this output, using the established standard times of production. The computed standard hours of production for a standard mix of products provides a good estimate of the productive capacity of a company. This technique is demonstrated fully in Section 10.2.1 of the following chapter.

9.9.4 Fixed investment

From the standpoint of appraising its rôle in productivity adjustments, the measurement of fixed investment is focused on the current value of the capital facilities and equipment which embody such investment (Ref. 6). In common practice, this represents a deduction from the original value of such capital goods in accordance with the estimated wear and obsolescence undergone since their initial acquisition. Such estimates may be made by a variety of means, with consequent differences in results. Moreover, there is no demonstrably correct basis for making such estimates -- every procedure being open to significant sources of error both in estimating the pattern of physical deterioration through time and in estimating resultant effects on the value of such goods. If the intention is clear, ~~however~~, such estimates can be made by the management of each enterprise by whatever means it deems most useful. And so long as a consistent policy is followed in this area, such estimates may be quite adequate for the analysis of changes through time in each firm.

9.9.5 Financial data

The other data required for analysis based on the framework presented in Figure 9.3 are of financial nature. These are not discussed here in detail as they were discussed elsewhere. In general, it is sufficient to say that accounting systems of most industrial enterprises provide for regular determination of such information.

9.10 Aggregate Quantity Index Number

Inasmuch as value is the product of price and quantity, changes in the total physical output of a multiproduct plant or firm may be defined as the change in its total product value between any two periods not due to changes in its product prices. As has been argued previously, in order to permit the aggregation of qualitatively different resources, to maintain consistency in input-output comparisons and to ensure relevance to managerial criteria for performance evaluation, inputs, too, must be gauged in economically-oriented terms (i.e., relative-value weighted) rather than purely physical measures.

There are various methods by which changes in physical output-input, using relative value weights can be calculated. Obviously, the method used in the formulation of index number affects the calculations, in so far that different formulations yield different results. In this section we discuss the most widely-used quantity indexes and criteria which a good index should meet.

9.10.1 Criteria for a good index number

Fisher (Ref. 18) proposed two criteria for a good index number. One is called the time-reversal test and the second is called the factor-reversal test.

The time-reversal test can be explained as follows: Let I_{on} be an index for the year n based on year o, and I_{no} be the index for year o based on year n. Then, if

$$I_{on} \cdot I_{no} = 1$$

it satisfies the time-reversal test.

The factor-reversal test requires that the product of price index P (showing the change in prices from year o to n) and quantity index Q (showing the change of quantities from year o to n), P x Q, to show the change of values from year o to year n. In symbols, it requires,

$$P \times Q = \frac{\Sigma p_n q_n}{\Sigma p_o q_o}$$

where $\Sigma p_o q_o$ shows the amount of expenditure in year o and $\Sigma p_n q_n$ shows the amount of expenditure in year n.

9.10.2 Quantity index number

The quantity indexes measure the changes in the quantities from a base period. Here we discuss Laspeyre's, Paasche's, and Fisher's ideal indexes.

9.10.2a Laspeyre's formula

Laspeyre's Quantity Index can be defined as follows:

$$I_{q_L} = \frac{\Sigma q_n p_o}{\Sigma q_o p_o} \qquad (9.11)$$

The numerator of the above formula shows the value of goods for year n. The denominator shows the value of goods for the base year. Since the prices P_o are kept fixed as weights, any change is due to changes in quantities. Laspeyre's index does not, in general, meet the time or factor-reversal tests, the exception being in cases of only one commodity.

9.10.2b Paasche's formula

Paasche's Quantity Index can be defined as follows:

$$I_{q_p} = \frac{\Sigma q_n p_n}{\Sigma q_o p_n} \qquad (9.12)$$

As is evident, the difference between Paasche's and Laspeyre's formula is that Paasche's formula uses current year prices P_n instead of base year prices P_o. The numerator of the above formula shows the value of goods in the current year n. The denominator shows the value of goods in the base year in terms of current prices. Paasche's Quantity Index of a given year can be compared only with the base year. This is a very considerable disadvantage, and for this reason, this formula was not used in our case studies. Further, Paasche's index does not in general meet the time or factor reversal tests.

9.10.2c Edgeworth's formula

Edgeworth's formula, in terms of structure, is very similar to Laspeyre's formula. The only difference is that the arithmetic average of prices is used instead of the base and current year prices. This can be shown as follows:

$$P = \tfrac{1}{2}(P_1 + P_n) \qquad (9.13)$$

$$I_{q_E} = \frac{\Sigma q_n P}{\Sigma q_o P} \qquad (9.14)$$

Edgeworth's formula does not meet the time or factor reversal tests. However, the formula is widely used. The average price mechanism is brought in to ensure that the output index remains unchanged when the product-mix and the physical quantities remain unchanged. The index of the formulation of the index number on output is shown in the next chapter.

Another variation is the use of geometric average prices instead of the arithmetic average prices:

$$P = \sqrt{P_1 \times P_n} \qquad (9.15)$$

The geometric average price satisfies the time reversal test. Another advantage of geometric average price is that price changes are symmetrical, i.e., if the price of one product doubles and the price of another product halves, they will offset one another.

9.10.2d The Fisher Ideal Index

Fisher's Ideal Index can be defined as follows:

$$I_{q_F} = \sqrt{\frac{\Sigma q_n P_o}{\Sigma q_o P_o} \times \frac{\Sigma q_n P_n}{\Sigma q_o P_n}} \qquad (9.16)$$

From the above, it is clear that Fisher's ideal index number is the geometric average of Laspeyre's and Paasche's indexes and can be written as follows:

$$I_{q_F} = \sqrt{I_{q_L} \times I_{q_P}} \tag{9.17}$$

Fisher's index satisfies the time reversal test. This can be verified as follows:

$$I_{q_F} \times I'_{q_F} = \sqrt{I_{q_L} \times I_{q_P}} \sqrt{I'_{q_L} \times I'_{q_P}}$$

$$= \sqrt{\frac{\Sigma q_n P_o}{\Sigma q_o P_o} \times \frac{\Sigma q_n P_n}{\Sigma q_o P_n}} \times \sqrt{\frac{\Sigma q_o P_n}{\Sigma q_n P_n} \times \frac{\Sigma q_o P_o}{\Sigma q_n P_o}}$$

$$= 1 \tag{9.18}$$

where I'_{q_L} is Laspeyre's index, showing the change from year n back to o; and I'_{q_p} is Paasche's index, showing the change from year n back to o.

The Fisher index also satisfies the factor reversal test. This can be verified as follows:

$$I_{P_F} = \sqrt{\frac{\Sigma P_n q_o}{\Sigma P_o q_o} \times \frac{\Sigma P_n q_n}{\Sigma P_o q_n}} \tag{9.19}$$

where I_{P_F} indicates the Fisher Ideal Price Index. Let:

$$I_{q_F} = \sqrt{\frac{\Sigma q_n P_o}{\Sigma q_o P_o} \times \frac{\Sigma q_n P_n}{\Sigma q_o P_n}} \tag{9.20}$$

be the ideal quantity index corresponding to I_{P_F}. Then:

$$I_{P_F} \cdot I_{q_F} = \sqrt{\frac{\Sigma P_n q_o}{\Sigma P_o q_o} \times \frac{\Sigma P_n q_n}{\Sigma P_o q_n}} \times \sqrt{\frac{\Sigma q_n P_o}{\Sigma q_o P_o} \times \frac{\Sigma q_n P_n}{\Sigma q_o P_n}}$$

$$= \frac{\Sigma P_n q_n}{\Sigma P_o q_o}$$

which is the value index, hence satisfying the factor reversal test.

The quantity index numbers introduced in this section provide an output measure which is entirely dependent upon the physical volume of output. Furthermore, the introduction of products not produced in the base year present little problem.

9.11 The Simulation Model

As has been mentioned, the productivity analysis framework presented in Figure 9.3 can be used for analysis of past operations. Analysis of historical data helps to explain past behaviour of the system and its criteria of performance. However, the model can also be used for predictive purposes. This involves the determination of the expected response of the system to certain changes that may occur. Some of these changes may be imposed on the system by outside factors, and some may be the result of management decisions which the manager of the plant is in a position to control or influence. The use of this model would help to provide predictions as to how the system is likely to behave in the future under given conditions. This makes the model an extremely powerful management control and planning tool.

9.11.1 The Choice of simulation model

Three major methods of analysis may be used for the predictive purpose. These are: (a) sensitivity analysis; (b) a deterministic analysis for a given set of circumstances; and (c) a probability simulation approach.

Sensitivity analysis seeks to establish the extent to which various criteria, as well as the system as a whole, are affected by a given incremental change of each variable. However, it is important to note that sensitivity analysis is not mutually exclusive, and, in fact, is a special case of the deterministic appraisal method.

The choice of simulation model was therefore between the deterministic and probability approaches. In view

of the similarity between the present work and computer models for corporate planning, the literature dealing with the latter was reviewed. Grinyer *et al.* (Ref. 19, 20) surveyed the corporate computer models, writing that:

> "Ninety seven per cent of the companies had deterministic simulation models. Deterministic models assume that the figures input to them are known with certainty; consequently each factor represented on a model run by a single figure. This is, of course, just the way that accountant and managers normally calculate, and often use little more than basic arithmetic. By contrast, probabilistic models use mathematical functions to generate input in such a way that the relative frequencies with which they are expected to occur in real life, and by repeated operation of the model a profile showing the probability with which each outocme may be expected can be obtained. Such probabilistic models give much more information to decisions taken, but are more difficult for one to understand and cost more to develop and run."

Based on the above findings, the simulation model developed for the purpose of the present study was based on the deterministic approach.

9.11.2 Description of the simulation program

The program is constructed in two segments. The main segment of the program carries out the historical analysis of the data based on the framework presented in Figure 9.3. The inputs to the program at this stage are the number of periods for which analysis is required, NPER; number of product types, NPRO; number of material types, NMT; number of different categories of hourly-paid employees, NHET; number of different categories of salaried staff, NSET; selling price of various products, PP(I,J); quantities produced of each product type, PQ(I,J); average material prices for various material categories, MP(I,J); material quantities, MQ(I,J); average hourly rate for various categories of employees, HR(I,J); number of hours attended by different categories of hourly employees, MH(I,J); average salary rate for various categories of salaried employees, AVS(I,J); number of salaried employees in each category, NEMP (I,J); maximum output of each category of each category of products, MPOU(I); net fixed investment, NFI(I); depreciation, DEP(I); total

material cost, TMC(I); total fixed cost, TFC(I); total revenue, TR(I); profit, PROF(I); total working capital, TWC(I); direct wages, DW(I); indirect wages (salaries), INDW(I); fringe benefits, FB(I); indirect inputs, INI(I); and other costs, OTC(I). Depending on the requirements, the program calculates the output index number, material input value, direct and indirect labour input, using either Laspeyre's, formulation, Edgeworth's (arithmetic, or geometric price averages), or Fisher's formulation, for a specified base period. The choice of approach is controlled using variable MARK which is read into the program, and the choice of base year is controlled using variable BPER.

The outputs of the program are physical output and inputs of the system, direct input productivities, indirect input productivities, factor proportions, factor prices, unit costs, cost proportions, index of revenue, investment and profits, managerial control ratios, r model analysis and finally analysis of factors contributing to relative change of total unit cost.

The main program is connected to a subroutine called SIMUL. This subroutine is called into operation if simulation runs are required using variable NSIMU. Whenever NSIMU is greater than zero (default value ϕ), this subroutine is called. The main input to this subroutine is the estimated percentage changes of various output and input prices and quantities and changes in capacity, net fixed investment, working capital, other inputs, and fringe benefits, etc. Depending on the number of runs specified, it is possible to run the program for various percentage changes in one or more factors. For instance, it is possible to run the program for 5, 10, 15, 20 per cent increases in output prices of one or more of the products and decrease in quantities of 1, 3, 5 and 7 per cent, etc. From the above, it can be appreciated that, although the program is deterministic, one is not limited to one guess per run. The subroutine calculates the new prices and quantities, etc.; and then it calls the main

program, which in turn would carry out the desired analysis for the historical data as well as the specified changes.

REFERENCES

1. Gold, B. "Foundations of Productivity Analysis". University of Pittsburgh Press, 1955.

2. Gold, B. "Productivity Analysis and System Coherence". Operational Research Quarterly, Vol. 16, No. 3, 1965.

3. Thorelli, H.B. "Productivity -- a tantalizing concept". Productivity Measurement Review, No. 2, 1960.

4. Gold, B. "Technology, Productivity, and Economics", Vol. 1, Part 1, 1973.

5. Gold, B. "Productivity Analysis". Business Economics, May, 1974.

6. Eilon, S., Gold, B. and Soesan, J. "Applied Productivity Analysis for Industry". Pergamon Press, 1976.

7. Samuelson, P. "Economics". McGraw-Hill, New York, 8th Edn., 1970.

8. Chamberlain, N.W. "The Firm: Micro Economics Planning and Action". McGraw-Hill, New York, 1962.

9. Gold, B. "New Managerial Control Ratios". Advanced Management, Vol. 21, No. 4, 1956.

10. Gold, B. and Kraus, R.M. "Integrating Physical with Financial Measures for Managerial Control". Journal of Academy of Management, June, 1964.

11. Gold, B. "Explorations in Managerial Economics: Productivity, Costs, Technology, and Growth". Macmillan, London, 1971.

12. Gold, B. "Productivity, Technology, and Capital". Lexington Books, 1979.

13. Horringam, J.O. "A Short History of Financial Ratio Analysis". The Accounting Review, April, 1968.

14. Jerome, W.T. "Executive Control". John Wiley, New York, 1961.

15. Weston, J.F. and Bingham, E.F. "Managerial Finance". Holt, Rhinehart and Winston, New York, 1968.

16. (No author; newspaper article). "How a Big Company Controls Itself". Business Week, December, 1952.

17. (No author; article). "Improved Tools of Management". American Management Association, Financial Management Series, No. III, New York, 1956.

18. Fisher, I. "The Making of Index Numbers". Houghton Mifflin, Co., New York, 1922.

19. Grinyer, P.H. and Wooller, J. "Computer Models for Corporate Planning". Long Range Planning, Vol. 8, No. 1, February, 1975.

20. Grinyer, P.H. and Batt, C. "Some Tentative Findings on Corporate Financial Models". Operational Research Quarterly, 1974.

CHAPTER TEN

PRODUCTIVITY ANALYSIS: APPLICATIONS

10.1 Introduction

In Chapter 9 a general framework for productivity was developed, in some detail. Two empirical studies in batch manufacturing industry have been undertaken, with the object of testing the analytical framework and its applicability, so that lessons may be learnt when measurement of productivity is attempted in increasingly complex operations. These are presented in the shape of two case studies in the following sections.

The characteristics of batch manufacturers vary depending on the scale of their operations. At one end are those which produce a large product range in small quantities, and at the other end are those with small product range and large batches. The latter could be thought of as a "Jobbing Shop", while the former is more like a "flow line" operation. In choosing the host companies we paid particular attention to their scale of production, as the difficulties involved in applying the technique is dependent on the nature of an enterprise's operations.

In the case of company A, as well as carrying out an historical analysis, using the computer program developed by the author, we tested the predictive usefulness of the technique. The effect of the choice of the base year and various index number formulations on the results were also examined. The computer output provides the analyst with a decomposition of the relative change in the rate of return and unit prices into their constituent parts, so that their relative contributions can be better appreciated.

In the second case study dealing with company B, "point efficiency" studies were undertaken, as effective management requires penetration beneath aggregate productivity relationships to the behaviour of the components which comprise them. This approach provides a more explicit guide to detecting the loci of all significant changes in input-output relationships.

The data collection exercise was designed so as to take account of the structure of relationships in Figure 9.3, by means of which changes in the underlying network affect total unit costs. At the first level, these involve interactions between changes in the volume of each category of inputs and in the price of that input factor. Resultant relative changes in each unit cost are then weighted by their respective proportions of total cost so as to determine resulting changes in total unit costs.

By adding the determinants of profitability, as represented by the managerial control ratios in Figure 9.3, a complete analytical framework is obtained. This provides a systematic approach to tracing the impact of actual or prospective changes in the network of physical productivity relationships on profitability.

10.2 Case Study 1: Company A

This case study refers to company A. The background of this company was described in Chapter 6 and is not repeated here. The case study is composed of two sections. In the first section we deal with the basic measurements and in the second section we present the result of the historical and simulation analysis which was carried out.

10.2.1 Basic measurements

The measurement required for the analytical framework relies heavily on historic accounting data, which can then be brought together in special ways to permit appropriate evaluations.

Data were collected for 2½ years (beginning with the financial year 1977/78 and continuing to the middle of the financial year 1979/80), which involved no significant changes in plant facilities or accounting practices. Most of the data required were available, but were not easily accessible owing to the inefficiency of the company's record-keeping. Actual sources used included production

schedules, sales invoices, profit and loss accounts, balance sheets, and manpower statistics. The interval between each measurement was six months.

10.2.1a Outputs

As discussed in Chapter 9, the physical output of different products can easily be measured in terms of their values through the use of any of the formulae presented in Section 9.10.2. These enable the analyst to determine the change in the total output between any two periods not due to accompanying changes in the price of each product category.

To use any of these formulae, one requires appropriate prices and quantities data for the duration of the analysis. Despite the fact that company A's batch sizes were relatively large and their production was continuous, nevertheless, collection of the necessary data provided us with our first difficulty since 184 different types of products were produced per period. To overcome this difficulty, the products of the company were divided into seven groups. The bases for these divisions were dimensional characteristics and design specifications of the products. A Pareto analysis was carried out ~~for each~~ of these groups, identifying products which accounted for more than 70 per cent and in some cases, 90 per cent of the total output within each specific group. Detailed quantity and price information were collected for these products. The products accounting for the remainder of the output within each product category were treated as a single product. Their prices were determined by taking an arithmetical mean of the appropriate product prices. This approach, in fact, considerably reduced the volume of the data required, thus saving valuable time. It is difficult to assess the effect of this procedure upon the accuracy of the result. However, it is the opinion of the author that the resultant inaccuracy is negligible, especially when viewed as a trade-off with time saved in collection of data.

Thus, from the standpoint of managerial valuations, the plant produced 31 products. These were combined, using Laspeyre's, Edgeworth's (arithmetic and geometric price means), and Fisher's formulation.

10.2.1b Materials volume

As stated previously, one cannot measure the total volume of purchased materials and supplies by adding physical units such as length and weight. Nor is this need met by adding their respective costs. Once again, Laspeyre's, Edgeworth's and Fisher's formulae were used to determine the change in the total volume of materials between any two periods not due to accompanying changes in the price of each component category.

The purchased materials and services were divided into six categories. The basis of this division was solely the physical attributes, i.e., tubes, bars, strips, etc., were each placed in an appropriate class. An average price was computed for each category for the duration of the analysis. Data concerning the volume of each group of material used by the production department were also collected.

At first glance, using an arithmetic mean of prices for such a broadly-based category of material, inputs may appear to be an unjustifiable approximation. However, the margin of price variation within each group was small, thus justifying the use of the arithmetic mean of prices.

10.2.1c Direct labour input (weighted man-hours)

Changes in direct labour input were computed, weighting the attendance hours by wage rates using Laspeyre's, Edgeworth's and Fisher's formulae.

Initially we divided the shop floor employees into three categories of direct, indirect and inspection. However, this division was too general and did not meet the requirements of this analysis. Consequently, the labour

force within each of the above categories was further subdivided, according to the function performed. By this we mean, for example, direct labour force was divided into Automatic, General, Press, Heat Treatment, Grinding and Assembly shop employees, i.e., a total of 14 categories. The rationale behind this division was simply that employees working within each shop have a similar degree of skill and their productive contributions vary only marginally. This fact was reflected in the very narrow range of wage rates within each labour category.

The attendance hours and monetary compensation for each category of labour was collected for the period under consideration. The wage rate was computed by simply dividing the monetary compensation by the attendance hours.

10.2.1d Indirect labour input (salaried employees)

Changes in indirect labour input were calculated by weighting the number of employees in each category by the appropriate average salary rates using Laspeyre's, Edgeworth's and Fisher's formulae.

The salaried employees were divided into five categories according to the function they performed. These were Production, Production Services, Work Services, Administration, and Management employees. The rationale behind this division was simply that employees working within a specific group have a similar degree of skill and their productive contributions vary only marginally. Clearly, in such a division one cannot expect a narrow salary range, because of the effects of length of service and the specific function performed. However, for the duration of the analysis, the mix of skills within each division did not change appreciably: thus, the justification for the above division.

As in the case of direct labour, data concerning the number of employees within each category and total salary received by them were collected. Average salary for each

group of indirect labour was computed by dividing the total salary received by total number of employees. Physical number of employees was used because they all worked forty hours per week.

10.2.1e Other inputs (miscellaneous goods and services input)

This category of input include items such as non-productive (indirect) materials and supplies, utilities, rents, etc.

Data concerning each category of miscellaneous goods and services input were collected for the duration of the study. The total cost of other inputs for each period was computed by summing up these individual monetary values. As before, we were interested in physical changes, i.e., changes not due to price variations. Consequently, the total cost values were deflated using the published retail price index to remove the price variation effects.

For detailed calculations, see Tables 6.10 and 6.10d presented in Chapter 6.

10.2.1f Working capital input

The monetary value of working capital input was collected from the balance sheets. As stated in Chapter 6, Section 6.4.3a, balance sheet values at purchase prices are virtually identical with values at current prices. Working capital input was deflated to its base year values using a composite index of average hourly earnings, salaries and prices of operating materials and other supplies. For more explanations, see Section 6.4.3a of Chapter 6 and Table 6.7a.

10.2.1g Capacity

In the network of productivity relationships, capacity is regarded as the "output" of investment in productive facilities and equipments.

In Section 9.9.3, we discussed at length the problems associated with capacity estimation. Accepting these limitations, it is possible to obtain acceptable estimates of practical capacity, largely based on management's estimates (however crude) of the productive capacity which it administers.

We evaluated capacity in company A using management estimates of the maximum quantity of each product which could be produced, and also the standard hours of production available, in terms of both machine and labour times, for producing a standard output mix. In the former case, we asked the production manager and controllers to take into account known bottlenecks, including normal maintenance, omit marginal facilities, and to consider only such patterns and rates of production as would accord with current costs and prices. The product range was divided into seven categories, as before (Section 10.2.1a), and estimates were made with regard to these categories.

The latter method is best described by means of an example. An example is used rather than the actual calculation performed because of the length of the work involved. Assume that the company produced ten products coded 1 to 10. The standard mix was calculated, by ignoring the peripheral outputs (e.g., anything accounting for less than 7 per cent of outputs) and distributing their contributions to other products according to their weights, as shown in Table 10.1.

Product Code	No. of Units Produced	Item as Percentage of Total Units Produced	Revised Percentages Standard Mix
1	40	-	-
2	700	12.8	13.6
3	500	9.2	9.8
4	80	-	-
5	1,400	25.7	27.4
6	1,900	34.7	38.00
7	10	-	-
8	100	-	-
9	100	-	-
10	620	11.4	11.2
Total	5,450	93.8	100

Table 10.1 Calculation of standard mix

Next the cycle of operation for standard mix was analysed. Now consider the case where products pass only through one shop and one machine. Multiplying column (a) by (b) (Standard Processing Time x Product Weight) and summing the results (Column C) yields the standard machinery hours required for standard product mix, Table 10.2.

Product Code	(a) Standard Processing on Machine A Per Unit	(b) Product Weight	(c) a x b
2	5	13.6	68.0
3	4	9.8	39.2
5	6	27.4	164.4
6	9	38.0	342.0
10	4	11.2	44.8
Total Machining Hours			658.4

Table 10.2 Machine Time Calculations for Standard Mix

If labour is the limiting factor, it is possible to convert the machine-hours to man-hours using the following formula:

Man-Hours = Machine-Hours x Men/Machines

We used the above method for estimating the productive capacity of the company A for the periods under consideration. Any change in productive capacity between two periods could be determined simply by dividing the standard hours (man or machine) required to produce a standard mix for the two periods.

As was mentioned in Section 9.10.2 capacity is dependent on product mix. Variation in product mix from period to period provides the analyst with one of the biggest problems in attempting to estimate the capacity

of a batch manufacturing company. The above approach in fact removes this difficulty. However, the technique suffers from two disadvantages: (1) it is laborious to carry out; and (2) it depends on standard hours which are not always reliable.

Obviously, any variation in working patterns such as introduction of shift work would affect the standard hours available for production. Fortunately, no such changes took place for the period under consideration.

10.2.1h Fixed investment

Fixed investment for the purpose of this case study is defined as the current net value of investment in fixed capital facilities and is an important component in determining the productivity of capital within the network of productivity relationships (see Figure 9.3 and Equation 9.5, Chapter 9). This was computed by subtracting the depreciation for a given period from the gross fixed investment for the corresponding period.

As mentioned in Section 9.9.4 of the previous chapter, measurement of fixed investment depends on the accounting procedures adopted by the firm for determining its fixed assets. These procedures may vary from replacement costs of the assets, or reliance on inflation accounting, to gradual write-offs due to depreciation -- each will have a significant impact on the computed productivity of capital ratio. Thus, caution must be exercised in interpreting trends in this ratio, and particularly when comparison of performance is made for different periods of the same plant or between different plants; unless the measurement of fixed investment is consistent throughout, there is a risk that such comparative studies would be meaningless.

10.2.1i Factor prices

Factor prices are the intermediate link between changes in input quantities per unit of output and changes in the unit cost of such inputs, as shown in Figure 9.3. Accordingly,

one may either collect factor price data for each input directly or calculate them by dividing any change in the total cost per unit of output for each input category by accompanying changes in its quantity per unit of output.

In this study the latter approach was adopted, because of the availability of data for total costs and total input quantities for each category -- thus yielding measures of any changes in the average price of each input factor. It was simpler in all cases to collect data on total costs for each category of input and to work backwards to the implied rate. For example, the materials price index (Mp) was determined by first obtaining total materials cost (M) and employing the identity M ÷ Mv = Mp, where Mv denotes the materials volume and Mp the price.

10.2.1j Financial data

The top part of the network of productivity analysis is dominated by financial measures such as turnover, total costs, profits and investments, as shown in Figure 9.3. These data were readily available from company A's management accounting package. Generally, few problems are likely to be encountered in seeking financial data, because accounting systems provide for the regular determination of such information.

10.2.1k. Predictive nature of the model

As was mentioned in Chapter 9, the network of productivity analysis could be used to provide predictions as to how the system is likely to behave in the future under given conditions. Indeed, the program written for productivity analysis is capable of appraising the effects of changes in any of the components of the model at whatever level (including changes in factor productivities, proportions or prices) on the other components and on the total cost. In particular, the consequence of changes in quantities and prices of input and output factors, various

categories of cost, fixed investments, working capital and capacity can be systematically evaluated.

To demonstrate this dimension of the model, as well as analysing the past operations of the company A, we simulated the effect of changes of various factors on the network of productivity analysis. For the first period of simulation we made the following assumptions:

- An increase of 11 per cent in output prices;
- No change in output quantity;
- An increase of 9 per cent in material prices;
- No change in material quantity;
- An increase of 8 per cent in wage rates;
- No change in the number of hours worked;
- An increase of 9 per cent in salary rates;
- No change in the number of indirect employees;
- No change in capacity;
- No change in fixed investments;
- An increase of 4 per cent in fixed costs;
- No change in working capital;
- An increase of 5 per cent in employment fringe benefits;
- No change in indirect inputs; and
- An increase of 6 per cent in other costs.

For the second period of simulation the following assumptions were made:

- No change in output prices;
- An increase of 13 per cent in output quantity;
- No change in material prices;
- An increase of 10 per cent in material quantity;
- No change in wage rates;
- An increase of 9 per cent in number of hours worked;
- No change in salary rates;
- No change in the number of indirect employees;
- No change in capacity;
- No change in fixed investment;
- No change in fixed costs;
- No change in working capital;
- No change in employment fringe benefits;
- An increase of 5 per cent in indirect inputs; and
- No change in other costs.

In the third period of simulation we assumed:

- An increase of 13 per cent in output prices;
- An increase of 12 per cent in output quantities;
- An increase of 11 per cent in material prices;
- An increase of 12 per cent in material quantity;
- An increase of 10 per cent in wage rates;
- An increase of 12 per cent in the number of hours worked;

- An increase of 14 per cent in salary rates;
- An increase of 2 in the number of indirect employees;
- No change in capacity;
- No change in fixed investment;
- An increase of 4 per cent in fixed costs;
- An increase of 3 per cent in working capital;
- An increase of 6 per cent in employment fringe benefits;
- An increase of 4 per cent in indirect inputs; and
- An increase of 7 per cent in other costs.

Finally, in the fourth period of simulation we assumed:

- An increase of 15 per cent in output prices;
- An increase of 21 per cent in output quantity;
- An increase of 13 per cent in material prices;
- An increase of 18 per cent in material quantity;
- An increase of 13 per cent in wage rates;
- An increase of 14 per cent in the number of hours worked;
- An increase of 16 per cent in salary rates;
- An increase of 4 in the number of indirect employees;
- An increase of 10 per cent in capacity;
- An increase of 15 per cent in fixed investment;
- An increase of 7 per cent in fixed costs;
- An increase of 5 per cent in working capital;
- An increase of 8 per cent in employment fringe benefits;
- An increase of 7 per cent in direct inputs; and
- An increase of 9 per cent in other costs.

10.2.2 Results of analysis

In this section we present the results of the historical analysis based on the structure of relationships in Figure 9.3 (Chapter 9), as well as the result of simulation runs based on parameter changes specified in Section 10.2.1k.

The data collected and the results are summarised in Tables 10.3 to 10.13 and Figures 10.1 to 10.17.

10.2.2a The computer output

A sample of computer output is presented in Tables 10.3 to 10.13. The program firstly prints the number of periods of the historical analysis; secondly, the number of simulations required; thirdly, the total period of the analysis; fourthly, the period from which simulation runs start; and finally, the base period.

Table 10.3 shows the changes in the physical output and inputs. The program also prints the formulation used

for indexing the output and inputs. The direct and indirect input productivities are presented in Tables 10.4 and 10.5. Tables 10.6 and 10.7 show the factor proportions and factor prices. The method for calculating the factor prices were described in Section 10.2.1i. The total unit costs were calculated by dividing the total costs by output and partial unit costs by dividing the appropriate cost by the physical output. This information is presented in Table 10.8. Table 10.9 shows the cost proportions. An index of changes of revenue, investment and profits are shown in Table 10.10. Managerial control ratios, based on Equation 9.5, is presented in Table 10.11. Table 10.12 indicates how a relative change in the rate of return between two periods can be attributed to relative changes in the unit profit for the output a, capacity utilisation of the plant e, and capacity/total investment ratio Z and to the interactions between them. Finally, the components of the relative change of the total Unit cost between two periods are presented in Table 10.13. The basis for these calculations was Equation 9.1.

10.2.2b Outputs and inputs

The outputs of the company were divided into seven main categories. Figure 10.1 shows the combined output of the company for the 2½-year period, as well as the outputs of its four major product lines. The total physical output of the company shows a declining trend, as, indeed, is the output of product line 1. The output of product line 2 shows an ascending trend; in particular, it rose sharply between periods 4 and 5. Product line 3's output fluctuates widely around the 100 per cent mark. The pattern of variation is similar to that of the total physical output. The output of product line 4 rose sharply up to the period 3 and then fell rapidly between periods 3 and 4. In seeking explanations for these adjustments, consideration must be given to the market in which company A operates.

Most of company A's products are bought by automotive manufacturers. Any fall in demand for the end products, i.e., cars, trucks, etc., affects the output. Product line 4 is mostly manufactured for export. The sharp fall in the output of this product was due to cancellations of orders from a foreign buyer. Product 2 is also principally manufactured for export to the United States and hence, the rise in the quantities produced.

The total materials volume was divided into six broad categories of materials. Figure 10.2 shows the total material volume for the period under consideration, as well as the variation of its three major components. The total material volume varies widely around the 100 per cent mark with no clear trend emerging. The same pattern of variation is repeated for material types 2 and 3, while usage of material type 1 initially rose, and then from period 2 followed the general pattern of variation of the total volume used in production.

Changes in physical output and inputs are presented in Table 10.3. Figure 10.3 is a graphical representation of the physical variations of output and inputs. The analyses up to and including period 5 are based on the historical data, and from then onwards results of the simulation based on changes in operating factors outlined in Section 10.21k are presented. The same pattern of variation is observed for physical output, material input, and direct labour input (man-hours), although the magnitude of changes is different (see Figure 10.3). Fixed investment was depreciated based on a reducing balance over 15 years, hence its fall up to period 4. The sharp rise between period 4 and 5 was due to investment in new toolings. This, however, did not affect the capacity of the plant. The reduction in indirect labour input was due to redundencies, and to natural wastage.

Between periods 5 and 6, prices of inputs and outputs were varied, but the physical quantities were kept constant; hence, no changes occurred in output or input levels. This

clearly demonstrates the fact that price changes have no effect upon physical quantities of outputs or inputs calculated using Equations 9.11, 9.12, 9.14 or 9.16.

10.2.2c Apparent direct input productivities and factor proportions

Direct input productivities for the last five periods and the future four periods are presented in Table 10.4. In considering these data, it may be useful to start with an analysis of the factors associated with changes in physical output per man-hour, since this ratio is quoted so often and so misleadingly, both by the press and by more learned sources. As is evident from Figure 10.4, direct labour productivity on average rose between periods 1 to 5, remained constant between periods 5 to 6, and then rose between periods 6 to 9. In determining the causes for the observed trends, the network of productivity relationships used in the model reminds us that changes in the productivity of any input (in this case labour) may be attributable to changes in its use proportional to another input (material or capital) and to changes in the productivity of that input. Thus, labour productivity may increase because new labour-saving equipment or facilities have been introduced. This would be reflected in the ratio of labour to actively utilised capital and possibly in the productivity of capital (CAP/I_F, where CAP = capacity and I_F = net fixed investment), hence:

$$\frac{PO}{\text{Man-Hours}} = \frac{CAP}{I_F} \times \frac{I_F \times PO/CAP}{\text{Man-Hours}}$$

where PO = physical output.

Thus, Figure 10.5 shows that the upward trend in the productivity of labour, as expected, is not due to the increase in actively-utilised fixed investment in relation to labour. However, increases in the productivity of capital helped to push the labour productivity upwards.

Introduction of more fabricated or better quality materials may also lead to increases in the direct labour productivity. Table 10.6 shows the changes in factor proportion. These data are shown graphically on Figure 10.7. Comparison of Figures 10.5 and 10.7 reveals a close correlation between the direct labour productivity and Material Volume/Man-Hours ratio. In fact, this ratio is exercising an upward force on the direct labour productivity.

The reason for the observed upward influence was simply the replacement of steel tubes and bars of a certain hardness by new materials of a different hardness, which required less machining times. However, the new materials used did not in any way affect the performance of the final products.

Turning to the productivity of materials, it is evident from Figure 10.4 that it rose by an average of 2 per cent up to period 5, remained constant between periods 5 and 6, and then fell by an average of 2 per cent between periods 6 to 9. It would be useful to assess the effects, if any, of actively utilised capital and productivity of capital on materials productivity, hence:

$$\frac{PO}{M_v} = \frac{CAP}{I_F} \times \frac{I_F \times PO/CAP}{M_v}$$

where M_v = material volume.

Figure 10.6 shows the relationship between the material productivity and capital (actively utilised capital and capital productivity). As is evident from Figure 10.6, there is little correlation between material productivity and actively utilised capital. This was to be expected, as there had been no investment which could have lead to improved material productivity. In fact, the improvement in material productivity up to period 5 was due to the higher quality of materials used. This means that on average the volume of material required for a given unit of output had actually declined. It is interesting to note

that variations in operating factors between periods 6 to 9 lead to a reduction in material productivity.

Fixed investment productivity rose sharply up to period 4, declined between periods 4 and 5, and then started to rise sharply again. This pattern conforms to expectations, as fixed investment fell up to period 4, rose between periods 4 and 5, and started to decline again from period 5 onwards, while the capacity remained constant except for the last period.

10.2.2d Apparent indirect inputs productivities

Apparent indirect inputs productivities are presented in Table 10.5. Figure 10.8 shows graphically variations of indirect input productivities and the physical output. Comparison of the indirect labour productivity with the physical output for the first five periods reveals a similar pattern of variations. This demonstrates the fixed nature of the indirect labour. However, for the same period the indirect labour productivity shows a rising trend while the physical output is falling. The improvement in indirect labour productivity was achieved through natural wastage and some redundencies. From period 5 to period 7, the indirect labour productivity rose sharply as it was assumed that higher levels of output could be attained without new recruitments of indirect labour.

Working capital productivity falls sharply up to period 4. The reason for this phenomenon was the failure of company A to control its finished goods stock. This meant an increase in real terms of working capital while output was falling. The sharp rise in working capital productivity between periods 5 and 9 was due to large increases in outputs combined with moderate increases in working capital requirements.

The productivity of indirect inputs shows a similar pattern of variation to that of physical output. This suggests that either (1) the indirect inputs are fixed

for the normal range of company A's operations; and (2) the management has failed to implement measures necessary for reducing the volume of this input category in accordance with the falling physical outputs; or a combination of these two possibilities.

10.2.2e The structure of costs (unit costs and cost proportion)

The company A's costs were divided into six categories. These were direct wages, salaries, materials, fixed, and other costs and depreciation costs. Total employment costs were calculated by summing up the direct wages, salaries, and employment fringe benefits (including employment-related contributions to the Government). Fixed costs were comprised of interest, establishment, plant and machinery's rental, maintenance (plant and tools), etc., while other costs included the indirect material and supplies and overheads such as building rentals, personnel costs, competer charges, etc.

Before analysis of the structure of costs at company A, it may be helpful to bear in mind six prevailing assumptions (Ref. 1) that appear to have gained widespread acceptance:

(1) That manufacturing wage costs account for the greater part of the selling price of products in most manufacturing industries;

(2) That the increasing efficiency of production processes and the more thorough utilisation of by-products have led to a progressive and substantial reduction in the ratio of cost of materials to the selling price of manufactured goods;

(3) That sharply-increased production per man-hours, attributable largely to more extensive mechanisation and more effective management controls, has steadily reduced the relative importance of wage costs in total product costs;

(4) That the proportion of total selling price accounted for by salaries, overheads and profits has risen significantly as a result of the combined effects of a higher ratio of managerial and technical personnel to wage earners; of the increased overhead costs attendant on heavier mechanisation; and of the maintenance or expansion of profits presumed to have supplied the necessary incentive to further investment in technological improvements; also

(5) That, because of frequent fluctuations in raw materials prices, wage rates, profit margins and levels of production, the internal composition of manufacturing costs is subject to continuous and substantial variation; and

(6) That total unit cost is inversely related to output level.

It seems useful to learn whether or not these assumptions are supported by the company A's data by looking at the performance of total costs, cost proportions and unit costs in turn, although conclusions reached are ~~open to~~ criticism, because of the short span of the historical data analysed.

(i) Changes in turnover, total costs and cost proportion

The total turnover over the first five periods rose by 15 per cent, but the increase was by no means steady, as Figure 10.9 shows. During the four simulation periods, as a result of changes in operating and marketing factors, turnover rose sharply by 260 per cent. Total costs rose by 14 per cent for the first five periods, and by 206 per cent for the remaining four periods (see Figure 10.9). Fluctuations in total costs for the first five periods were by no means steady, but were always in the same direction as turnover.

The relative magnitude and fluctuations of cost proportions are shown in Figure 10.10. As is evident, the share of wages averages 19.3 per cent of total costs; salaries, 10.2 per cent; employment-related costs, 7.6 per cent; wages plus salaries, 29.5 per cent; and total employment costs (wages plus salaries plus employment-related costs), 37.1 per cent. The share of material cost averages 44.9 per cent of total costs. Comparison between salaries plus wages costs and materials costs shows that at least 1.5 times as much was spent on materials. The other interesting fact emerging is the high cost of employment-related contributions. Depreciation costs were very low (averaging 2.8 per cent of total costs). However, if depreciation costs were to be calculated, based on replacement costs, then its share would have risen to approximately 11 per cent of the total costs. This wide magnitude of difference between the two methods of depreciating the fixed assets shows the fallacy inherent in basing management decisions solely on the rate of return considerations.

(ii) Changes in unit costs and unit prices

Figure 10.11 shows that employment unit cost (wages + salaries + employment-related costs), materials, fixed and other costs, rose by 27.4, 16.9, 38.9 and 13.3 per cent, respectively, for the first five periods. Fixed unit costs (including depreciation) peaked in period 5 (considering only the first five periods), when additional investments were incurred (new toolings). Total unit cost rose by 21.9 per cent over this period, the major increase occurring between periods 4 and 5. The adjustments of total unit costs and its components from period 5 onwards are the results of changes in operating factors outlined in Section 10.2.1k. As is evident from Figure 10.11, the total unit cost increased by approximately 25 per cent from period 5 to period 9, and employment and material costs by 31 and 32 per cent, respectively; while unit fixed costs and other costs declined by 29 and 20 per cent, respectively. Figure 10.12 shows the changes in

unit employment cost and the influence of its two major components. From this figure it is clear that the upward pressures on unit employment costs between periods 3 and 4 were caused by increases in salaries and between periods 4 and 5 by increases in wages cost.

Changes in unit costs are attributable, of course, to changes in input factor prices and in the quantities of these factors employed per unit of output -- and changes in the latter are usually traceable either to adjustments in output levels, in the case of inputs which are relatively inflexible, or the adjustments in the technology, organisation and manning of major production tasks. Among these three factors, changes in unit employment costs were almost entirely attributable to changes in input factor prices. In the case of unit material costs, two factors were influential, increases in factor prices; and quantities employed per unit of output. And in the case of unit fixed costs and other costs, all three factors were influential: increases in factor prices, increasing input levels (e.g., capital between years 4 and 5), and falling outputs.

The relative change in total unit costs over any period may be regarded as the product of the relative change in each of its component categories multiplied by its share of total costs at the beginning of the period (see Equation 9.1 presented in Chapter 9). Table 10.13 gives the components of relative change of the total unit cost. Such an analysis is clearly of great practical use to senior management, enabling them to identify cost components most influential in any adverse changes in total unit costs.

By examining the relationship between turnover and the volume of physical output, we can analyse fluctuations in the average selling price per unit of output and the contributions of changes in both output and the average selling price to changes in turnover. Figure 10.9 shows that the average selling price rose steadily and was 23.8 per cent higher at the end of the fifth period than at the beginning. The

average selling price continued to rise during the four simulation periods and was 69 per cent higher at the end of the ninth period than at the end of the fifth period. Over the first five periods, the turnover increased by some 15.5 per cent but output fell by 7 per cent. Thus, the increase in turnover during the first five periods was due to price inflation; that it did not rise more was because of the fall in output. Over the four simulation periods, turnover increased by 260 per cent, and output by 49.5 per cent. Thus, the increase in turnover during the four simulations periods was due to increased output as well as price inflation.

(iii) Relative effects of cost adjustments on price

In theory it is possible to estimate the relative contribution of each cost factor to any change in the average selling price; if the change in unit cost is weighted by its proportionate share in turnover at the beginning of the period and all such weighted changes are summed, it will give the change in the average selling price. The weighted contribution as a percentage of this change gives the percentage of the change due to a change in that cost factor.

Such an analysis is clearly of great practical use to senior management, enabling them to see in which direction their pressure to reduce costs would be most usefully exercised. Unfortunately, the shorter the time period studied, the more difficult it becomes to apply the analysis to any meaningful end.

Taking the whole period studied at company A, the average selling price rose by 23.9 per cent. Unit costs of materials, employment (wages and salaries and fringe benefits), fixed and other costs rose by 16.9, 27.4, 38.9 and 13.3 per cent, respectively. In period 1 materials costs constituted 45.9 per cent of total value; employment costs, 35.7 per cent; fixed costs (including depreciation), 14.5 per cent; and other costs, 3.9 per cent. Table 10.14,

below, shows the calculation of the contribution of each factor to the change in selling price.

Cost Factor	% Change Periods 1-5	Weight Period 1	Total Contributions	% Contributions
Materials	16.9	0.459	7.8	32.8
Employment	27.4	0.357	9.8	41.2
Fixed	38.9	0.145	5.7	23.9
Other	13.3	0.039	0.5	2.1
TOTAL		1.000	23.8	100.0

Table 10.14 Relative Effects of Cost Adjustments on Price (Periods 1-5)

(iv) Cost behaviour at company A

Let us now examine whether or not the findings at company A support the beliefs outlined above concerning cost relationships in the manufacturing industry. We have no evidence to support assumption 2 regarding the more effective use of materials (see Figure 10.6), although the lack of evidence either way is probably a result of the particular period chosen. Production per man-hour has increased; however, this rise does not appear to be attributable to technological improvements in accordance with assumption 3 (see Figure 10.5). Also, there is no evidence to support the hypothesis that a reduction in the relative importance of wage costs in total product costs has occurred. Figure 10.10 shows that the ratio of wages to total cost remained fairly constant in the first five periods. Furthermore, we have no evidence to support assumption 4 that the proportion of salaries and overheads, etc., in the average selling price is likely to rise (see Fig. 10.10).

Figure 10.13 does not give good evidence of "frequent fluctuations in raw materials prices, wage rates, profit

margins, and levels of production"; and again, the shortness of the period under consideration may be to blame, but it should be noted that in spite of major changes in raw material prices and wage rates, the internal composition of manufacturing costs remained relatively stable, as shown in Figure 10.10, contrary to assumption 5. Figure 10.14 does not lend any support to assumption 6, that there is an inverse relationship between output and input unit costs, although the evidence is not conclusive owing to the short span of the analysis.

As for the first and most widely-held belief, regarding the large proportion of wages cost in the final price of the product, we found that wages averaged 16.7 per cent of selling price, while wages and salaries together averaged 26.1 per cent. This is by no means an insignificant proportion, although it is clearly less than the proportion of material costs (40.2 per cent) and by no means "the greater part of the selling price". That this belief is so widespread is perhaps due to the tendency of managers to regard prices of materials and other expenses as largely fixed and wages as the best target for possible cost cutting. The degree to which this is a reasonable attitude will depend not only on the nature of the operations involved but also on the degree of vertical integration of the particular plant.

In conclusion, findings at company A do not appear to support some widely-held beliefs concerning manufacturing costs and to indicate that a very thorough understanding of the nature of the cost structure of a plant is necessary to guide effective managerial decisions concerning cost reduction and performance improvement. It must be stressed again that for the various hypothesis to be properly tested, a much longer period of operations would need to be studied.

10.2.2f Managerial control ratios

We now extend the analysis to cover the range of financial and managerial control ratios suggested in Equation

9.5, Chapter 9. Short-term changes in return on investment are most likely to be due to changes in the average selling price, unit costs and capacity utilisation, while longer-term trends will be influenced by these three and by changes in the productivity of the fixed investment and the allocation of investment, which would not be expected to change dramatically in the short term. Figures 10.15 and 10.16 show that in the case of company A, the average prices have had a wider amplitude of fluctuations than unit costs, but that both moved in the same direction in eight periods out of nine. Costs rose more than prices in one occasion (between periods 4 and 5), thus reducing unit profits. And on one occasion when prices and costs moved in opposite directions (between periods 6 and 7), both tended to increase unit profits. Furthermore, comparison of Figures 10.15 and 10.16 suggests that in the short-term unit, profit and return on capital tend to vary together much more than the other determinants of return on capital, with the corollary that it is changes in unit profit which tend to influence the level of return on capital most strongly. Figure 10.17 shows return on capital plotted against unit profit and the results strongly support the hypothesis that return on capital is linearly correlated with unit profit (regression coefficient is 0.99). This means that changes in utilisation rates tended largely to offset changes in the productivity of the net fixed investment as shown in Figure 10.16, and that the structure of financing (Fixed Investment/Total Investment) was relatively stable.

Table 10.12 shows how the relative change in the rate of return can be attributed to relative changes in the three factors in Equation 9.9, presented in Chapter 9, and the interaction between them. Thus, the total effect of a change in unit profit "a", capacity utilisation of plant "e", and Capacity/Total Investment "Z", ignoring the last term a* e* Z* on the rate of return "r" would, respectively, be:

$a^* (1 + e^* + Z^*)$
$e^* (1 + a^* + Z^*)$
$Z^* (1 + a^* + e^*)$

Comparison between periods 2 and 1 (Table 10.12) reveals that 13.3 per cent change in the rate of return was caused by a 22.5 per cent change in unit profit, -13.7 per cent change in capacity utilisation of plant, and 1.7 per cent change in the ratio of capacity to total investment. This means that the unit profit, capacity utilisation and capacity/total investment ratio were, respectively, responsible for 60 per cent, 36 per cent and 4 per cent of changes in rate of return.

The above analysis does not identify the original cause or causes that subsequently lead to a series of changes in the system and thereby to changes in values of the three components a, e and z; it merely provides a decomposition of the relative change in the rate of return into its several constituent parts. Nevertheless, such analysis is clearly of great practical use to senior management, enabling them to see in which direction their pressure to increase rate of return would be most usefully exercised.

Another use of this model is in accessing the effects of forcasts regarding the possible changes in operating conditions. A comparison of the rate of returns for periods 6 and 5 (Table 10.12) shows that as a result of increases in prices of outputs and inputs, the rate of return decreased by 20.7 per cent and the change was almost entirely due to a drop in unit profit (a 24.7 per cent decrease).

10.2.2g Effect of base year

In theory any year can serve as a base year, although it is generally recommended that it should be as "normal" or "representative" as possible. It must be pointed out, however, that the choice of the base-year may affect the

results. Take the example of the output (using Fisher's, Edgeworth's Arithmetic, Edgeworth's Geometric, and Laspeyer's Formulations), Tables 10.5a, 10.5b, 10.5c, 10.5d, respectively; and man-hours (Fisher's and Laspeyer's Formulations), Tables 10.16a and 10.16b. We see, for example, that the output in period 9 (Fisher's Formulation, Table 10.15a) is 142.79, when year 1 is taken as base (column 1, Table 10.15a), but 160.33 compared with 112.06 when year 2 is taken as a base (column 2). This means that the ratio of outputs between period 9 and period 1 is

$$\frac{142.79}{100} = 1.4279 \text{ according to column 1, but}$$

$$\frac{160.33}{112.06} = 1.4308 \text{ according to column 2.}$$

These inconsistencies persist for the other columns (regardless of the calculation method), as demonstrated by the ratio of the outputs, and man-hours of period 9 to period 1 at the bottom of Tables 10.15a, 10.15b, 10.15c, 10.15d, 10.16a and 10.16b.

Admittedly, in many cases one finds that the discrepancies emanating from the choice of the base-year are very small. But Table 10.15d does demonstrate that serious discrepancies can occur (the difference between columns 2 and 5 in the last row amounts to some 4 per cent), their magnitude being affected by the pattern of price and physical output changes during the period under study.

The reason for such discrepancies lies in the fact that when we examine the structure of Equations 9.11, 9.12, 9.14 and 9.16, we must conclude that

$$OI_{b.a} \neq \frac{OI_{b.c}}{OI_{c.a}} ;$$

namely, that the output index for year b compared with base-year a is not identical to the ratio of year b compared with c to year c compared with a, although the special case

$$OI_{b.a} \cdot OI_{a.b} = 1$$

should be noted, namely that the output of b compared with base-year a is the inverse of the output of a compared with base-year b. It should also be realised that the ranking may be affected by the base year.

10.2.2h The effect of formulation on index number

As has been mentioned the fundamental problem of measuring outputs and inputs arises from the fact that a single physical measure of product-mix or input-mix is not possible, since different products require different resources for their manufacture. In this section we look at the effect of the formulation on output index, using a hypothetical case and the case study data.

To illustrate the effect of the formulation of the index number, we first look at a simple two-product case. Assume that in terms of productive capacity the two products A and B require approximately equal resources, so that total output in physical terms is 110, 115 and 120, respectively, for the years shown in Table 10.17. Owing to changing demand, the product-mix is dominated by product B in the first two years, but by product A in the third. Three methods for computing the output index are explored: the first method is based on weighting outputs in each year by prevailing prices in year 1, i.e., Laspeyer's formulation; the second method relies on weighting outputs in each year by arithmetic mean of year 1 and current-year prices, i.e., Edgeworth's arithmetic formula; and finally, the last method employs Edgeworth's Geometric formula.

					Output Index		
	Quantity		Price		Computation Method*		
Year	A	B	A	B	(1)	(2)	(3)
1	10	100	1.0	1.5	100.00	100.00	100.00
2	20	95	1.0	2.0	101.56	100.68	100.73
3	100	20	1.2	1.6	81.25	84.94	84.69

Table 10.17 An Example of Two-Product Case

Method (1) Laspeyer's Formulation
Method (2) Edgeworth's Arithmetic Formulation
Method (3) Edgeworth's Geometric Formulation

The divergent results for the output index, serves to demonstrate how the change in output can be affected by the computational procedure employed.

As mentioned in Section 9.10.2d of Chapter 9, only Fisher's formulation meets the criterion of being a good index number. However, Fisher's index requires a large number of calculations, and in practice can only be applied when computers are used for the computations. The effect of different formulation on the output index can also be assessed by comparing Tables 10.15a, 10.15b, 10.15c and 10.15d. As is evident, Edgeworth's Geometric Formulation yields results very close to the results of Fisher's index. The results of Edgeworth's Arithmetic formulation are also close to the results of Fisher's index, but not as close as when the geometric price average is used. However, relatively larger variations occur when Laspeyer's formulation is used (compare Tables 10.15a and 10.15d).

To conclude, the average price mechanism ensures that the output index remains unchanged when the product-mix and the physical quantities remain unchanged. However, it still allows the price to affect the output index, as suggested by Tables 10.15a to 10.15c, and it allows the choice of the base-year to affect results. In practice, this does not usually create serious problems. As for the four variants of the output index discussed here, Fisher's index is cumbersome and is only suitable when all the computations are relegated to a computer, Edgeworth's geometric approximation is a very good approximation and not too cumbersome to use in practice, Edgeworth's arithmetic approximation is simpler to apply and usually is accurate enough, while Laspeyer's is the simplest to use but is less accurate.

10.2.3 Conclusions: Company A

Our conclusions are based mainly on the analysis of the historical data (i.e., the first five periods). The reason for this was simply that changes outlined in Section

10.2.1k were arbitrary, and the only purpose of the simulation was to demonstrate the predictive nature of the model.

The total output of the company declined by an average of 6.6 per cent, with the sharpest fall occurring between periods 3 and 4 (17.6 per cent). The volume of material, direct labour and indirect labour inputs and fixed investment also on average fell by 8.7 per cent, 10.3 per cent, 4.8 per cent and 6.0 per cent, respectively. This led to average increases in material, direct labour, and fixed investment productivities of 2.4 per cent, 4.5 per cent and 6.0 per cent, respectively.

As was argued in Section 10.2.2c, the increase in the ratio of Material Volume/Man-Hours (2.1 per cent on average) was mainly responsible for the improvement in direct labour productivity. While the increase in material productivity was caused by a reduction in quantities of material employed per unit of output. Productivity of capital, as measured by the ratio of capacity to net fixed investment, rose because continuing depreciation more than offset new investment.

The indirect labour, working capital and ~~indirect~~ input productivities fell by an average of 1.9 per cent, 18.2 per cent, and 6.1 per cent, respectively. The possible causes for the decline in the above productivity ratios were discussed in Section 10.2.2d.

Over the first five periods the average wage rate, material price, salary rate, and rate of fixed charges, rose by 12.9 per cent, 10.7 per cent, 15.7 per cent and 4 per cent, respectively. Leading to an increase of 8.1 per cent, 18 per cent, 8 per cent, 11.7 per cent and 10.4 per cent in unit wages cost, salary, material, fixed and other costs, respectively, despite the improvements in physical productivity of the direct labour, material and fixed investment. This clearly demonstrates the importance of linking the effects of changes in physical output per

unit of inputs through the appropriate factor prices to unit costs.

The rate of return on investment rose by an average of 7 per cent during the first five periods. The increases in unit profits were mainly responsible for the observed trend. For a more detailed explanation, see Section 10.2.2f.

The structure of costs at company A did not conform with beliefs concerning manufacturing costs, although the conclusion reached must be tentative because of the short time span of the analysis.

The choice of the base period clearly affects the results, but the magnitude of variation is not very large (for more explanation, see Section 10.2.2f). In addition, the formulation of the index number has some bearing on the result. However, it was found that the variation between index numbers computed using Fisher's ideal index and simple approximations was small.

The model can be used to determine the effect of changes in operating conditions on the network of productivity analysis as is demonstrated from period 6 onwards (Tables 10.3 to 10.13). It can also be used to plan reactions to possible future changes. If, for example, a 30 per cent increase in employment rates is forecast and management wishes to know by how much prices must be raised (assuming that they can be raised) to prevent a fall in profits, given the data on company A, total costs and total unit cost will increase by 11.4 per cent. This means that turnover must increase by 9.9 per cent to produce the same level of profits and without altering output this can only be achieved by a price increase of 9.7 per cent. Thus, the model can become a useful part of the planning proces..

The case study clearly demonstrates that productivity analysis serves to draw attention to important relationships between various parameters within the plant. The model

can be used to trace the effects of expected changes in any of the operating conditions specified in Section 10.2.1k, and also to estimate the response needed on the part of management in order to maintain or to achieve desirable levels of profitability. It can also help to determine pricing policies and product mix as well as to provide valuable information in negotiations on wages and the cost of materials.

NUMBER OF PERIODS OF HISTORICAL DATA 5
NUMBER OF SIMULATIONS REQUIRED 4
TOTAL PERIODS OF ANALYSIS 9
SIMULATION RUNS START FROM PERIOD 6
BASE PERIOD 1
CALCULATIONS ARE BASED ON FISHER FORMULATION

TABLE 10.3 PHYSICAL OUTPUT AND INPUT MEASURES

PER	OUTPUT	CAPACITY	MAT-VOL	MAN-HOUR	FIX-INV	IND-LAB
1	100.000	100.000	100.000	100.000	100.000	100.000
2	89.242	100.000	84.307	89.672	98.141	100.683
3	100.944	100.000	100.394	95.342	90.740	97.611
4	83.370	100.000	83.042	73.449	83.579	89.519
5	93.240	100.000	88.402	89.818	101.546	88.407
6	93.240	100.000	88.706	89.818	91.392	88.407
7	105.361	100.000	104.568	97.902	82.253	88.407
8	118.004	100.000	117.198	109.650	74.027	98.999
9	142.785	110.000	138.396	125.001	76.618	120.182

TABLE 10.4 DIRECT INPUTS PRODUCTIVITES

PER	DIR-MAT-PRO	DIR-LAB-PRO	FIX-INV-PRO
1	100.000	100.000	100.000
2	105.854	99.520	101.895
3	100.547	105.876	110.205
4	100.395	113.506	119.647
5	105.472	103.809	98.477
6	105.110	103.809	109.419
7	100.758	107.619	121.577
8	100.687	107.619	135.085
9	103.171	114.227	143.569

TABLE 10.5 INDIRECT INPUTS PRODUCTIVITIES

PER	IND-LAB-PRO	WOR-CAP-PRO	IND-INP-PRO
1	100.000	100.000	100.000
2	88.637	90.666	87.483
3	103.415	78.741	98.861
4	93.131	67.083	91.073
5	105.466	72.526	92.151
6	105.466	72.526	92.151
7	119.177	81.954	99.172
8	119.197	89.116	106.801
9	118.807	102.695	120.775

TABLE 10.6 FACTOR PROPORTIONS

PER	MATV/MAN-HR	AUIF/MATV	AUIF/MAN-HR
1	100.000	100.000	100.000
2	94.017	103.886	97.670
3	105.299	91.237	96.072
4	113.060	83.909	94.867
5	98.424	107.103	105.414
6	98.762	96.062	94.873
7	106.809	82.876	88.519
8	106.884	74.536	79.667
9	110.716	71.862	79.562

TABLE 10.7 FACTOR PRICES

PER	AV-WAG-RATE	AV-MAT-PRIC	AV-SAL-RATE	RAT-CH-FIX-INV
1	100.000	100.000	100.000	100.000
2	103.230	115.116	101.394	104.550
3	109.092	108.401	114.057	98.260
4	114.741	106.837	124.685	94.480
5	137.526	123.217	138.482	122.650
6	165.543	132.434	161.119	141.729
7	165.543	131.234	161.119	157.477
8	182.097	145.568	184.120	185.473
9	205.770	164.371	214.338	195.329

TABLE 10.8 UNIT COSTS

PER	UN-WA-CO	UN-IN-WA-CO	UN-TO-WA-CO	UN-MA-CO	UN-FIX-CO	OT-UN-CO	TOT-UN-COS
1	100.000	100.000	100.000	100.000	100.000	100.000	100.000
2	103.728	114.392	109.301	108.750	114.974	114.146	109.975
3	103.038	110.291	108.058	107.811	88.328	95.807	105.420
4	101.088	133.882	116.703	106.417	94.717	132.422	110.595
5	132.480	131.305	126.391	116.825	133.577	106.869	121.840
6	159.468	152.769	146.812	125.995	138.920	113.281	134.833
7	153.823	135.193	136.297	130.247	122.938	100.249	129.626
8	169.206	154.467	147.759	144.574	116.352	95.774	138.472
9	180.141	180.409	157.576	159.318	104.813	86.275	146.375

TABLE 10.9 COST PROPORTIONS

PER	DIR-WAG	SALARIE	TO-EM-CO	DIR-MAT	FIX-COS	OT-COST	DEPRECI
1	17.833	9.254	35.530	44.930	11.620	4.937	2.984
2	16.820	9.626	35.313	44.429	12.148	5.124	2.987
3	17.430	9.682	36.419	45.949	9.736	4.486	3.410
4	16.300	11.203	37.493	43.232	9.951	5.911	3.412
5	19.390	9.973	36.857	43.080	12.739	4.330	2.994
6	21.091	10.486	38.687	41.985	11.972	4.148	3.209
7	21.162	9.652	37.359	45.145	11.020	3.818	2.658
8	21.791	10.323	37.913	46.909	9.763	3.414	2.000
9	21.947	11.406	38.249	48.902	8.320	2.910	1.618

TABLE 10.10 REVENUE,INVESTMENT AND PROFITS

PER	REVVNUE	TOT-COS	PROFITS	NE-F-IN	WOR-CAP	TOT-CAP
1	100.000	100.000	100.000	100.000	100.000	100.000
2	99.603	98.144	111.400	98.141	98.430	98.308
3	112.439	106.415	115.600	90.740	128.198	112.404
4	102.779	92.202	119.680	83.579	124.279	107.118
5	115.483	113.603	125.432	101.546	128.560	117.170
6	138.344	125.718	95.857	91.392	128.560	112.888
7	156.328	136.575	152.496	82.253	128.560	109.035
8	197.849	163.403	269.066	74.027	132.417	107.797
9	275.307	209.001	522.364	76.618	139.038	112.719

TABLE 10.11 MANAGERIAL CONTROL RATIOS

PER	REV/OUT	COS/OUT	OUT/CAP	CAP/NFI	NFI/TOI	PRO/TOI	PRO/OUT	OUT/TOI
1	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
2	111.610	109.975	89.242	101.895	99.830	113.317	124.829	90.778
3	111.388	105.420	100.944	110.205	80.727	102.843	114.519	89.804
4	123.281	110.595	83.370	119.647	78.025	111.727	143.553	77.830
5	123.856	121.840	93.240	98.477	86.666	107.051	134.527	79.576
6	148.375	134.833	93.240	109.419	80.958	84.913	102.808	82.594
7	148.375	129.626	105.361	121.577	75.437	139.860	144.737	96.630
8	167.663	138.472	118.004	135.085	68.673	249.604	228.014	109.468
9	192.813	146.375	129.804	143.569	67.973	463.421	365.840	126.673)S

TABLE 10.12 COMPONENTS IN RELATIVE CHANGE IN RATE OF RETURN

COMPARISON PERIOD PER	V PER	CH-IN-R	CH-IN-A	CH-IN-E	CH-IN-Z	AE	EZ	AZ	AEZ
2	1	.133	.248	-.108	.017	-.027	-.002	.004	-.000
3	1	.028	.145	.009	-.110	.001	-.001	-.016	-.000
4	1	.117	.436	-.166	-.066	-.072	.011	-.029	.005
5	1	.071	.345	-.068	-.147	-.023	.010	-.051	.003
6	1	-.151	.028	-.068	-.114	-.002	.008	-.003	.000
7	1	.399	.447	.054	-.083	.024	-.004	-.037	-.002
8	1	1.496	1.280	.180	-.072	.230	-.013	-.093	-.017
9	1	3.634	2.658	.298	-.024	.792	-.007	-.064	-.019
2	2	0	0	0	0	0	0	0	0
3	2	-.092	-.083	.131	-.125	-.011	-.016	.010	.001
4	2	-.014	.150	-.066	-.082	-.010	.005	-.012	.001
5	2	-.055	.078	.045	-.161	.003	-.007	-.013	-.001
6	2	-.251	-.176	.045	-.129	-.008	-.006	.023	.001
7	2	.234	.159	.181	-.098	.029	-.018	-.016	-.003
8	2	1.203	.827	.322	-.088	.266	-.028	-.073	-.023
9	2	3.090	1.931	.455	-.041	.878	-.018	-.078	-.036
2	3	.102	.090	-.116	.143	-.010	-.017	.013	-.001
3	3	0	0	0	0	0	0	0	0
4	3	.086	.254	-.174	.049	-.044	-.009	.013	-.002
5	3	.041	.175	-.076	-.041	-.013	.003	-.007	.001
6	3	-.174	-.102	-.076	-.004	.008	.000	.000	-.000
7	3	.360	.264	.044	.031	.012	.001	.008	.000
8	3	1.427	.991	.169	.043	.167	.007	.042	.007
9	3	3.506	2.195	.286	.097	.627	.028	.213	.061
2	4	.014	-.130	.070	.090	-.009	.006	-.012	-.001
3	4	-.080	-.202	.211	-.047	-.043	-.010	.010	.002
4	4	0	0	0	0	0	0	0	0
5	4	-.042	-.063	.118	-.086	-.007	-.010	.005	.001
6	4	-.240	-.284	.118	-.051	-.034	-.006	.015	.002
7	4	.252	.008	.264	-.018	.002	-.005	-.000	-.000
8	4	1.234	.588	.415	-.006	.244	-.003	-.004	-.002
9	4	3.148	1.548	.557	.045	.862	.025	.070	.039
2	5	.059	-.072	-.043	.192	.003	-.008	-.014	.001
3	5	-.039	-.149	.083	.042	-.012	.004	-.006	-.001
4	5	.044	.067	-.106	.094	-.007	-.010	.006	-.001
5	5	0	0	0	0	0	0	0	0
6	5	-.207	-.236	-.000	.038	.000	-.000	-.009	.000
7	5	.306	.076	.130	.075	.010	.010	.006	.001
8	5	1.332	.695	.266	.087	.185	.023	.060	.016
9	5	3.329	1.719	.392	.143	.674	.056	.247	.097
2	6	.335	.214	-.043	.148	-.009	-.006	.032	-.001
3	6	.211	.114	.083	.004	.009	.000	.000	.000
4	6	.316	.396	-.106	.054	-.042	-.006	.021	-.002
5	6	.261	.309	.000	-.037	.000	-.000	-.011	-.000
6	6	0	0	0	0	0	0	0	0
7	6	.647	.408	.130	.035	.053	.005	.014	.002

8	6	1.940	1.218	.266	.047	.323	.013	.058	.015
9	6	4.458	2.558	.392	.102	1.003	.040	.260	.102
2	7	-.190	-.138	-.153	.109	.021	-.017	-.015	.002
3	7	-.265	-.209	-.042	-.030	.009	.001	.006	-.000
4	7	-.201	-.008	-.209	.018	.002	-.004	-.000	.000
5	7	-.235	-.071	-.115	-.069	.008	.008	.005	-.001
6	7	-.393	-.290	-.115	-.034	.033	.004	.010	-.001
7	7	0	0	0	0	0	0	0	0
8	7	.785	.575	.120	.011	.069	.001	.007	.001
9	7	2.313	1.528	.232	.064	.354	.015	.098	.023

TABLE 10.13 COMPONENTS OF RELATIVE CHANGE OF TOTAL UNIT COST

COMPARISON PERIOD PER	V PER	CH-TUC	CH-EMC	CH-MAC	CH-FIX *	CH-OTC	CH-CAPC
2	1	9.9747	9.3006	8.7495	14.9744	14.1463	8.2819
3	1	5.4204	8.0576	7.8115	-11.6720	-4.1931	16.8320
4	1	10.5945	16.7033	6.4170	-5.2831	32.4221	21.7578
5	1	21.8400	26.3907	16.8246	33.5773	6.8693	18.2732
6	1	34.8329	46.8121	25.9954	38.9204	13.2815	36.9822
7	1	29.6260	36.2971	30.2469	22.9384	.2491	12.7269
8	1	38.4724	47.7586	44.5740	16.3524	-4.2263	-5.9165
9	1	46.3750	57.5765	59.3182	4.8133	-13.7245	-16.9471
2	2	0	0	0	0	0	0
3	2	-4.5542	-1.2430	-.9380	-26.6464	-18.3394	8.5501
4	2	.6198	7.4027	-2.3325	-20.2575	18.2758	13.4759
5	2	11.8654	17.0901	8.0750	18.6029	-7.2769	9.9913
6	2	24.8582	37.5115	17.2459	23.9459	-.8648	28.7003
7	2	19.6513	26.9965	21.4974	7.9640	-13.8972	4.4450
8	2	28.4977	38.4580	35.8245	1.3780	-18.3726	-14.1985
9	2	36.4003	48.2758	50.5687	-10.1611	-27.8708	-25.2291
2	3	4.5542	1.2430	.9380	26.6464	18.3394	-8.5501
3	3	0	0	0	0	0	0
4	3	5.1741	8.6457	-1.3945	6.3889	36.6152	4.9258
5	3	16.4196	18.3331	9.0131	45.2493	11.0624	1.4412
6	3	29.4125	38.7545	18.1839	50.5924	17.4746	20.1502
7	3	24.2055	28.2395	22.4354	34.6104	4.4422	-4.1051
8	3	33.0519	39.7010	36.7626	28.0244	-.0332	-22.7485
9	3	40.9545	49.5188	51.5067	16.4853	-9.5314	-33.7791
2	4	-.6198	-7.4027	2.3325	20.2575	-18.2758	-13.4759
3	4	-5.1741	-8.6457	1.3945	-6.3889	-36.6152	-4.9258
4	4	0	0	0	0	0	0
5	4	11.2455	9.6874	10.4075	38.8604	-25.5528	-3.4846
6	4	24.2384	30.1088	19.5784	44.2035	-19.1406	15.2244
7	4	19.0315	19.5937	23.8299	28.2215	-32.1730	-9.0309
8	4	27.8778	31.0553	38.1570	21.6355	-36.6484	-27.6744
9	4	35.7805	40.8731	52.9012	10.0964	-46.1466	-38.7049
2	5	-11.8654	-17.0901	-8.0750	-18.6029	7.2769	-9.9913
3	5	-16.4196	-18.3331	-9.0131	-45.2493	-11.0624	-1.4412
4	5	-11.2455	-9.6874	-10.4075	-38.8604	25.5528	3.4846

5	5	0	0	0	0	0	0
6	5	12.9929	20.4214	9.1708	5.3431	6.4122	18.7090
7	5	7.7860	9.9063	13.4223	-10.6389	-6.6202	-5.5463
8	5	16.6323	21.3679	27.7495	-17.2249	-11.0956	-24.1898
9	5	24.5349	31.1857	42.4936	-28.7640	-20.5938	-35.2204
2	6	-24.8582	-37.5115	-17.2459	-23.9459	.8648	-28.7003
3	6	-29.4125	-38.7545	-18.1839	-50.5924	-17.4746	-20.1502
4	6	-24.2384	-30.1088	-19.5784	-44.2035	19.1406	-15.2244
5	6	-12.9929	-20.4214	-9.1708	-5.3431	-6.4122	-18.7090
6	6	0	0	0	0	0	0
7	6	-5.2069	-10.5151	4.2515	-15.9820	-13.0324	-24.2553
8	6	3.6395	.9465	18.5786	-22.5680	-17.5078	-42.8988
9	6	11.5421	10.7643	33.3228	-34.1071	-27.0060	-53.9293
2	7	-19.6513	-26.9965	-21.4974	-7.9640	13.8972	-4.4450
3	7	-24.2055	-28.2395	-22.4354	-34.6104	-4.4422	4.1051
4	7	-19.0315	-19.5937	-23.8299	-28.2215	32.1730	9.0309
5	7	-7.7860	-9.9063	-13.4223	10.6389	6.6202	5.5463
6	7	5.2069	10.5151	-4.2515	15.9820	13.0324	24.2553
7	7	0	0	0	0	0	0
8	7	8.8464	11.4616	14.3272	-6.5860	-4.4754	-18.6434
9	7	16.7490	21.2794	29.0713	-18.1251	-13.9736	-29.6740

COMPARISON PERIOD

PER	V PER	CH-TOC	CP*CEMC	CP*CMAC	CP*CFIX	CP*COTC	CP*CCAP
2	1	.0997	.0330	.0393	.0174	.0070	.0025
3	1	.0542	.0286	.0351	-.0136	-.0021	.0050
4	1	.1059	.0593	.0288	-.0061	.0160	.0065
5	1	.2184	.0938	.0756	.0390	.0034	.0055
6	1	.3483	.1663	.1168	.0452	.0066	.0110
7	1	.2963	.1290	.1359	.0267	.0001	.0038
8	1	.3847	.1697	.2003	.0190	-.0021	-.0018
9	1	.4637	.2046	.2665	.0056	-.0068	-.0051
2	2	0	0	0	0	0	0
3	2	-.0455	-.0044	-.0042	-.0324	-.0094	.0026
4	2	.0062	.0261	-.0104	-.0246	.0094	.0040
5	2	.1187	.0603	.0359	.0226	-.0037	.0030
6	2	.2486	.1325	.0766	.0291	-.0004	.0086
7	2	.1965	.0953	.0955	.0097	-.0071	.0013
8	2	.2850	.1358	.1592	.0017	-.0094	-.0042
9	2	.3640	.1705	.2247	-.0123	-.0143	-.0075
2	3	.0455	.0045	.0043	.0259	.0082	-.0029
3	3	0	0	0	0	0	0
4	3	.0517	.0315	-.0064	.0062	.0164	.0017
5	3	.1642	.0668	.0414	.0441	.0050	.0005
6	3	.2941	.1411	.0836	.0493	.0078	.0069
7	3	.2421	.1028	.1031	.0337	.0020	-.0014
8	3	.3305	.1446	.1689	.0273	-.0000	-.0078
9	3	.4095	.1803	.2367	.0160	-.0043	-.0115
2	4	-.0062	-.0278	.0101	.0202	-.0108	-.0046
3	4	-.0517	-.0324	.0060	-.0064	-.0216	-.0017
4	4	0	0	0	0	0	0

5	4	.1125	.0363	.0450	.0387	-.0151	-.0012
6	4	.2424	.1129	.0846	.0440	-.0113	.0052
7	4	.1903	.0735	.1030	.0281	-.0190	-.0031
8	4	.2788	.1164	.1650	.0215	-.0217	-.0094
9	4	.3578	.1532	.2287	.0100	-.0273	-.0132
2	5	-.1187	-.0630	-.0348	-.0237	.0032	-.0030
3	5	-.1642	-.0676	-.0388	-.0576	-.0048	-.0004
4	5	-.1125	-.0357	-.0448	-.0495	.0111	.0010
5	5	0	0	0	0	0	0
6	5	.1299	.0753	.0395	.0068	.0028	.0056
7	5	.0779	.0365	.0578	-.0136	-.0029	-.0017
8	5	.1663	.0788	.1195	-.0219	-.0048	-.0072
9	5	.2453	.1149	.1831	-.0366	-.0089	-.0105
2	6	-.2486	-.1451	-.0724	-.0287	.0004	-.0092
3	6	-.2941	-.1499	-.0763	-.0606	-.0072	-.0065
4	6	-.2424	-.1165	-.0822	-.0529	.0079	-.0049
5	6	-.1299	-.0790	-.0385	-.0064	-.0027	-.0060
6	6	0	0	0	0	0	0
7	6	-.0521	-.0407	.0178	-.0191	-.0054	-.0078
8	6	.0364	.0037	.0780	-.0270	-.0073	-.0138
9	6	.1154	.0416	.1399	-.0408	-.0112	-.0173
2	7	-.1965	-.1009	-.0970	-.0088	.0053	-.0012
3	7	-.2421	-.1055	-.1013	-.0381	-.0017	.0011
4	7	-.1903	-.0732	-.1076	-.0311	.0123	.0024
5	7	-.0779	-.0370	-.0606	.0117	.0025	.0015
6	7	.0521	.0393	-.0192	.0176	.0050	.0064
7	7	0	0	0	0	0	0
8	7	.0885	.0428	.0647	-.0073	-.0017	-.0050
9	7	.1675	.0795	.1312	-.0200	-.0053	-.0079

TABLE 10.15A OUTPUT INDEX (FISHER,S METHOD)

BASE PERIOD	1	2	3	4	5	6	7	8	9
OUTPUT PER PERIOD									
1	100.0000	112.0600	99.0700	119.9500	107.2500	107.2500	94.9100	84.7400	70.0400
2	89.2400	100.0000	88.1000	106.7200	95.5200	95.5200	84.5300	75.4700	62.3700
3	100.9400	113.5100	100.0000	121.7700	109.2800	109.2800	96.7100	86.3500	71.3600
4	83.3700	93.7000	82.1200	100.0000	89.6200	89.6200	79.3100	70.8100	58.5200
5	93.2400	104.7000	91.5100	111.5800	100.0000	100.0000	88.5000	70.0200	65.3000
6	93.2400	104.7000	91.5100	111.5800	100.0000	100.0000	88.5000	79.0200	65.3000
7	105.3600	118.3100	103.4000	126.0800	113.0000	113.0000	110.0000	89.2900	73.7900
8	118.0000	132.5000	115.8100	141.2200	126.5600	126.5600	112.0000	100.0000	89.6500
9	142.7900	160.3300	140.1300	170.8700	153.1400	153.1400	135.5200	121.0000	100.0000
OP-PR9/OP-PR1	1.4279	1.4308	1.4145	1.4245	1.4279	1.4279	1.4279	1.4279	1.4278

TABLE 10.15B OUTPUT INDEX (EDGEWORTH ARITHMATIC METHOD)

BASE PERIOD	1	2	3	4	5	6	7	8	9
OUTPUT PER PERIOD									
1	100.0000	112.0500	99.0900	120.0000	107.4200	107.4900	95.1300	85.0000	70.3200
2	89.2400	100.0000	88.1000	106.7300	95.6100	95.6700	84.6700	75.6500	62.5700
3	100.9200	113.5100	100.0000	121.7800	109.3200	109.3500	96.7700	86.4300	71.4600
4	83.3400	93.7000	82.1200	100.0000	89.6400	89.6600	79.3500	70.8700	58.5900
5	93.1000	104.5900	91.4800	111.5600	100.0000	100.0000	88.5000	79.0100	65.3000
6	93.0300	104.5200	91.4500	111.5300	100.0000	100.0000	88.5000	79.0100	65.3000
7	105.1200	118.1100	103.3300	126.0300	113.0000	113.0000	100.0000	89.2900	73.7900
8	117.6400	132.1900	115.7000	141.1000	126.5600	126.5600	112.0000	100.0000	82.6500
9	142.2200	159.8300	139.9400	170.7000	153.1400	153.1400	135.5200	121.0000	100.0000
OP-PR9/OP-PR1	1.4222	1.4264	1.4123	1.4225	1.4256	1.4247	1.4246	1.4235	1.4221

TABLE 10.15C OUTPUT INDEX (EDGEWORTH GEOMETRIC METHOD)

BASE PERIOD	1	2	3	4	5	6	7	8	9
OUTPUT PER PERIOD									
1	100.0000	112.0500	99.0700	119.9600	107.2300	107.2300	94.8900	84.7300	70.0200
2	89.2400	100.0000	88.1000	106.7000	95.4900	95.4900	84.5000	75.4500	62.3600
3	100.9400	113.5100	100.0000	121.7600	109.2600	109.2600	96.6900	86.3300	71.3500
4	83.3600	93.7200	82.1300	100.0000	89.6200	89.6200	79.3100	70.8100	58.5200
5	93.2600	104.7300	91.5300	111.5900	100.0000	100.0000	88.5000	79.0100	65.3000
6	93.2600	104.7300	91.5300	111.5900	100.0000	100.0000	88.5000	79.0100	65.3000
7	105.3800	118.3400	103.4200	126.0900	113.0000	113.0000	100.0000	89.2900	73.7900
8	118.0300	132.5400	115.8300	141.2200	126.5600	126.5600	112.0000	100.0000	82.6500
9	142.8200	160.3700	140.1600	170.8800	153.1400	153.1400	135.5200	121.0000	100.0000
OP-PR9/OP-PR1	1.4282	1.4312	1.4148	1.4245	1.4282	1.4282	1.4282	1.4281	1.4282

TABLE 10.15D OUTPUT INDEX (LASPEYERS, METHOD)

BASE PERIOD	1	2	3	4	5	6	7	8	9
OUTPUT PER PERIOD									
1	100.0000	111.9300	99.4600	120.5800	108.7600	108.7600	96.2500	85.9400	71.0200
2	89.1400	100.0000	88.0900	106.8300	96.6600	96.6600	85.5400	76.3800	63.1200
3	101.3500	113.5000	100.0000	121.9100	109.9100	109.9100	97.2600	86.8400	71.7700
4	83.8100	93.8000	82.2100	100.0000	90.1200	90.1200	79.7600	71.2100	58.8500
5	94.5600	105.9500	92.0300	112.2000	100.0000	100.0000	88.5000	79.0100	65.3000
6	94.5600	105.9500	92.0300	112.2000	100.0000	100.0000	88.5000	79.0100	65.3000
7	106.8500	119.7300	103.9900	126.7900	113.0000	113.0000	100.0000	89.2900	73.7900
8	119.6700	134.0900	116.4700	142.0000	126.5600	126.5600	112.0000	100.0000	82.6500
9	144.8000	162.2500	140.9300	171.8300	153.1400	153.1400	135.5200	121.0000	100.0000
OP-PR9/OP-PR1	1.4480	1.4496	1.4170	1.4250	1.4081	1.4081	1.4080	1.4080	1.4081

TABLE 10.16A MAN-HOUR INDEX (FISHER,S METHOD)

BASE PERIOD	1	2	3	4	5	6	7	8	9
OUTPUT PER PERIOD									
1	100.0000	111.5200	104.8900	136.1500	111.3400	111.3400	102.1400	91.2000	79.9900
2	89.6700	100.0000	94.1500	122.0800	99.9100	99.9100	91.6700	81.8400	71.7900
3	95.3400	106.2100	100.0000	130.0900	106.3900	106.3900	97.6100	87.1500	76.4500
4	73.4500	81.9100	76.8700	100.0000	81.7700	81.7700	75.0200	66.9800	58.7600
5	89.8200	100.0900	93.9900	122.2900	100.0000	100.0000	91.7400	81.9100	71.8500
6	89.8200	100.0900	93.9900	122.2900	100.0000	100.0000	91.7400	81.9100	71.8500
7	97.9000	109.1000	102.4500	133.2900	109.0000	109.0000	100.0000	89.2900	78.3200
8	109.6500	122.1900	114.7500	149.2900	122.0800	122.0800	112.0000	100.0000	87.7200
9	125.0000	139.2900	130.8100	170.1900	139.1700	139.1700	127.6800	114.0000	100.0000
OP-PR9/OP-PR1	1.2500	1.2490	1.2471	1.2510	1.2499	1.2499	1.2501	1.2500	1.2500

TABLE 10.16B MAN-HOUR INDEX (LASPEYERS, METHOD)

BASE PERIOD	1	2	3	4	5	6	7	8	9
OUTPUT PER PERIOD									
1	100.0000	111.6100	104.9000	136.2000	111.3300	111.3300	102.1400	91.2000	80.0000
2	89.7500	100.0000	94.2900	122.2900	100.0500	100.0500	91.7900	81.9500	71.8900
3	95.3600	106.3700	100.0000	129.9500	106.2600	106.2600	97.4900	87.0400	76.3500
4	73.4800	82.0500	76.7900	100.0000	81.7700	81.7700	75.0200	66.9800	58.7600
5	89.8200	100.2200	93.8800	122.2900	100.0000	100.0000	91.7400	81.9100	71.8500
6	89.8200	100.2200	93.8800	122.2900	100.0000	100.0000	91.7400	81.9100	71.8500
7	97.9000	109.2400	102.3300	133.3000	109.0000	109.0000	100.0000	89.2900	78.3200
8	109.6500	122.3500	114.6100	149.2900	122.0800	122.0800	112.0000	100.0000	87.7200
9	125.0000	139.4700	130.6500	170.1900	139.1700	139.1700	127.6800	114.0000	100.0000
OP-PR9/OP-PR1	1.2500	1.2496	1.2455	1.2496	1.2501	1.2501	1.2501	1.2500	1.2500

Fig. 10.1 Index of Physical Output and Its Components

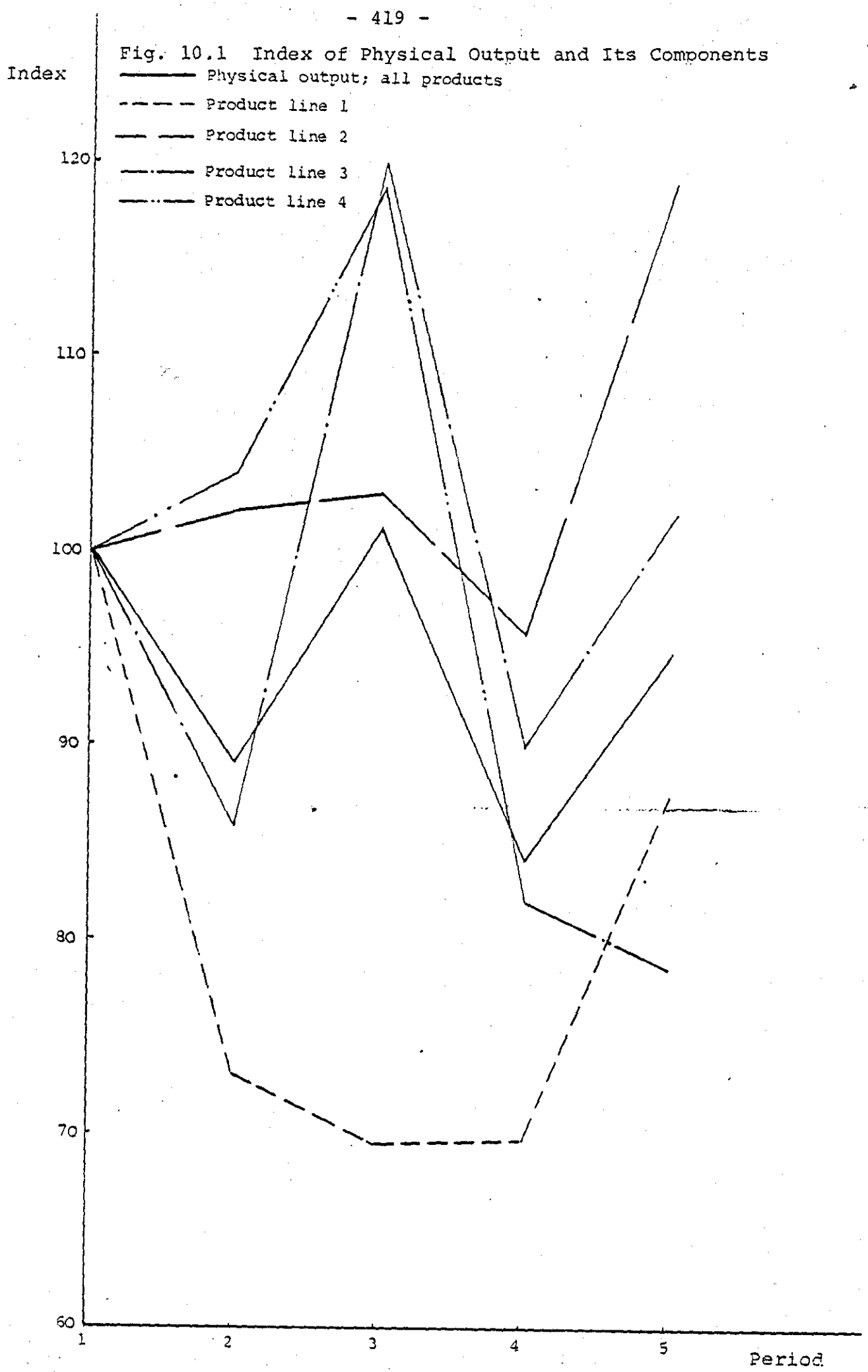


Fig. 10.2 Index to Total Volume of Material Input and Its Components

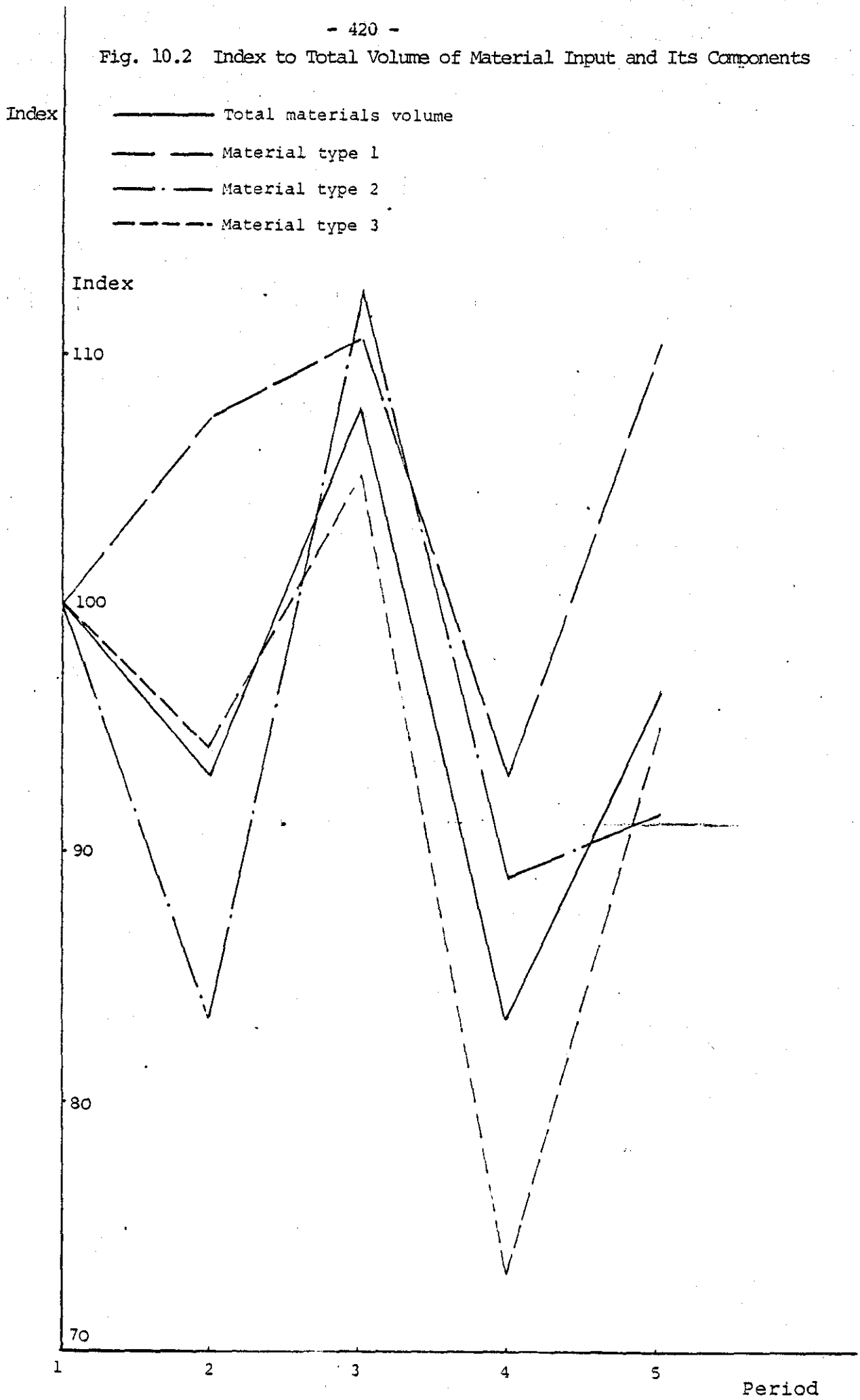


Fig. 10.3 Physical Inputs and Output

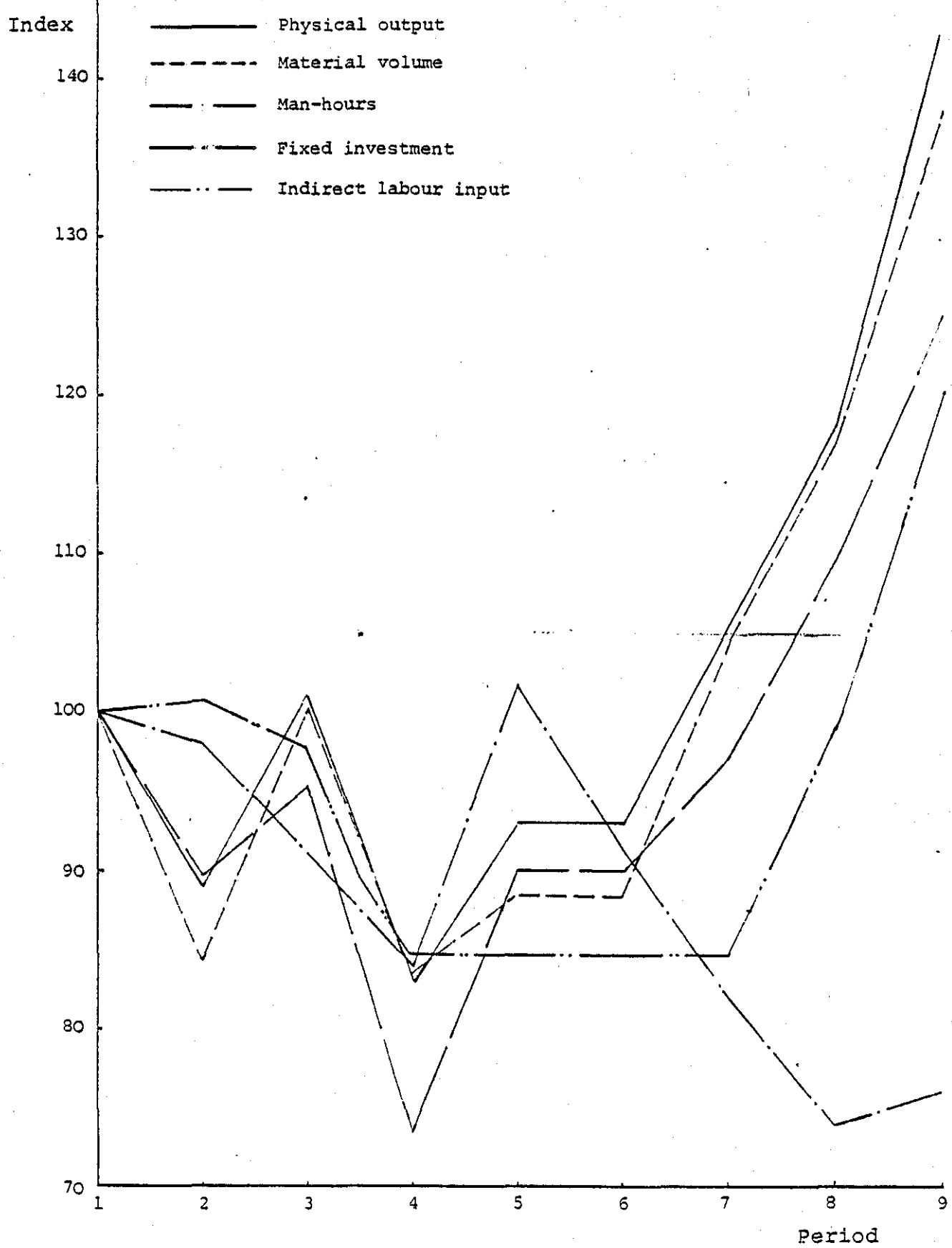


Fig. 10.4 Physical Output and Apparent Productivity of Direct Inputs

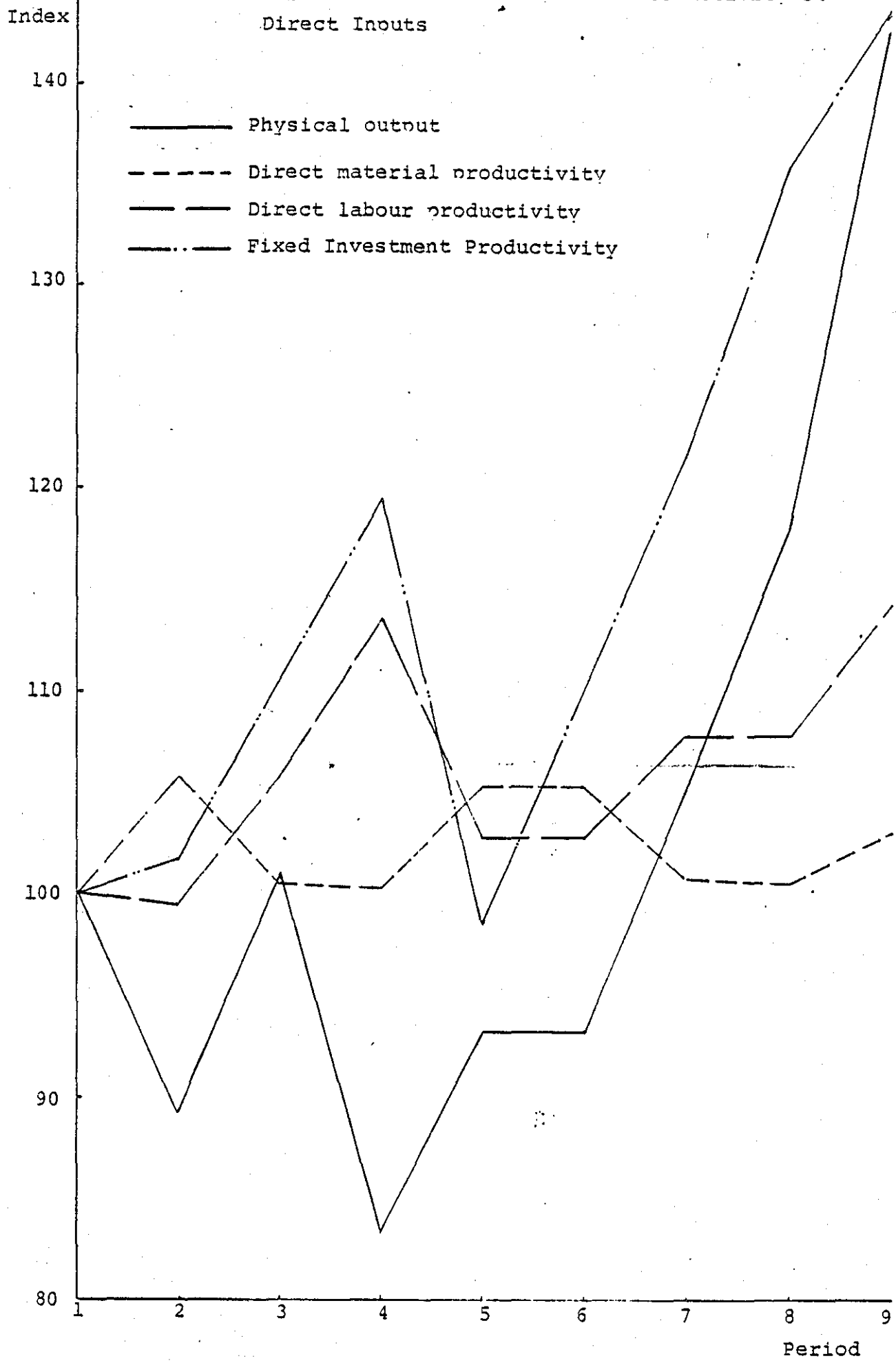


Fig. 10.5 The Relationship between Labour and Capital

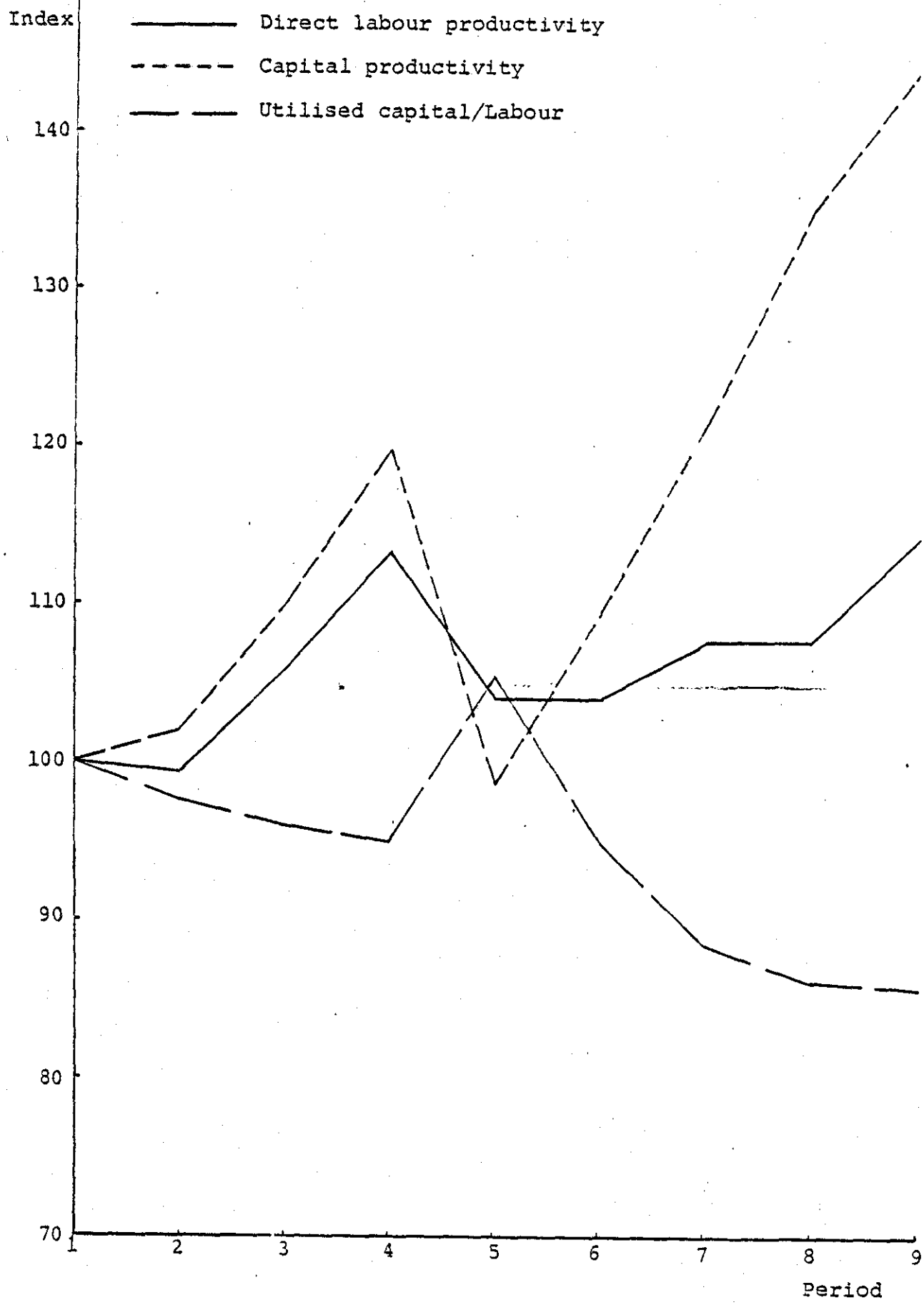


Fig. 10.6 The Relationship between Materials and Capital

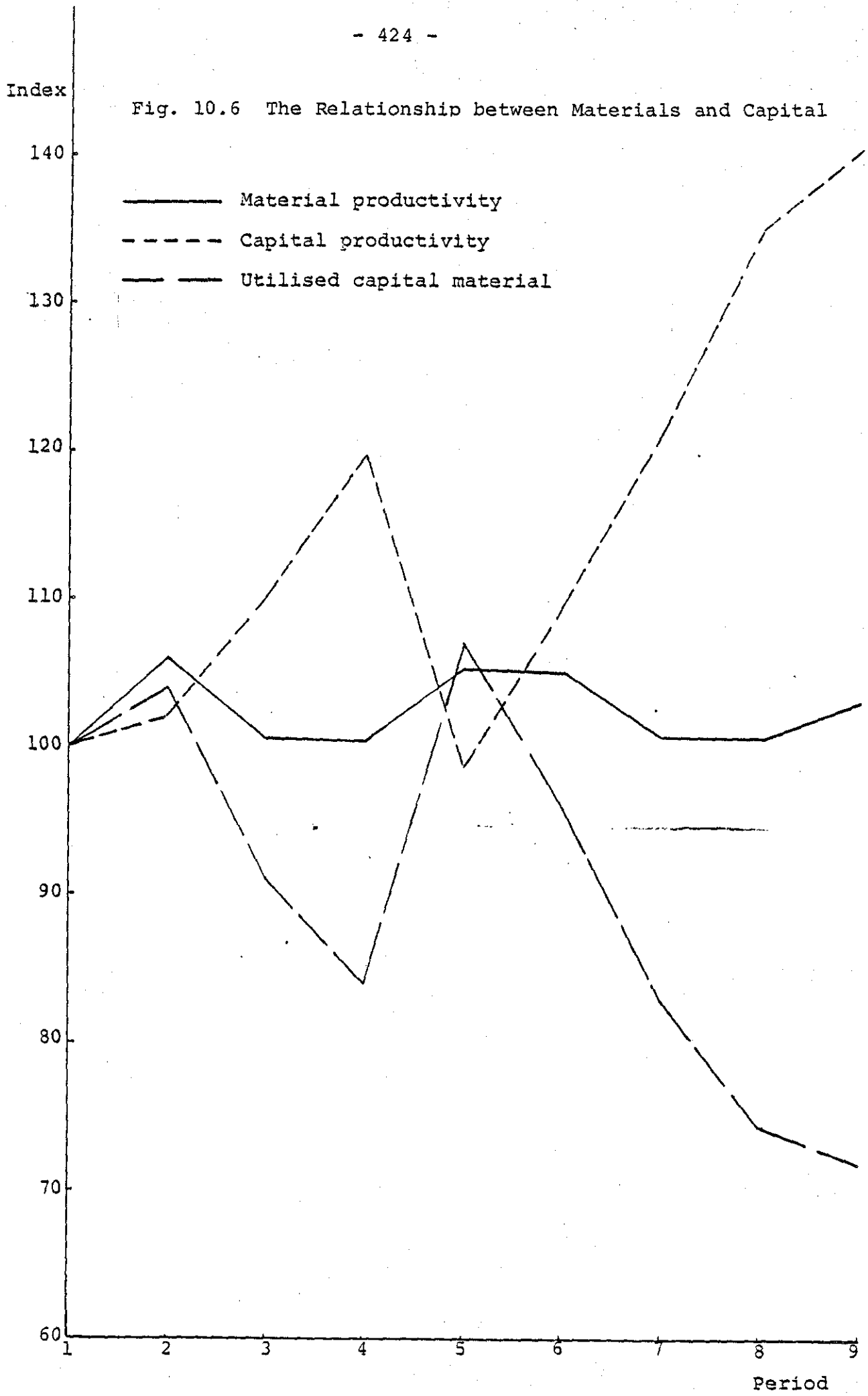


Fig. 10.7 Physical Output and Factor Proportions

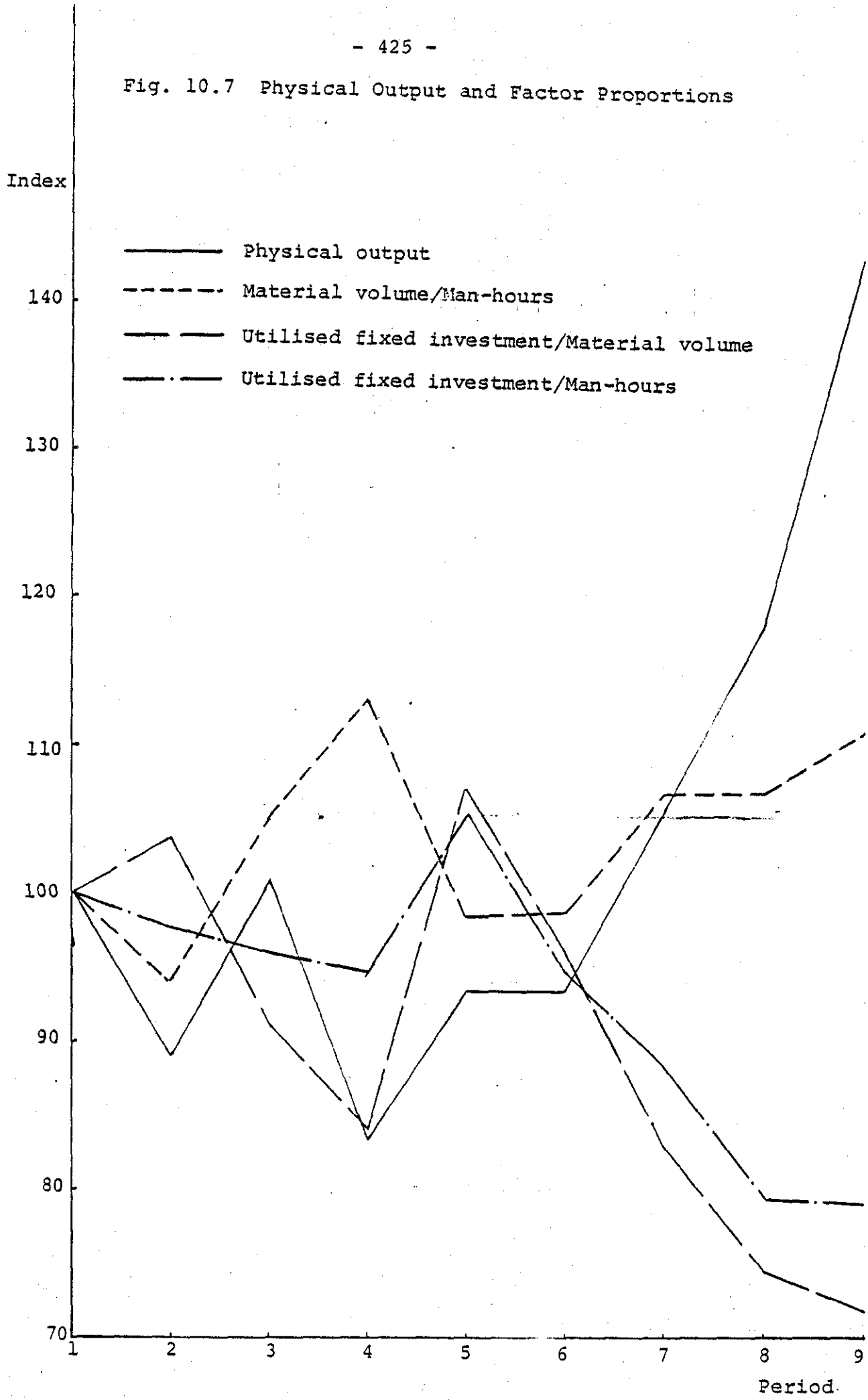


Fig. 10.8 Physical Output and Apparent Productivity of Indirect Inputs

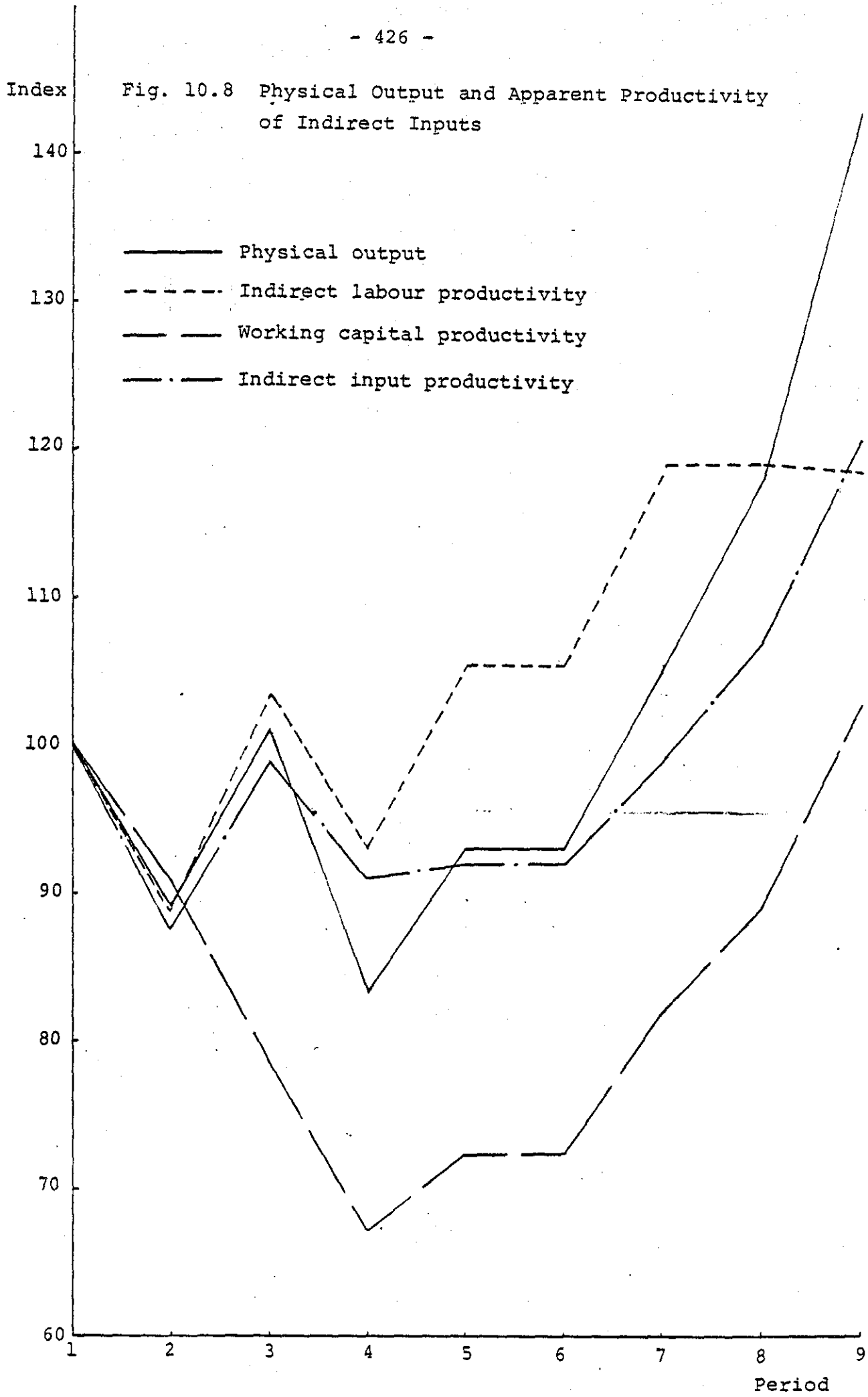


Fig. 10.9 The Calculation of Average Selling Price

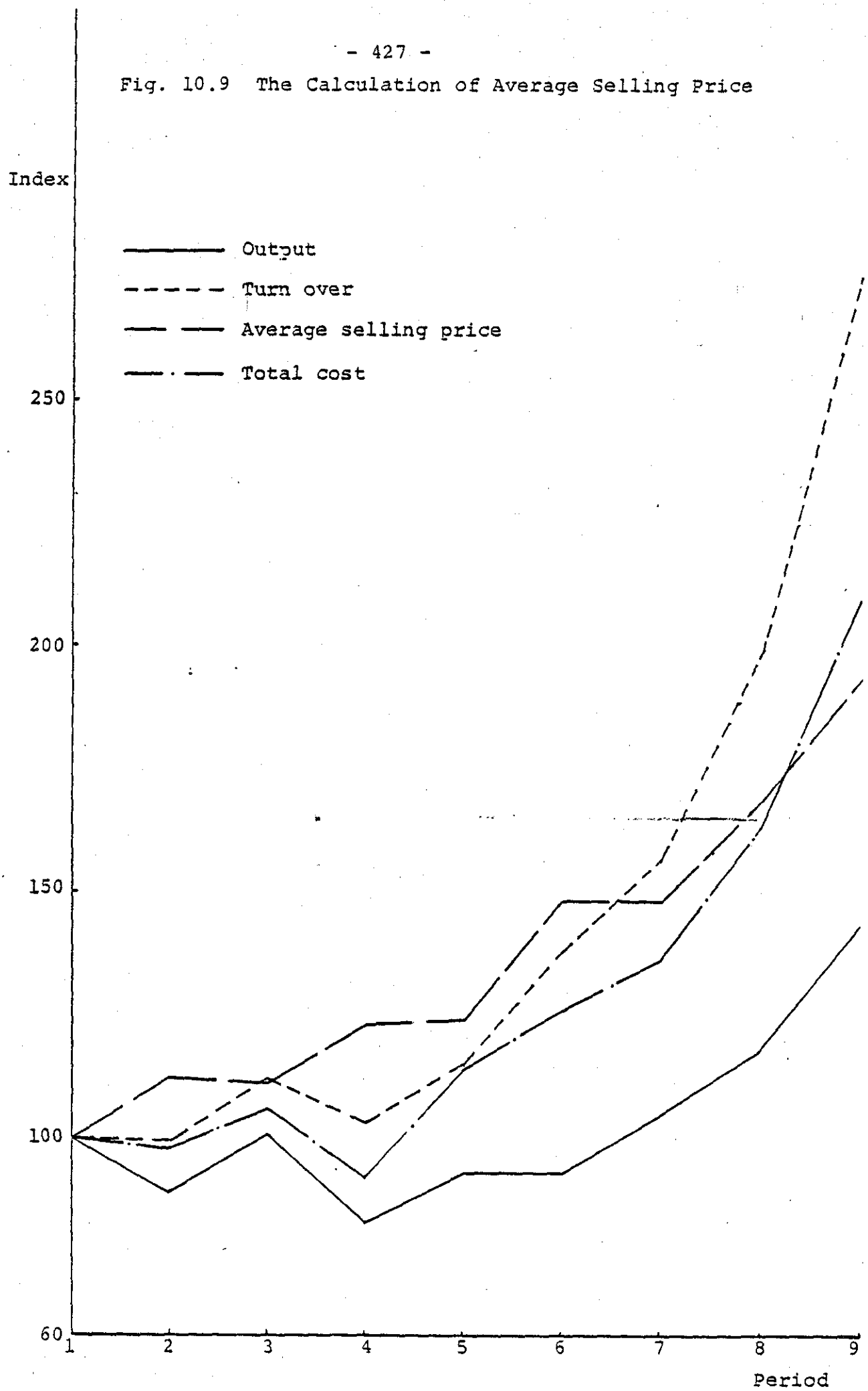


Fig. 10.10 Cost Proportions

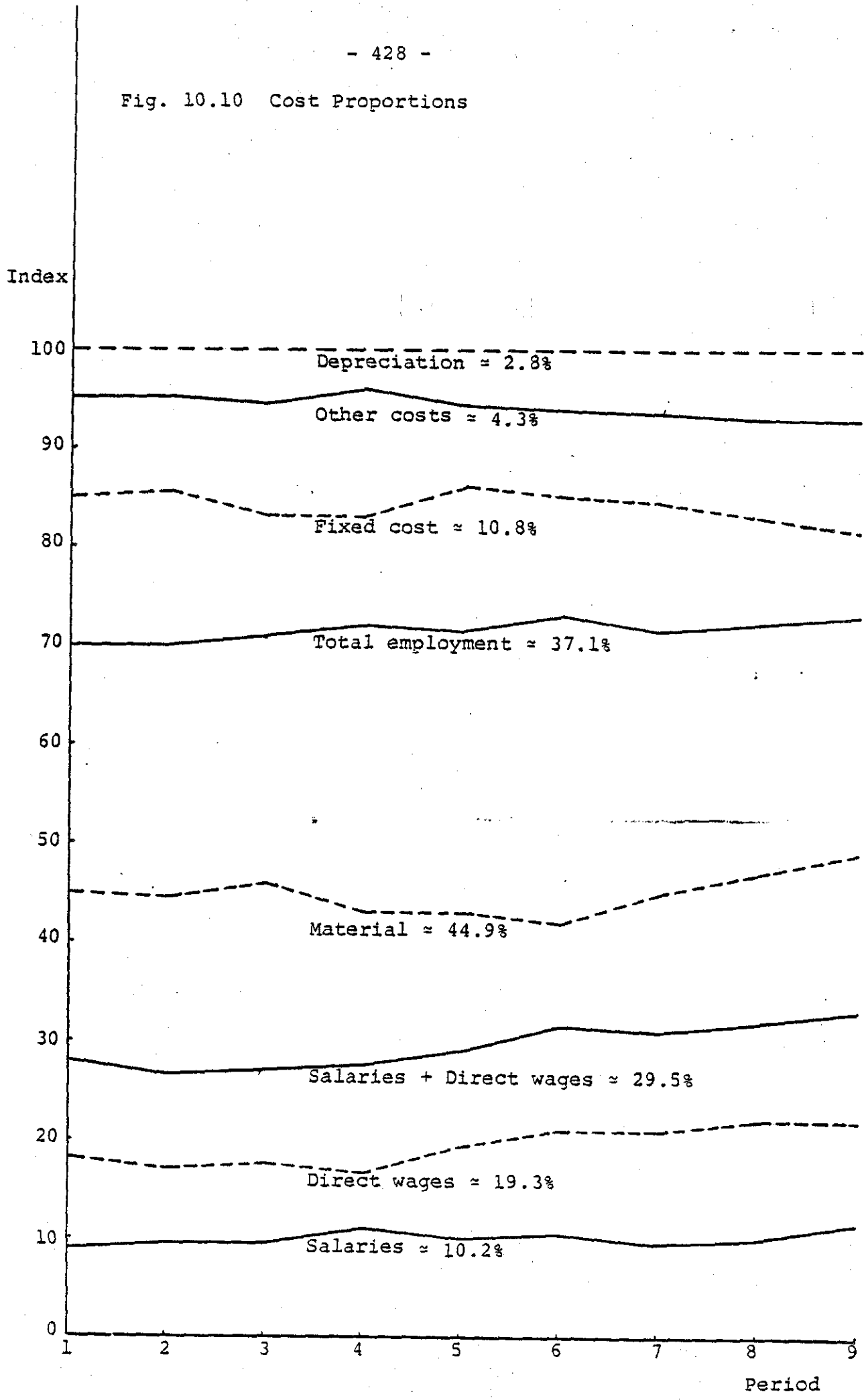


Fig. 10.11 Total Unit Costs and Its Components

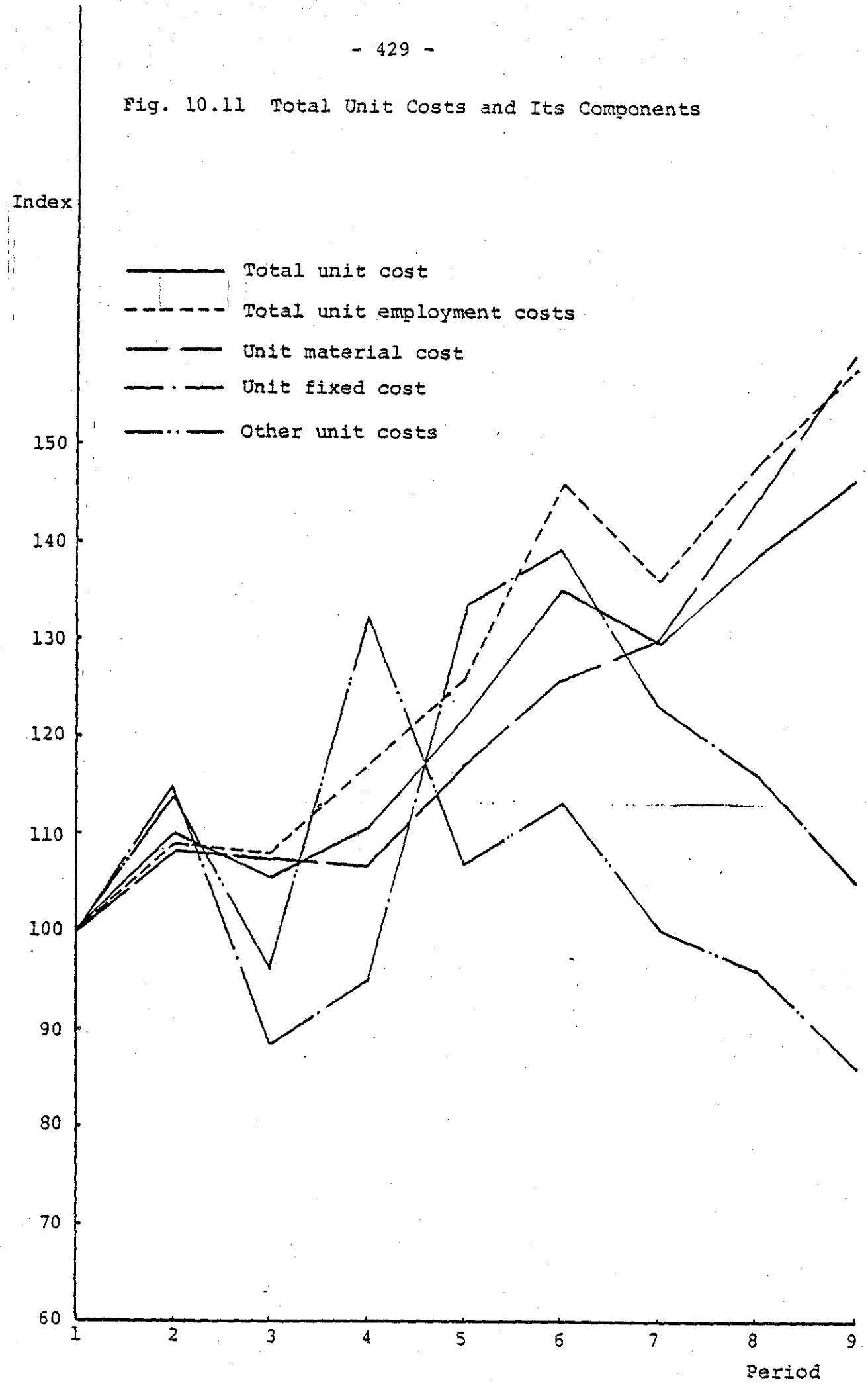


Fig. 10.12 Total and Partial Labour Unit Cost and Total Unit Cost

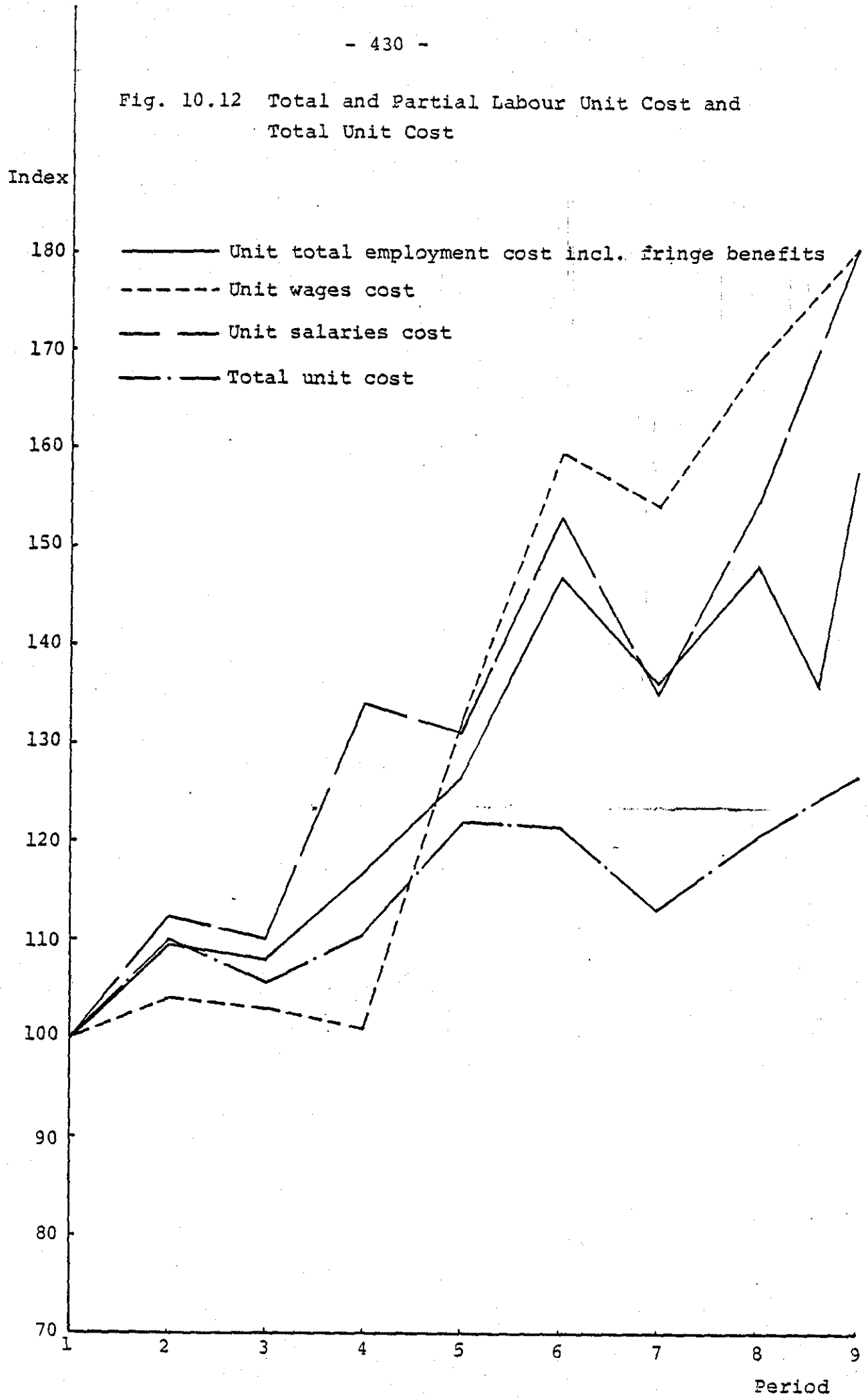


Fig. 10.13 Input Prices, Output and Profit Margins

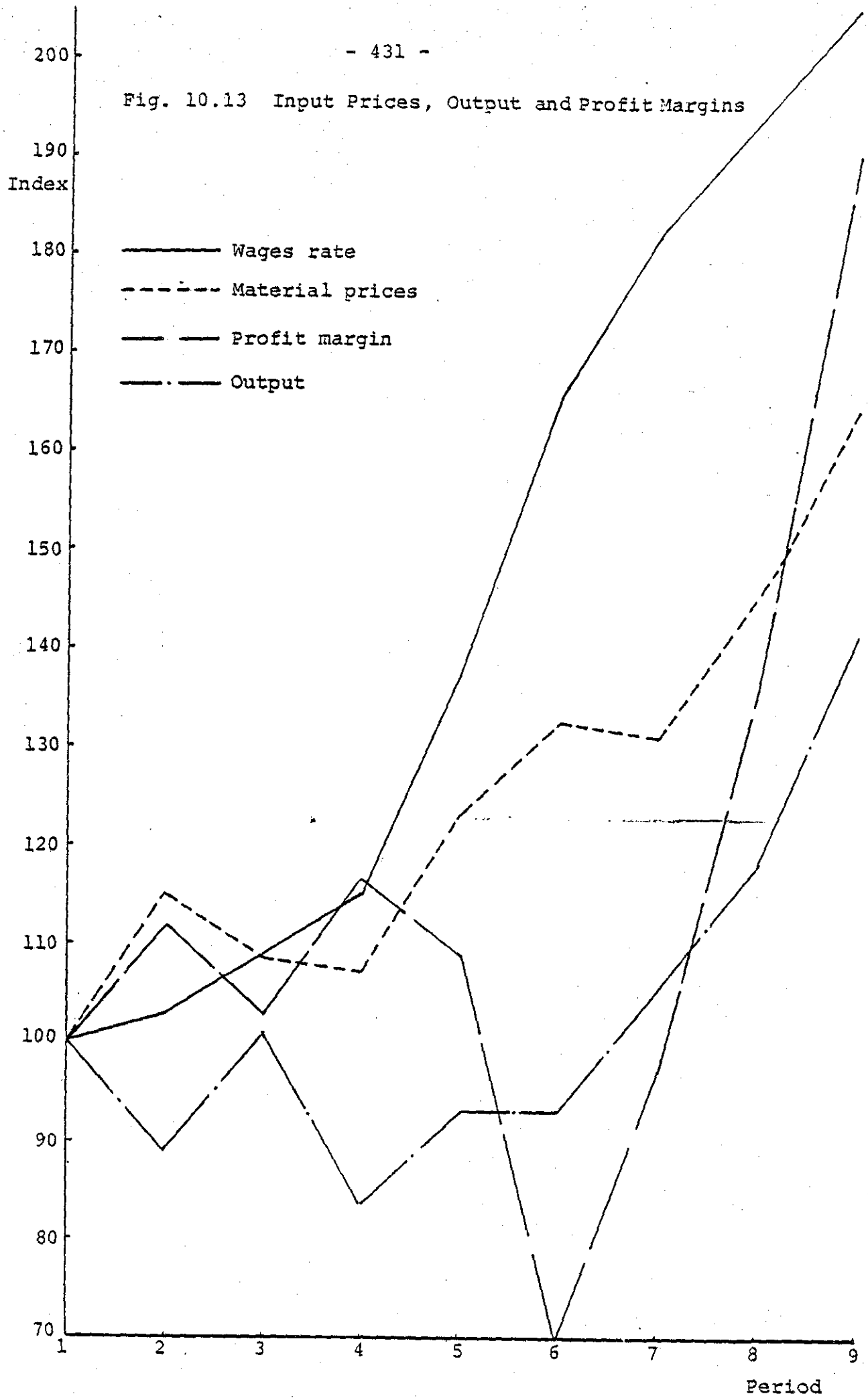


Fig. 10.14 Output vs. Total Unit Cost

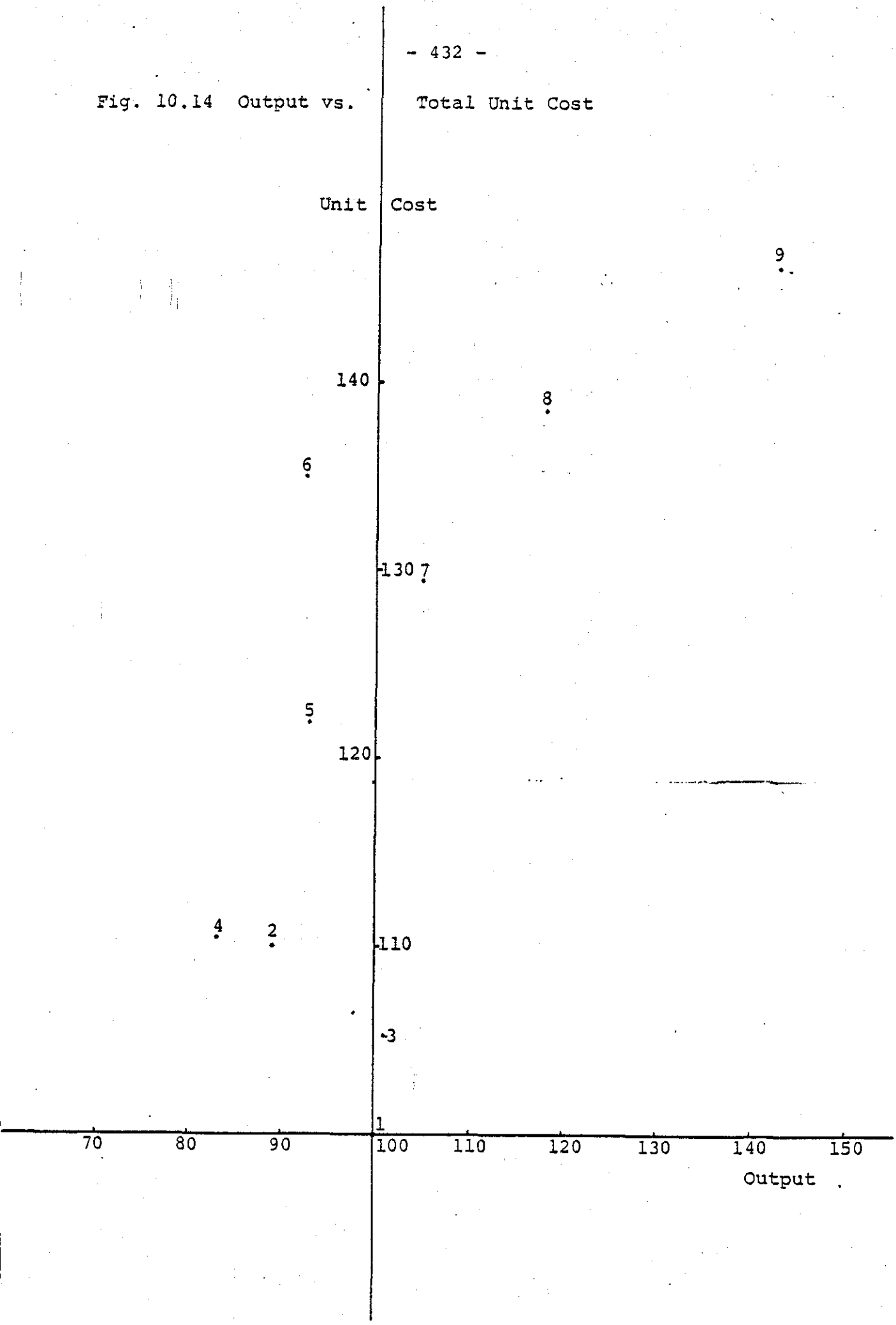


Fig. 10.15 The Calculation of Unit Profit

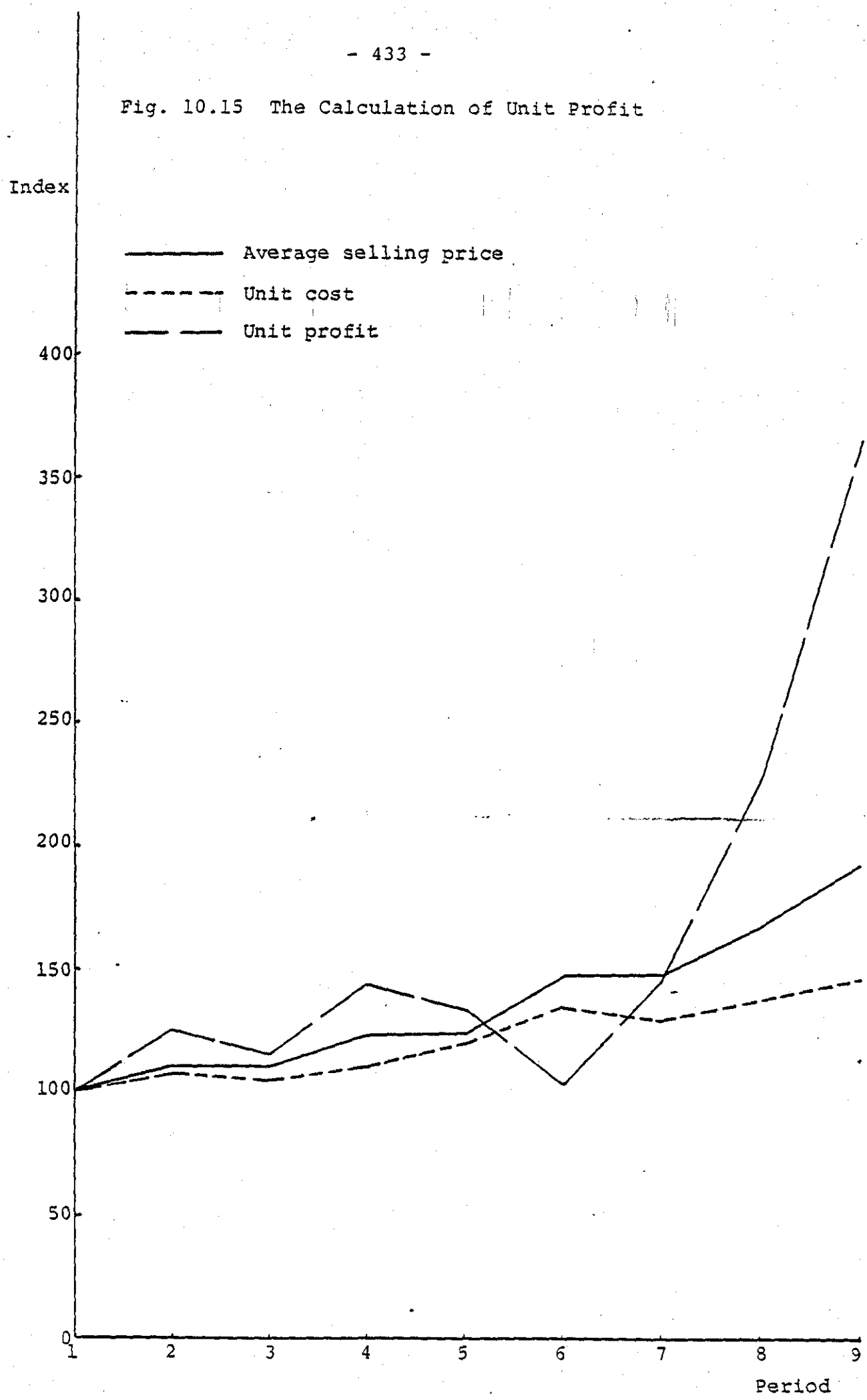


Fig. 10.16 Return on Capital and Its Major Components

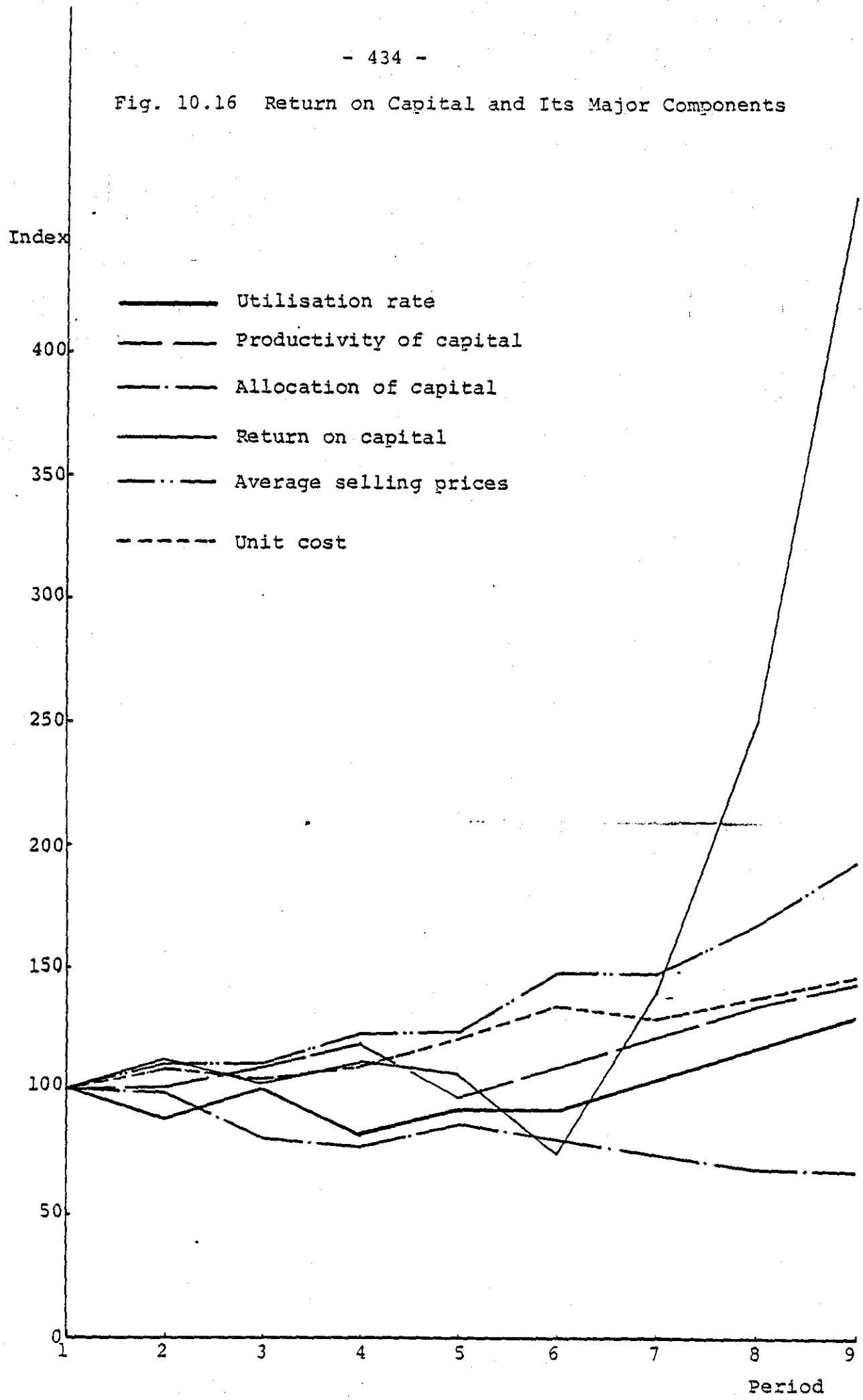
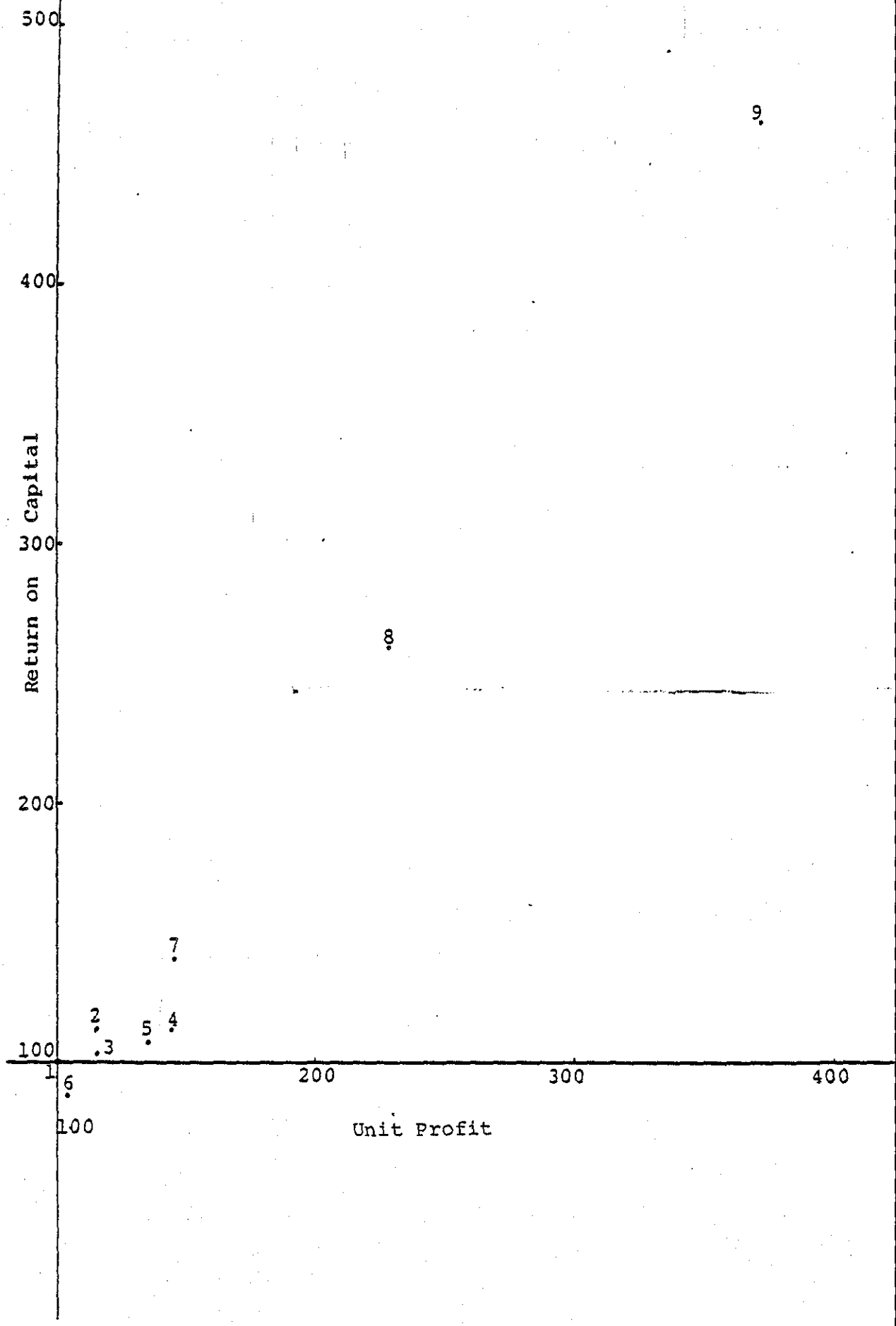


Fig. 10.17 Unit Profit vs Return on Capital



10.3 Case Study 2: Company B

This case study refers to company B. The background of this company was described in Chapter 6 and is not repeated here. As before, the case study is composed of two sections. In the first section we deal with the basic measurement, and in the second section we present the result of the historical analysis carried out.

The case study provides an interesting contrast to the one described previously, as company B manufactures a wide range of products in small batches. These vary between two to several thousand. Because of this "jobbing shop" characteristic, the measurement problems presented and their solutions are entirely different from those described in the previous section.

As was mentioned in Section 9.5 of the previous chapter, effective management requires penetration beneath aggregate productivity relationships to the behaviour of the components which comprise them. To demonstrate this concept, interior sectoral studies were undertaken. For this purpose the aggregate output was decomposed into the output of each product line and separate networks of input-output measures were developed for each.

10.3.1 Basic measurements

Data were collected for the 12 months between April 1978 and March 1979, which involved no significant changes in plant facilities, accounting practices, or job structures.

Most of the data required were available, but not in a format compatable with the analytical model presented in the previous chapter. Actual sources used included: sales invoices, profit and loss accounts, balance sheets, and manpower statistics. The interval between each calculation was one month. Data used in computations had to be adjusted for a coverage of three- and five-week months.

10.3.1a Outputs

As stated previously, company B produces a wide range of products. Each basic design could be used to produce an infinite number of slightly different products, as is the case frequently. As well, unit prices are greatly affected by very minor variations in product design. For this reason it was not possible to collect the data necessary for computation of an output index using any of the formulae 9.11, 9.14 or 9.16 as presented in Chapter 9.

This problem was overcome by collecting revenue data. These consist of two factors, prices and quantities. At the lower part of network of productivity analysis interest is focused on physical relationships. Consequently, as long as the price component of sales revenue is kept constant, any change from one period compared to another is due to a change in quantities weighted by base year prices, i.e., physical change. This could be achieved by deflating the sales revenue to a base period value using a deflation factor. The choice of deflation factor depends on the information available. An internally calculated price index is perhaps most suitable for this purpose. Unfortunately, the information required for construction of such an index was not available.

The index we used for deflation purposes was the whole sale price index for the electrical engineering section published monthly by the Central Statistics Office. This method is much less refined than using an internally-developed index. The difficulty is that one cannot be sure of the appropriateness of a global index to the firms' special circumstances. Nevertheless, the wholesale price index was the only deflation factor available to us.

Each month, sales turnovers were adjusted for changes in finished goods and work-in-progress inventories, in order to convert the sales output to a production output.

The production function is divided according to product

lines. There are four main products, hence four production control departments, each being responsible for one product line. Sales turnover for each main product category was available from the company's management accounting package. This information was collected for use in interior sectoral studies.

10.3.1b Materials volume

We were unable to use any of the formulae 9.11, 9.14 or 9.16 presented in previous chapter for computing the physical changes in volume of materials used in production. The reason for this was simply the wide range of material and parts purchased, hence lack of reliable quantity and prices data.

Usage value of material input was calculated by adjusting the monthly direct material expenses for changes in materials and parts inventory. These values were then deflated to a base period value using the purchases wholesale price index for the electrical engineering sector.

The above process was repeated in the case of the four product lines to determine the material usage in each instance.

10.3.1c Direct labour input

The direct labour force was divided into six categories, according to the sections they were employed. The attendance hour for each category was collected from manpower statistics. Total wages for each group of direct employees was available from company's payrolls. The base period hourly rate, for each category of direct employees, was computed by dividing the appropriate total wages by total attendance hours.

Changes in man-hour input were computed using Laspeyer's formulation (Equation 9.11, presented in Chapter 9).

10.3.1d Capacity

Techniques described in Section 10.2.1g for determination of capacity are inappropriate to the present study. The

reason for this is simply the vast range of products. The number of products the plant can produce in a day or in a year, assuming other factors remain constant, depends entirely upon the product mix.

Because of the impracticability of techniques available for estimations of capacity, no calculations of capacity were made in the present study. We simply assumed that its level remained unchanged over the period covered. This assumption is justified on the grounds that other factors affecting capacity remained constant for duration of this study, as there were no new investment on plant expansion, and work practices remained unchanged.

10.3.1e Fixed investment

Net fixed investment is of concern in productivity analysis because it indicates the volume of capital funds still tied up in facilities and equipment which management seeks to utilise so as to yield the required rates of returns.

During the period studied, no new investments were made. However, there were some additional fixed investments, mainly replacing old tools. These we ignored, because it was difficult to ascertain their effects on the fixed investment under the control of various production managers.

Inasmuch as all facilities and equipment in company B are depreciated on a straight-line basis over a 15-year period, changes in fixed investment were computed by depreciating the net fixed investment (book value of the gross fixed investment minus accumulated depreciation) at the initial period over the subsequent periods.

10.3.1f Factor prices

The method used for the calculation of factor prices is identical to the technique described in Section 10.2.1i and is not repeated here.

10.3.1g Financial data

The sources used for collecting the financial information were similar to those described in Section 10.2.1j. Again, no problem was encountered in seeking these data.

10.3.2 Results and analysis

In this section we present the result of historical analysis of network of productivity, cost and financial relationships of company B, as well as the results of interior sectoral studies.

The data collected and the results are summarised in Tables 10.18 to 10.20 and Figures 10.18 to 10.24.

10.3.2a Outputs and inputs

Figure 10.18 shows that the total physical output of company B fell steadily up to period 10 and then rose sharply. This pattern was repeated in the case of product lines 2 and 4, while the output of the product line 1 remained steady. The output of product line 3 declined sharply up to period 2 and then remained relatively steady. The reason for this was the management's decision to concentrate on product lines 1 and 4 and gradually to phase out product line 3.

Figure 10.19 shows the physical variation of inputs as compared to the output. As is evident, material input and the output have a similar pattern of fluctuations. The close correlation between the output and material input shows the large material contents of the product. Direct labour input in some instances fell as the output rose and vice versa, e.g., periods 4, 5, 7 and 12. This, in fact, is due to the varying content of labour in the batches produced. It also shows that the labour cost is fixed within the normal operating conditions.

10.3.2b Input-output relationships

The output, plant capacity, direct inputs, apparent

input productivities and factor proportions for company B are shown in Table 10.18. The same information for product lines 1, 2, 3 and 4 is presented in Tables 10.18a, 10.18b, 10.18c and 10.18d, respectively.

Apparent input productivities of the company B are shown in Figure 10.20 together with the output. Material productivity shows a steady improvement, despite changes in output. However, output per man-hour is seen to vary with output, reflecting the fact that labour is largely fixed. The productivity of fixed investment, as expected, shows a steady rise. This takes us back to Section 10.2.1h, in which we argued that caution must be exercised in interpretation of trends in this ratio.

Figure 10.2a shows the apparent input productivities and physical output of product line 1. Material productivity shows a rising trend. While physical output and labour productivity, although varying sharply from period to period, on average remained constant.

The apparent input productivities of product line 2 are shown in Figure 10.20b, together with output. Both output and labour productivity show a declining trend, while material productivity is improving. This product line has been subject to rationalisation; however, no significant change has occurred in the levels of labour input, hence the declining labour productivity. The improvement in material productivity, too, is attributable to the rationalisation programme. It is also important not to forget the effect of the product mix on input productivities. Period 9 shows a sharp fall in output and a sharp rise in material productivity. The most likely cause of this rise and fall is the type of products produced during that period.

Figure 10.20c shows the apparent input productivities and physical output of product line 3. The labour productivity, although fluctuating from period to period, over the twelve-months shows a relatively modest decline. The material

productivity shows wild variations in periods 7, 10 and 11. This was again due to products produced in those periods.

Finally, Figure 10.20d shows the apparent input productivities and physical output of product line 4. The labour productivity is declining somewhat with falling outputs, while the material productivity on average over the twelve-month period remains constant.

By embarking on interior sectoral studies it becomes apparent that the main contributors to the aggregate rise in material productivity were product line 1 and 2, while product lines 2 and 4 were responsible for the slight decline in labour productivity. Development of networks of input-output measures at lower levels of aggregation helps the management to control the utilisation of all resources rather than concentrating only on labour, a common practice. This would also increase the accountability of line managers and heighten their awareness.

10.3.2c Factor proportions

The input levels over the twelve months of analysis are compared with each other in three ratios. The object is to determine if one input had declined and had been replaced by the increased input of the other two.

Figure 10.21 illustrates the factor proportions for the company B. The ratio of materials volume to labour input declines on average over the twelve-month period, and its shape is governed by the materials productivity. If Figure 10.20 is compared with Figure 10.21, it can be seen that the shape of the materials volume over the labour graph is almost the inverse of materials productivity between April 1978 and March 1979. This suggests that material volume fell, while labour input remained relatively constant.

The ratio of actively-utilised investment to labour input shows a falling trend, indicating a decrease in the proportions of capital input in relation to labour input,

while the proportion of capital in relation to material input is increasing, as is indicated by the rising trend of the ratio of actively-utilised investment to material input.

Changes in factor proportions for product line 1 are shown in Figure 10.21a. The ratios of materials volume to labour input and actively-utilised investment to man-hour fluctuate randomly about the 100 per cent mark without yielding a clear trend. Actively-utilised investment over material value shows a rising trend, indicating an increase in the proportion of capital input in relation to material input.

Figure 10.21b illustrates the factor proportions for product line 2. Comparison of Figure 10.21 and 10.21b reveal that ratios of material volume to labour input, and actively-utilised investment to man-hour and materials volume for this product line, follow a similar trend to those of the company as a whole.

Changes in factor proportions for product line 3 are shown in Figure 10.21c. Material volume over labour input fluctuates randomly about the hundred per cent mark. This clearly demonstrates the effect of batches on material and labour contents of the product. The ratio of actively-utilised investment to materials input shows a small decline over the twelve months. Similarly, the ratio of actively-utilised investment to labour input is declining.

Figure 10.21e illustrates the changes in factor proportions for product line 4. The factor proportion ratios for this product line follow the aggregated company's trend, presented in Figure 10.21.

10.3.2d Unit costs

The company B's costs were divided into four categories. These were materials, direct wages, fixed and other costs. Fixed costs were comprised of depreciation, interest, establishment and maintenance costs (tools and machinery).

While other costs included the non-direct labour costs (weekly and monthly staff), indirect materials and supplies and production overheads (building rentals, computer charges, personnel, etc.).

As was mentioned in Section 10.2.1i, factor prices were calculated by dividing the appropriate total cost by the volume of the relevant input. The rate of fixed investment charges on capital was computed, dividing the fixed investment charges incurred by the average fixed capital employed during that period to give a rate of fixed investment charges. These rates were compared in turn with the base year rates to give the indexes presented in Table 10.19.

The unit costs of wages and materials were determined by inverting their apparent input productivities given in Table 10.18 and multiplying by the appropriate cost rate from Table 10.19. The unit fixed investment charges, other unit costs, and total unit cost were determined by dividing the cost incurred for each category and deflated output for the relevant period.

Figure 10.22 shows how the total unit cost remained constant over the twelve-month period, while the ~~unit~~ material cost decreased slightly and unit wages cost increased over the same period. From Figure 10.20 it can be seen that material productivity increased; and although the average material prices rose consistently throughout the period under consideration, the improved productivity was more than sufficient to lower the material unit cost. The wage rate also rose consistently during this period, while at the same time labour productivity fell, leading to higher unit wage costs. The other unit costs and fixed costs fluctuated about the 100 per cent mark, but on average remained constant over the period.

10.3.2e <u>Cost proportions</u>

The total cost of all inputs were determined for the

twelve-month period. The proportion of that total accounted for by the following cost categories was then computed:

(a) Direct wages

(b) Direct materials

(c) Fixed investment costs:

i) Depreciation
ii) Interest charges
iii) Establishment costs
iv) Maintenance costs

(d) Other costs:

i) Non-direct employment cost
ii) Indirect materials and supplies cost
iii) Production overheads

A graphical representation of the results is shown in Figure 10.23. As is evident, materials and fixed costs in relation to total cost remained steady, while the other unit cost and wages proportion increased slightly. In general, wages accounted for about 8 per cent of total costs, materials about 38 per cent, fixed costs about 13 per cent and other costs about 41 per cent.

10.3.2f Managerial control ratios

Managerial control ratios computed for the company B are presented in Table 10.20. Figure 10.24 shows that average prices rose steadily through the twelve months, while the unit cost had a wider amplitude of fluctuations, but that both moved in the same direction in seven months out of twelve. Costs rose more than prices in six periods, thus reducing unit profits. And in three of the four months when costs and prices moved in opposite directions, both tended to increase unit profits. As is evident, unit profit reacted quickly to changes in unit revenue and cost because it is basically the difference between these two nearly equal numbers. Any small percentage changes in revenue and costs lead to large percentage changes in profit.

Figure 10.25 suggests that in the short term, unit profit and return on capital tend to vary together much

more than the other determinants of return on capital, with the corollary that it is changes in unit profit which tend to influence the level of return on capital most strongly. In fact, the correlation coefficient between these two factors was 0.99. This means that increasing unit profit increases return on capital invested. In order to test this hypothesis we plotted unit profit against the rate of return (Figure 10.26) to observe any meaningful path or pattern that emerged. In eleven out of twelve cases, when unit profit increases or decreases, return on capital investment does likewise. There is, however, a hysteresis effect, because when return on capital increases and declines, unit profit is left with a residual effect. This can be traced to the effects of inflation in the unit profit ratio, since profit was measured in pounds and output was measured in constant unit terms.

Figure 10.27 shows the fluctuations of unit cost and output. As can be seen seven times out of twelve, unit cost and output moved in opposite directions, indicating an inverse relationship between unit cost and output. Figure 10.28 depicts the pattern traced by unit cost plotted against output. In seven cases out of twelve, output and unit cost moved in opposite directions, i.e., a decrease in output led to an increase in unit cost and vice versa. In fact, the unit cost and output had a correlation efficient of - 0.63.

10.3.3 Conclusions: Company B

It is difficult to arrive at definite conclusions because of the short period of analysis. However, based on this short period of analysis it is clear that the total output is greatly affected by the outputs of product lines 1 and 4.

Clearly, the materials productivity of company B is increasing. This is most certainly the result of recognition by management of importance of controlling the material input. The labour productivity and output, on the other

hand, are declining. This demonstrates the fixed nature of the labour resources in normal operating conditions.

The importance of linking the physical output-input relationships through factor prices to unit costs is also demonstrated. An improvement in physical output-input relationships is economically beneficial only when it leads to lower unit cost. As is the case for material productivity, in which case the improvement in utilisation of resources outpaces the increases in average material prices.

The other interesting fact emerging from this analysis is the high degree of correlation (o.99) between unit profit and the rate of return. This suggests that in the short term at least unit profit affects the rate of return much more than the other determinants of return on capital. Unit profit in turn is strongly influenced by product mix. Hence, the influence of product mix on return on capital as demonstrated in Figure 10.25.

10.4 General Discussion

The central objective of the studies undertaken were: to test the applicability of the original productivity network and cost structure framework to batch production which has variegated arrays of inputs, intricate production flows and wide arrays of product categories; to make a practical determination of the availability of the sort of data required for such analysis on the basis of the kinds of manning, production control and accounting information already being collected for established managerial purposes; and finally, to assess the managerial and predictive usefulness of the model.

The applicability of the model to batch producers was clearly demonstrated with the aid of the two case studies described in Sections 10.2 and 10.3. Batch production encompasses companies with different characteristics. The two companies were chosen from either spectrum of character-

istics, i.e., "flow line" and 'jobbing shop". The problems involved in the application of the model were different as was demonstrated.

The framework for collecting data was derived from the model in Chapter 9 (Figure 9.3), which required information about output and capacity; inputs of labour, materials, fixed investment, working capital and other costs; factor prices, including wage rates, material prices and capital charge rates. These data then made possible the calculation of indexes of changes in each of the following components of the network of productivity relationships and its superstructure of cost relationships:

Direct input productivities: labour materials and net fixed investment;

Indirect input productivities: employer, working capital and other inputs;

Unit production costs: wages, salaries, materials, capital charges and other costs;

Cost proportions: wages/total costs, salaries/total costs, capital charges/total costs, and other costs/total cost; and

Total unit production costs, decomposition of total unit production costs, managerial ratios, and decomposition of rate of return.

In practice we met difficulties in obtaining price and quantity data required for calculating the physical output and input quantities. In the case of company A, because of the large number of products being produced and the widely-diverse range of materials and labour inputs, we were forced to group output and inputs into a limited number of categories instead of differentiating not only various product lines and inputs but also the entire array of models and sizes within each. However, inasmuch as the computational method can encompass any number of products, management can take advantage of the widest array of

product categories with respect to which output and revenue data are available. In the case of company B, because of its "jobbing shop" nature, it proved impossible to obtain quantity and revenue data for products or material inputs. Consequently, physical changes in outputs and material inputs were computed, by deflating the sales revenues and material costs to a base period value. This method although not as accurate as the former method nevertheless proved satisfactory. Measurement of capacity also proved a difficult problem, particularly in the case of company B. As in batch manufacturing, companies' capacity is greatly affected by the batch mix. In the case of company A (flow-line characteristics) it was possible to obtain reasonable estimates of capacity.

However, it is our conclusion that even crude estimates of capacity in companies with "jobbing shop" characteristics, are difficult to obtain; thus, the productivity of fixed investment is made a dubious measure. In all cases we found the financial data required readily available.

The two case studies clearly demonstrate the value of the model in assessing the effectiveness of past decisions; analysing the effects of changes in any of the components of the model at whatever level, on the other components and on the total cost; and planning reactions to predicted changes in externally- or internally-given variables.

Methodologically, the basic conclusion is that the proposed productivity network and cost structure model proved applicable to a variety of highly-complex industrial operations both in terms of concepts involved and in terms of the availability of the data required (with some modifications) as a by-product of existing managerial planning and control functions. Hence, it seems eminently practicable to apply the model to a wide range of industries at relatively small cost in the interests of providing additional valuable guides for managerial evaluations of past performance or of prospective alternatives.

It should also be noted in this connection that the model readily lends itself to further elaboration, either in the interests of probing progressively smaller sectors of operations or in the interests of exploring more fully the alternative means of affecting given functional purposes. The former, was illustrated through examining separate product lines within company B and through approaches to analysing and planning alternatives, was demonstrated in the case of company A using the computer program.

10.5 General Discussion

The two case studies clearly demonstrate that the model proposed in Chapter 9 is applicable to batch manufacturers. Furthermore, the analysis in this chapter illustrates the three important attributes of the model. The value of each will naturally depend on the nature of the plant, on the constraints imposed upon it and on the ability of management to question the constraints and to institute possible changes.

The first attribute is that the model provides a systematic process for collection of data and analysis that is bound to improve the user's understanding of the plant and the interrelationships between the major parameters at play. It can help to tighten definitions of inputs, outputs and costs. It can be used to ascertain what level of aggregation of inputs and/or outputs is most appropriate for the plant in question.

Secondly, the model can be used for recording productivity ratios, factor and cost proportions over time, so that when significant changes occur their causes can be traced back through the model. The figures illustrate how such historical records can be analysed; where certain trends can be established, or where particular factors are found to be predominant, management may be forewarned about undesirable events and may wish to examine possible courses of action.

Thirdly, the model can be used to anticipate future results. The effects of changes in exogenous variables, as well as in those parameters which the manager can influence, are important for the decision-making process and they can improve his ability to forecast and assess the outcome of various arrays of possible events. The first case study, coupled with the computer program, illustrates these points; it showed what would happen if certain changes occur outside the manager's control (such as the level of demand and the cost of materials) and by implication the actions required of him in order to offset their adverse effect upon profitability.

TABLE 10.18 INDEXES OF OUTPUT, INPUTS AND INPUT OUTPUT RELATIONSHIPS

PERIOD	OUTPUT	CAPACITY	MAT-VOL	MAN-HOU	FIX-INV	MAT-VOL	LAB-PRO	CAP-PRO	MV/MH	AUIF/MV	AUIF/MH
APR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MAY	111.5	100.0	115.2	122.3	99.4	96.8	91.2	100.6	94.2	96.2	90.6
JUNE	81.4	100.0	79.5	100.4	98.9	102.4	81.1	101.1	79.2	101.3	80.2
JULY	89.2	100.0	90.7	89.8	98.3	98.4	99.3	101.7	101.0	96.7	97.7
AUG	81.6	100.0	73.5	102.8	97.8	111.0	79.4	102.3	71.5	108.6	77.6
SEP	83.4	100.0	75.8	106.0	97.2	110.0	78.7	102.9	71.5	107.0	76.5
OCT	90.9	100.0	82.3	84.7	96.6	110.4	107.3	103.5	97.2	106.7	103.7
NOV	102.7	100.0	88.3	140.1	96.1	116.3	73.3	104.1	63.0	111.8	70.4
DEC	71.8	100.0	68.3	86.6	95.5	105.1	83.5	104.7	79.4	100.4	79.8
JAN	84.9	100.0	79.5	86.0	95.0	106.8	98.7	105.3	92.4	101.5	93.8
FEB	97.0	100.0	88.7	132.1	94.4	109.4	73.4	105.9	67.2	103.3	69.3
MAR	110.9	100.0	93.3	113.8	93.8	118.9	97.5	106.6	82.0	111.5	91.4

TABLE 10.18A INDEXES OF OUTPUT, INPUTS AND INPUT-OUTPUT RELATIONSHIPS-PRODUCT LINE 1

PERIOD	OUTPUT	CAPACITY	MAT/VOL	MAN-HOU	FIX-INV	MAT-PRO	LAB-PRO	CAP-PRO	MV/MH	AUIF/MV	AUIF/MH
APR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MAY	107.8	100.0	87.6	95.3	94.4	123.1	113.1	100.6	91.9	116.2	106.8
JUNE	85.2	100.0	90.5	75.0	98.9	94.1	113.6	101.1	120.7	93.2	112.4
JULY	116.7	100.0	120.1	82.8	98.3	97.2	140.9	101.7	145.1	95.5	138.5
AUG	95.9	100.0	76.1	101.5	97.8	126.0	94.5	102.3	75.0	123.3	92.4
SEP	105.7	100.0	83.1	109.1	97.2	127.2	96.9	102.9	76.2	123.6	94.1
OCT	96.7	100.0	86.3	83.5	96.6	112.1	115.8	103.5	103.4	108.2	119.0
NOV	121.4	100.0	88.6	173.9	96.1	137.0	69.8	104.1	51.0	131.7	67.1
DEC	81.5	100.0	72.4	83.1	95.5	112.6	98.1	104.7	87.1	107.5	93.6
JAN	101.5	100.0	87.0	85.2	95.0	116.7	119.1	105.3	102.1	120.7	123.2
FEB	114.2	100.0	97.5	159.0	94.4	117.1	71.8	105.9	61.3	110.6	67.8

TABLE 10.18B INDEXES OF OUTPUT, INPUTS AND INPUT-OUTPUT RELATIONSHIPS-PRODUCT LINE 2

PERIOD	OUTPUT	CAPACITY	MAT-VOL	MAN-HOU	FIX-INV	MAT-PRO	LAB-PRO	CAP-PRO	MV/MH	AUIF/MV	AUIF/MH
APR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MAY	113.2	100.0	112.9	231.7	99.4	100.3	48.9	100.6	48.7	99.7	48.6
JUNE	104.3	100.0	82.2	108.8	98.9	126.9	95.9	101.1	75.6	125.6	94.8
JULY	93.9	100.0	70.8	147.8	98.3	132.6	63.5	101.7	47.9	130.4	62.5
AUG	102.2	100.0	99.3	195.1	97.8	102.9	52.4	102.3	50.9	100.7	51.3
SEP	90.9	100.0	82.9	194.7	97.2	109.7	46.7	102.9	42.6	106.6	45.4
OCT	88.2	100.0	81.9	94.9	96.6	107.7	92.9	103.5	86.3	104.0	89.8
NOV	97.7	100.0	105.8	283.6	96.1	92.3	34.5	104.1	37.3	88.8	33.1
DEC	53.5	100.0	26.2	141.6	95.5	204.2	37.8	104.7	18.5	195.0	36.1
JAN	74.5	100.0	55.8	61.8	95.0	133.5	120.6	105.3	90.3	126.9	114.6
FEB	88.2	100.0	73.1	246.5	94.4	120.7	35.8	105.9	29.7	114.0	33.8

TABLE 10.18C INDEXES OF OUTPUT, INPUTS AND INPUT-OUTPUT RELATIONSHIPS-PRODUCT LINE 3

PERIOD	OUTPUT	CAPACITY	MAT-VOL	MAN-HOU	FIX-INV	MAT-PRO	LAB-PRO	CAP-PRO	MV/MH	AUIF/MV	AUIF/MH
APR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MAY	88.4	100.0	75.5	99.3	99.4	117.1	89.0	100.6	76.0	116.4	88.5
JUNE	50.5	100.0	117.0	59.2	98.9	43.2	85.3	101.1	197.6	42.6	84.3
JULY	55.8	100.0	51.5	98.5	98.3	108.3	56.7	101.7	52.3	106.6	55.7
AUG	64.1	100.0	64.8	58.5	97.8	98.9	109.6	102.3	110.8	96.8	107.2
SEP	44.5	100.0	87.1	58.4	97.2	51.1	76.2	102.9	149.1	49.7	74.1
OCT	85.5	100.0	43.6	75.9	96.6	196.1	112.7	103.5	57.4	189.5	108.8
NOV	58.3	100.0	63.2	94.5	96.1	92.3	61.7	104.1	66.9	88.6	59.3
DEC	55.4	100.0	67.2	75.5	95.5	82.4	73.4	104.7	89.0	78.7	70.1
JAN	88.5	100.0	52.0	74.1	95.0	170.2	119.4	105.3	70.2	161.7	113.5
FEB	54.4	100.0	37.2	55.5	94.4	146.2	98.0	105.9	67.0	138.2	92.6

TABLE 10.18D INDEXES OF OUTPUT, INPUTS AND INPUT-OUTPUT RELATIONSHIPS-PRODUCT LINE 4

PERIOD	OUTPUT	CAPACITY	MAT-VOL	MAN-HOU	FIX-INV	MAT-VOL	LAB-PRO	CAP-PRO	MV/MH	AUIF/MV	AUIF/MH
APR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MAY	121.8	100.0	148.5	149.0	99.4	82.0	81.8	100.6	99.7	81.6	81.3
JUNE	80.3	100.0	63.6	131.5	98.9	126.3	61.1	101.1	48.4	124.8	60.4
JULY	72.4	100.0	72.0	73.9	98.3	100.6	98.0	101.7	97.4	98.9	96.4
AUG	67.1	100.0	66.4	89.5	97.8	101.1	75.0	102.3	74.2	98.8	73.3
SEP	72.3	100.0	67.3	89.3	97.2	107.4	81.0	102.9	75.4	104.5	78.7
OCT	87.9	100.0	80.5	142.3	96.6	109.2	61.8	103.5	56.6	105.5	59.7
NOV	100.6	100.0	76.7	126.0	96.1	131.2	80.0	104.1	60.9	126.1	76.8
DEC	73.8	100.0	70.6	118.0	95.5	104.5	62.5	104.7	59.8	99.9	59.8
JAN	71.7	100.0	80.1	69.5	95.0	89.5	103.2	105.3	115.3	85.0	98.0
FEB	97.4	100.0	86.5	146.2	94.4	112.6	66.6	105.9	59.2	106.4	62.9

TABLE 10.19 COST PROPORTIONS AND INDEXES OF FACTOR PRICES AND UNIT COSTS (APRIL 78=100.0)

PERIOD	AV-WA-RA	AV-MA-PR	RCFI	UWC	UMC	UFIC	OUC	TUC	W/TC	M/TC	FC/TC	OC/TC
APR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	6.9	40.0	13.4	39.7
MAY	84.0	101.0	109.2	92.1	104.3	96.7	95.1	99.9	7.6	41.4	12.4	38.6
JUNE	115.4	101.8	79.0	142.3	99.4	94.5	110.7	101.5	8.3	38.5	11.3	41.9
JULY	86.3	101.8	80.8	86.9	103.5	87.6	100.5	97.1	7.3	41.8	10.3	40.6
AUG	107.4	103.0	100.2	135.2	92.8	116.9	98.1	102.6	8.4	35.2	17.6	38.8
SEP	110.9	104.0	83.7	140.9	94.6	94.5	104.9	97.9	8.9	37.4	12.3	41.4
OCT	112.6	105.1	99.8	104.9	95.2	101.8	112.2	99.4	6.5	36.7	14.1	42.7
NOV	108.0	105.6	116.8	147.3	90.8	104.0	99.5	98.3	9.6	35.2	15.1	40.1
DEC	118.3	105.8	102.6	141.7	100.7	129.3	72.7	102.3	8.1	37.4	16.4	38.1
JAN	118.9	106.7	74.6	120.4	99.9	78.0	98.1	91.1	7.7	41.7	11.0	39.6
FEB	101.1	108.9	91.3	137.7	99.5	82.4	101.0	95.3	9.9	39.6	11.3	39.2
MAR	102.9	113.1	130.4	105.5	95.1	101.8	112.7	98.7	7.2	35.5	14.3	43.0

TABLE 10.20 REVENUE, INVESTMENT, PROFIT INDEXES AND MANAGERIAL CONTROL RATIOS (APRIL 78=100.0)

PERIOD	REV	TC	PRO	NFI	WC	TI	REV/OUT	TC/OUT	OUT/CAP	CAP/NFI	NFI/TI	PRO/TI	PRO/OUT	OUT/TI
APR	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MAY	112.5	112.3	108.9	99.4	97.8	98.3	100.9	100.7	111.5	100.6	101.1	110.8	97.7	113.4
JUNE	82.8	84.0	55.7	98.9	94.9	96.2	101.7	103.2	81.4	101.1	102.8	57.9	68.4	84.6
JULY	90.8	88.2	83.5	98.3	91.7	93.9	101.8	98.8	89.2	101.7	104.7	88.9	93.6	95.0
AUG	83.8	86.0	41.8	97.8	92.2	94.0	102.7	105.4	81.6	102.3	104.0	44.5	51.2	86.8
SEP	86.1	84.3	86.1	97.2	91.8	93.6	103.2	101.1	83.4	102.9	103.9	92.0	103.2	89.1
OCT	94.8	94.2	62.0	96.6	93.0	94.2	104.3	103.6	90.9	103.5	102.6	65.8	68.2	96.5
NOV	107.8	106.0	69.6	96.1	96.1	96.1	105.0	103.2	102.7	104.1	100.0	72.4	67.8	106.9
DEC	75.8	77.6	26.6	95.5	95.6	95.6	105.6	108.1	71.8	104.7	99.9	27.8	37.0	75.1
JAN	90.8	82.7	143.0	95.0	102.3	99.9	107.0	97.4	84.9	105.3	95.1	143.1	168.4	85.0
FEB	104.6	99.6	111.4	94.4	101.8	94.3	107.8	102.7	97.0	105.9	95.1	112.2	114.9	97.7
MAR	120.4	118.7	94.9	93.8	101.4	98.9	108.6	107.0	110.9	106.6	94.8	96.0	85.6	112.1

Fig. 10.18 Index of Physical Output and Its Components

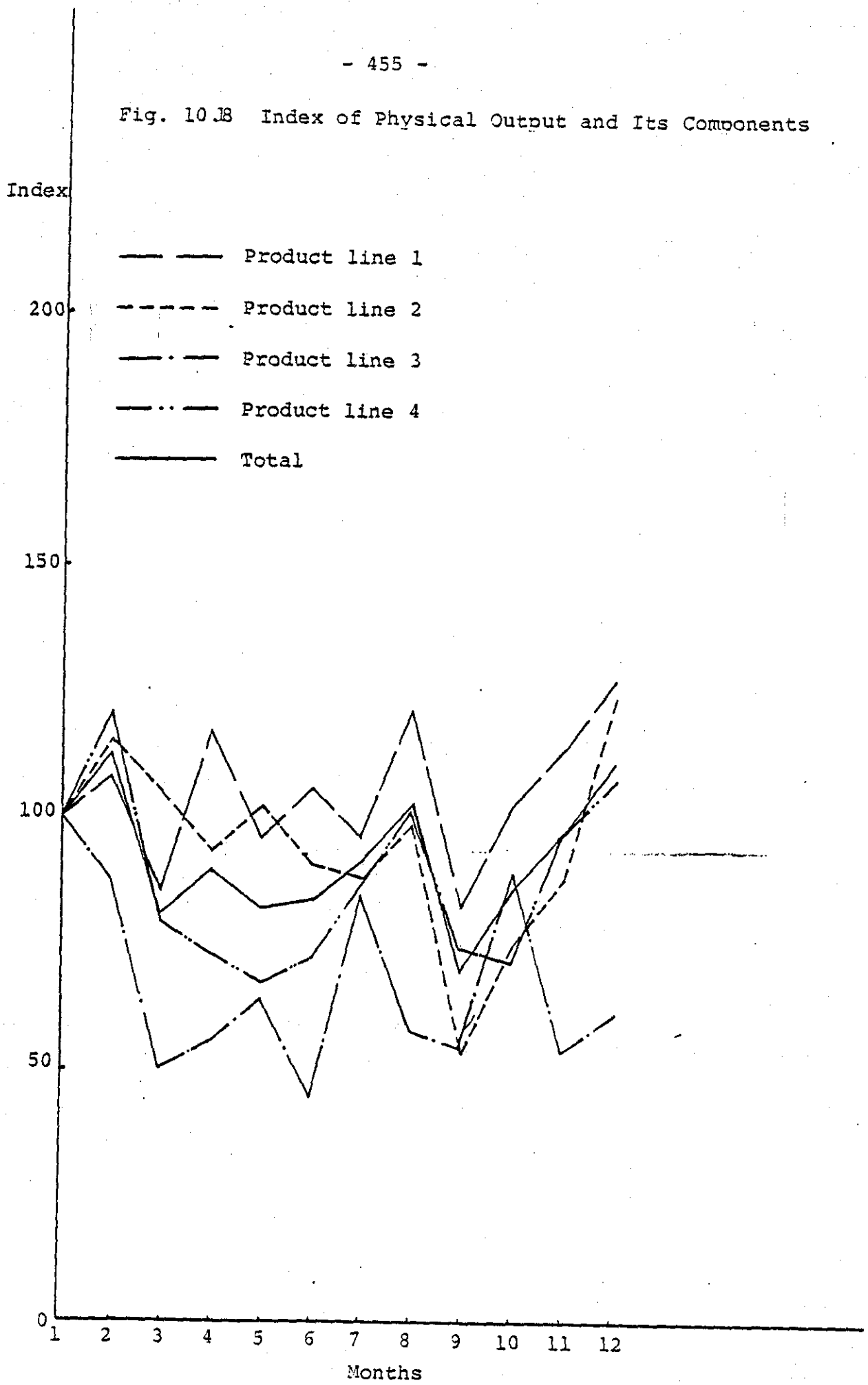


Fig. 10.19 Index of Physical Output and Inputs

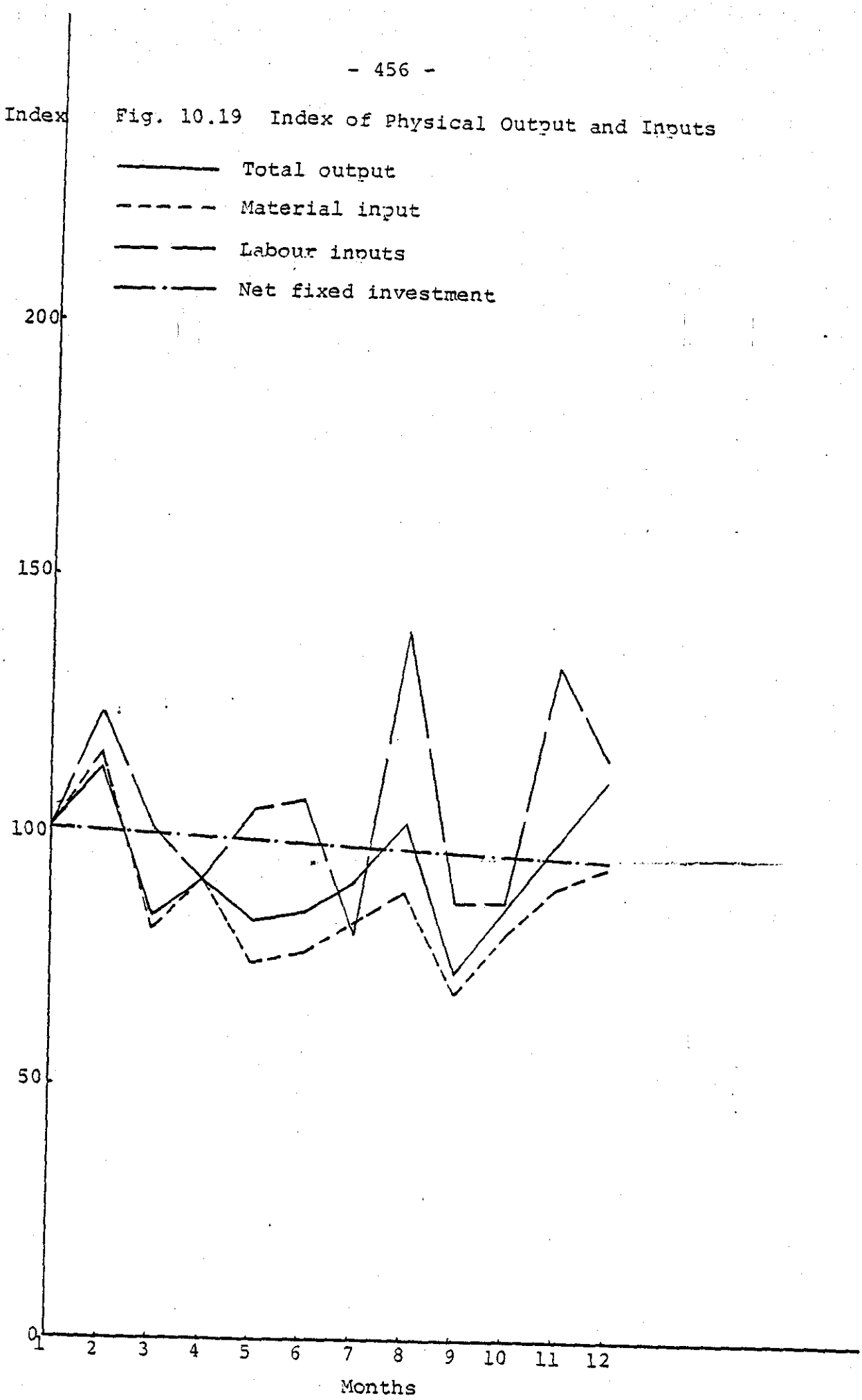


Fig. 10.20 Physical Output and Apparent Productivity of Direct Inputs

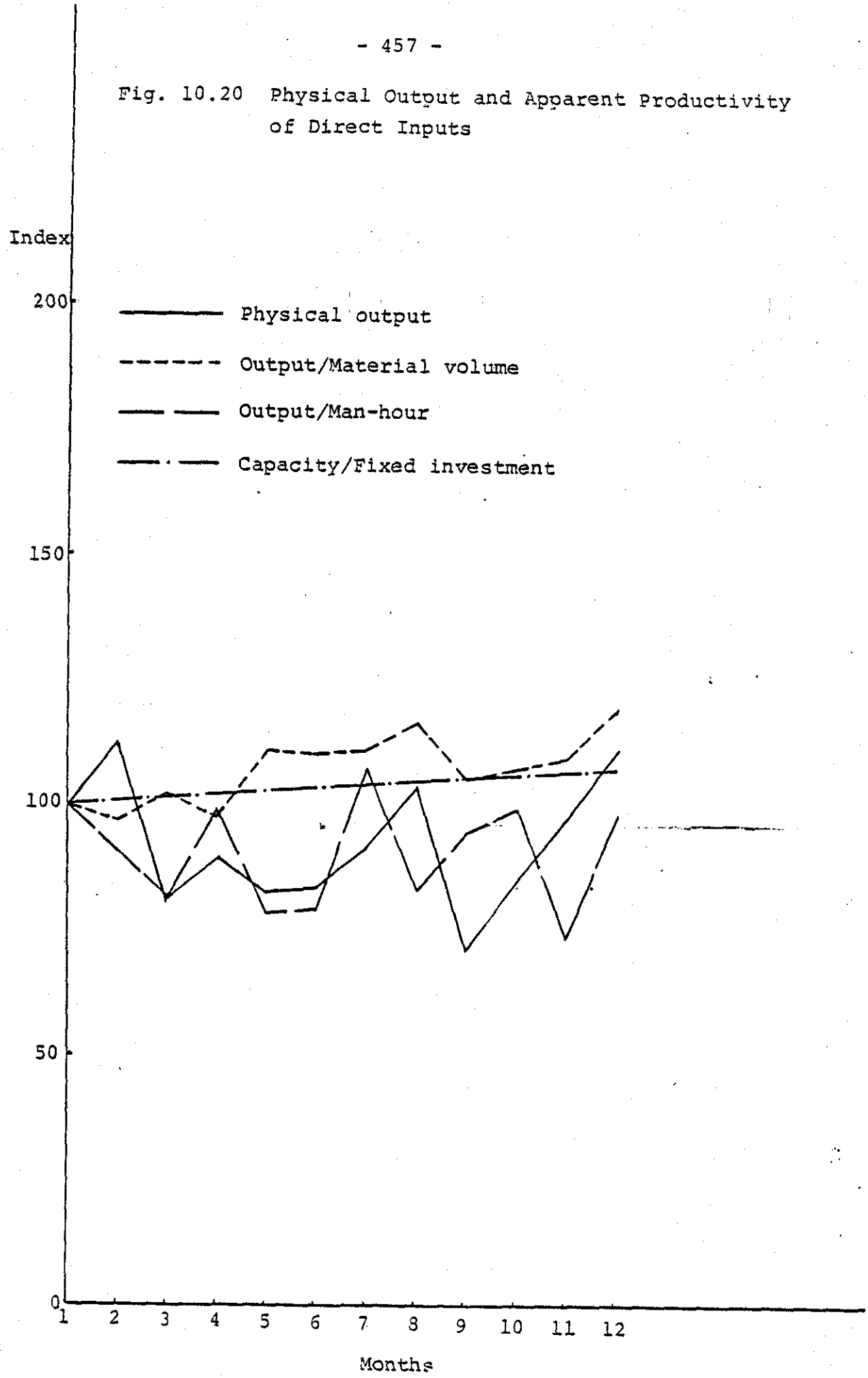


Fig. 10.20a Physical Output and Apparent Productivity of Direct Inputs
Product line 1

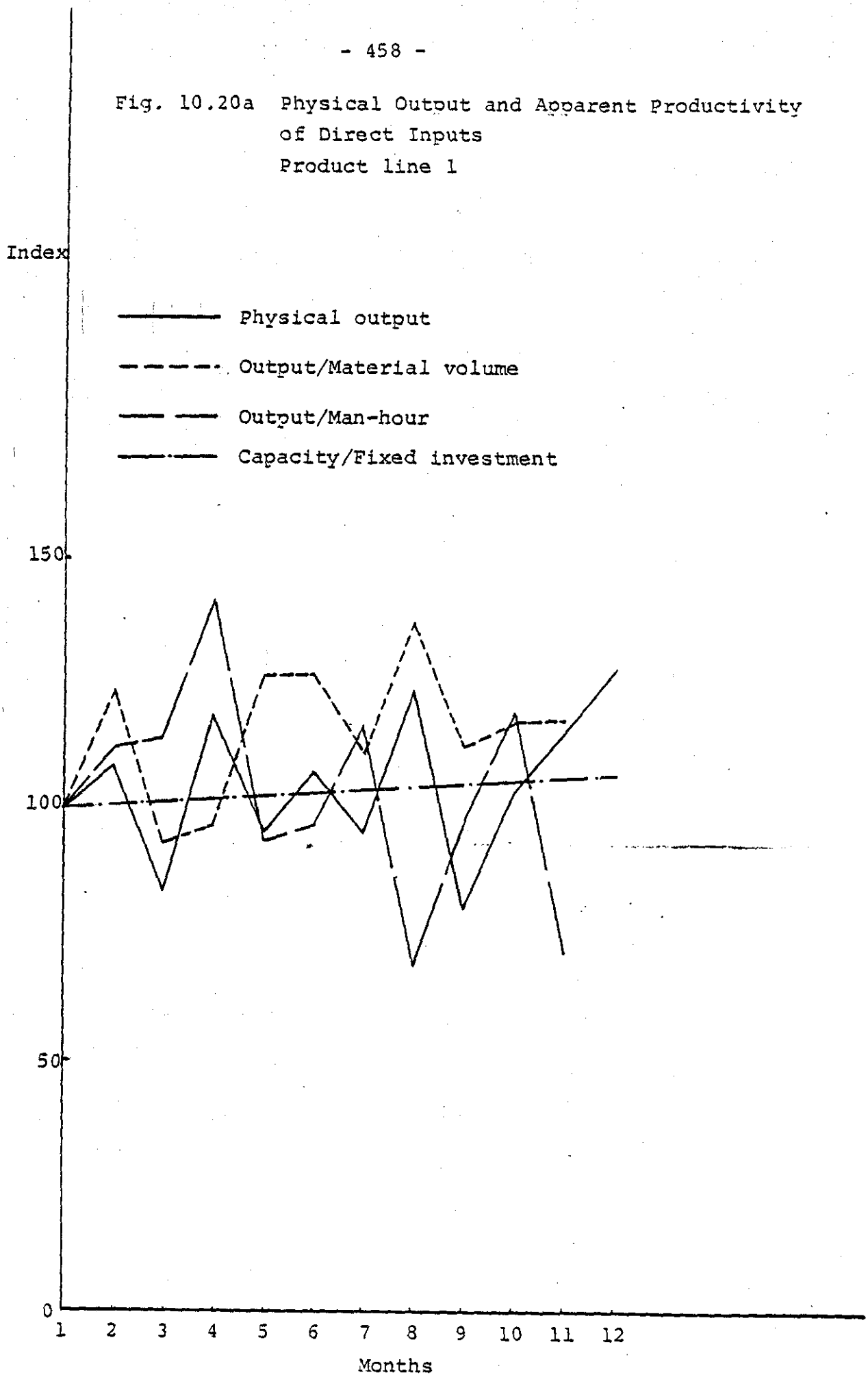


Fig. 10.20b Physical Output and Apparent Productivity of Direct Inputs
Product Line 2

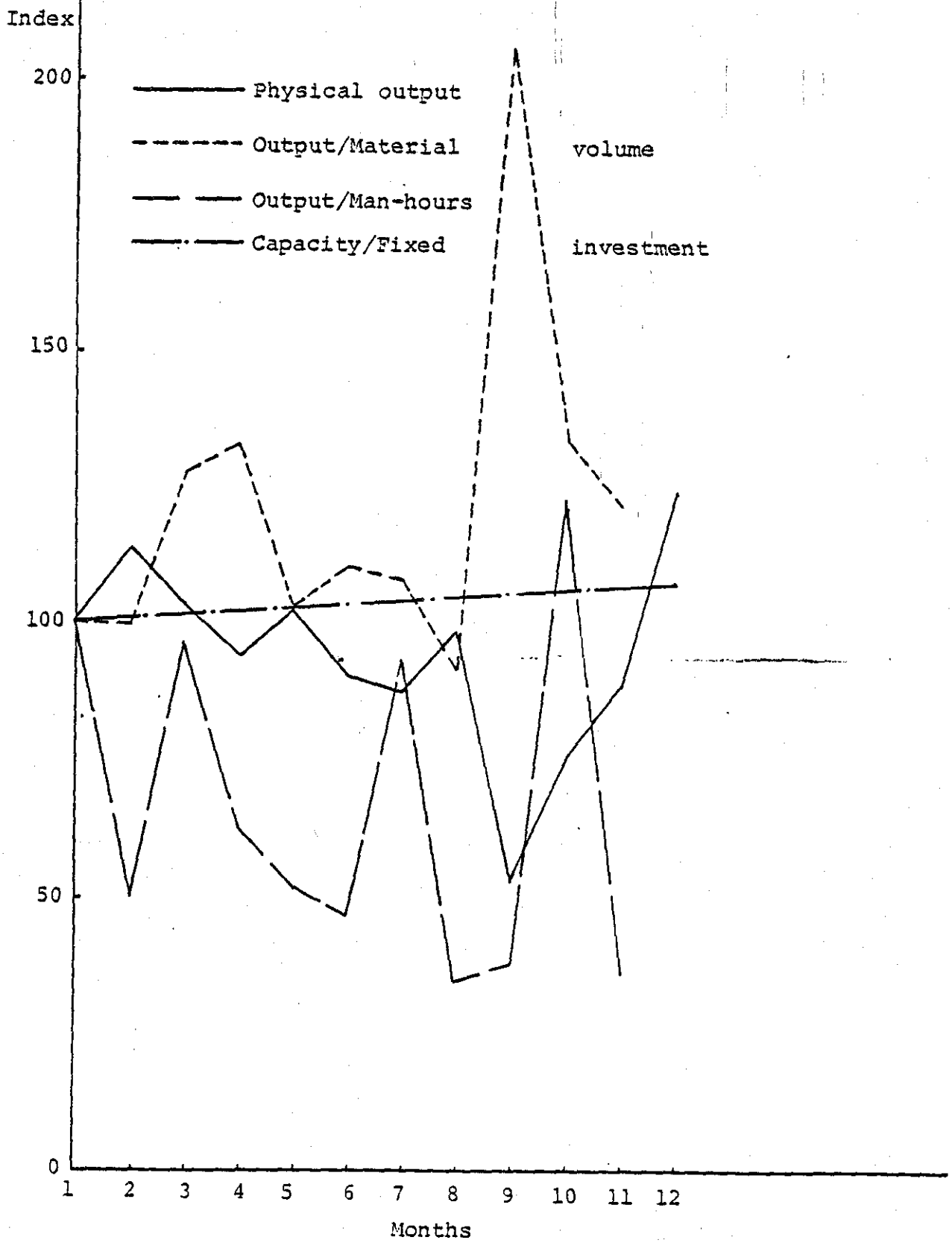


Fig. 10.20c Physical Output and Apparent Productivity of Direct Inputs Product Line 3

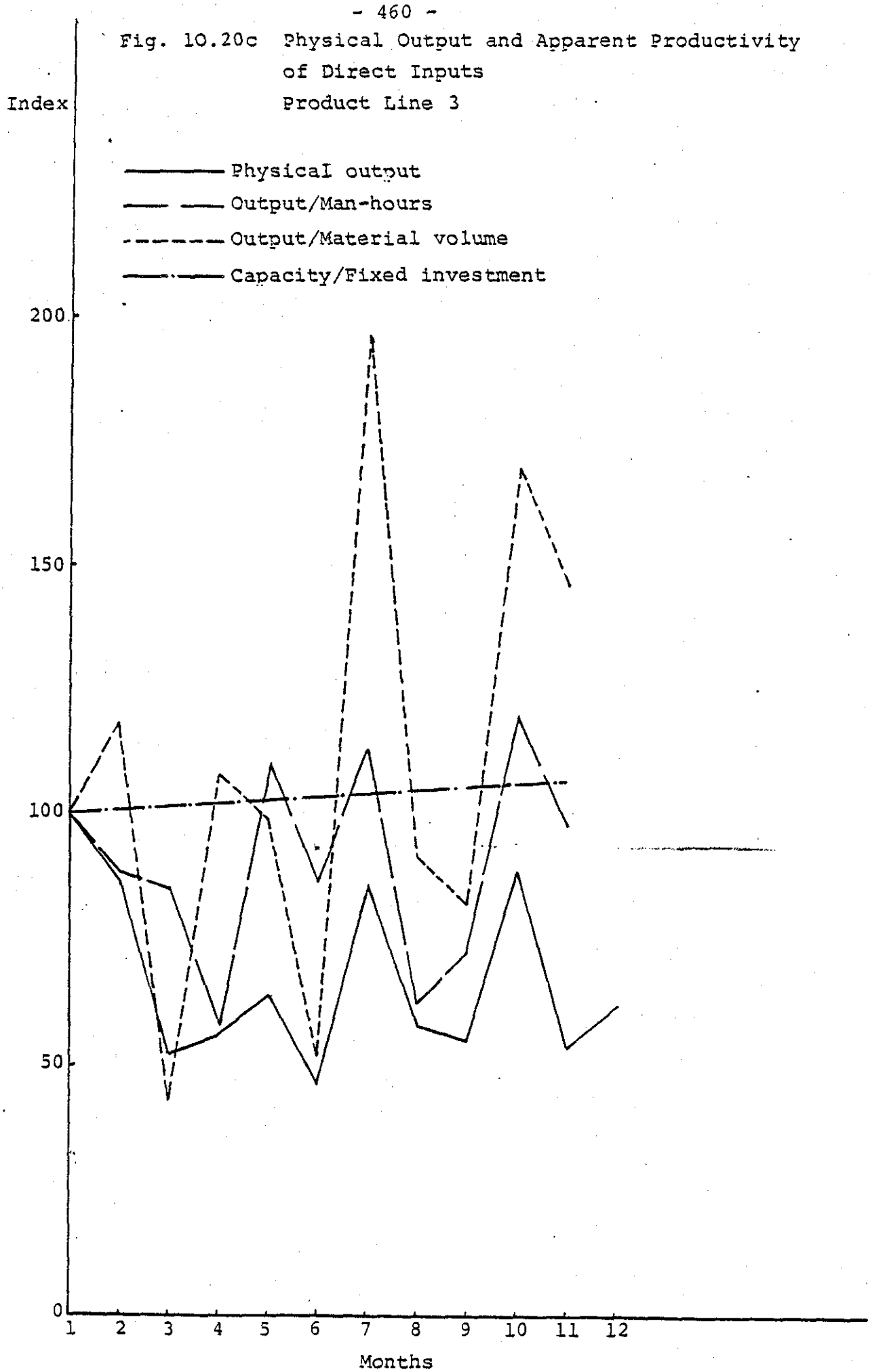


Fig. 10.20d Physical Output and Apparent Productivity of Direct Inputs
Product Line 4

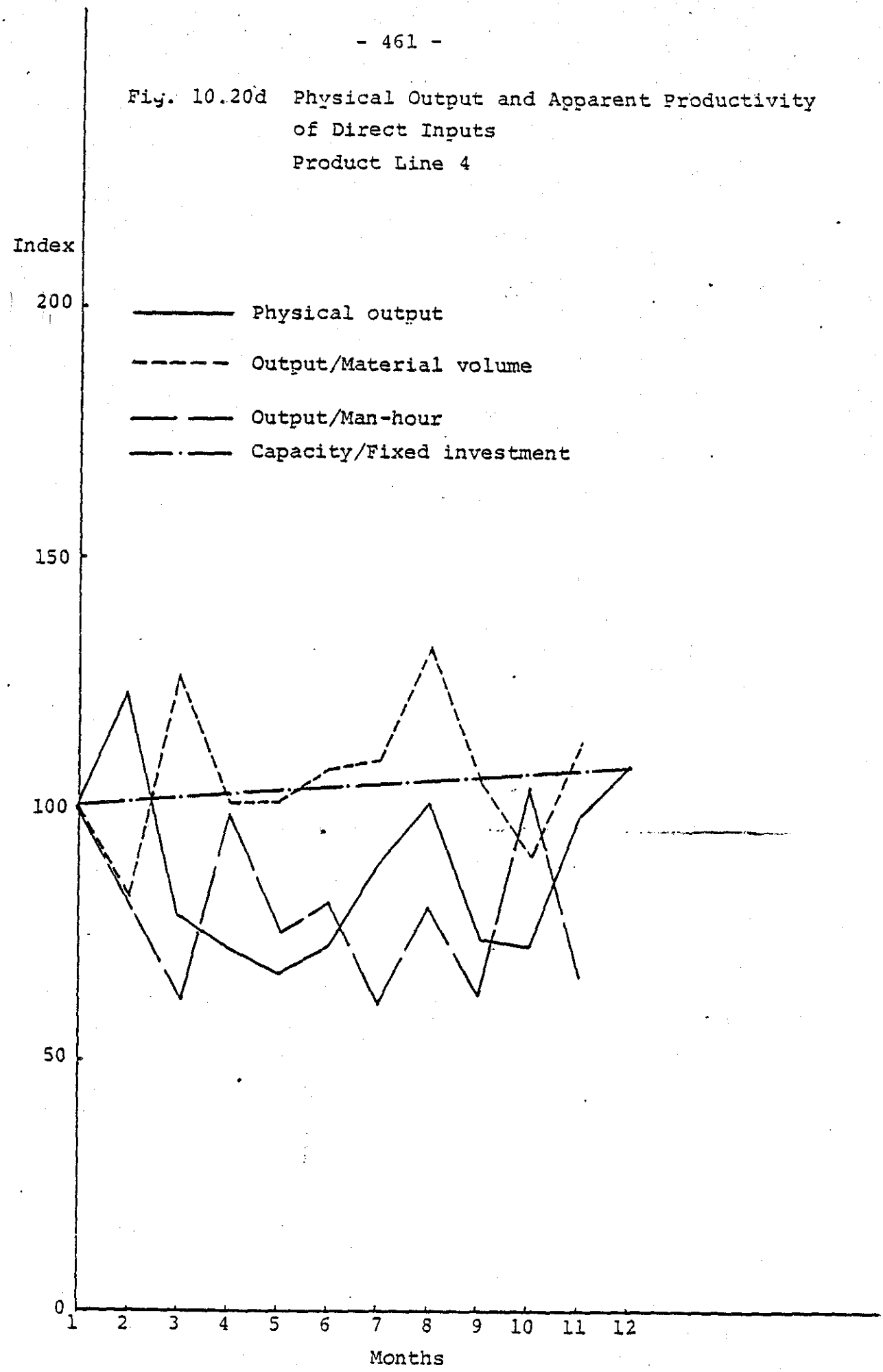


Fig. 10.21 Physical Output and Factor Proportions

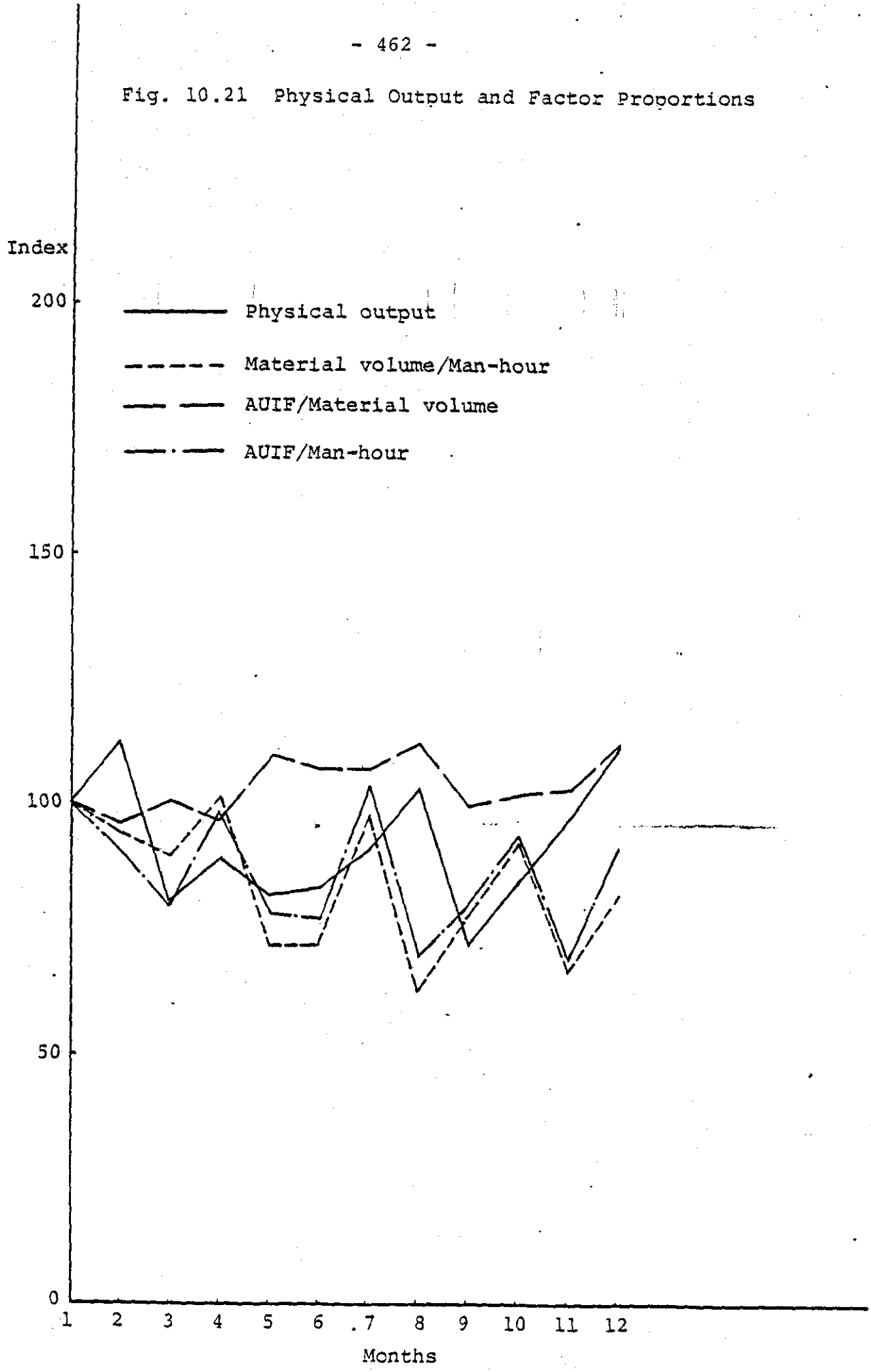


Fig. 10.21a Physical Output and Factor Proportions
Product Line 1

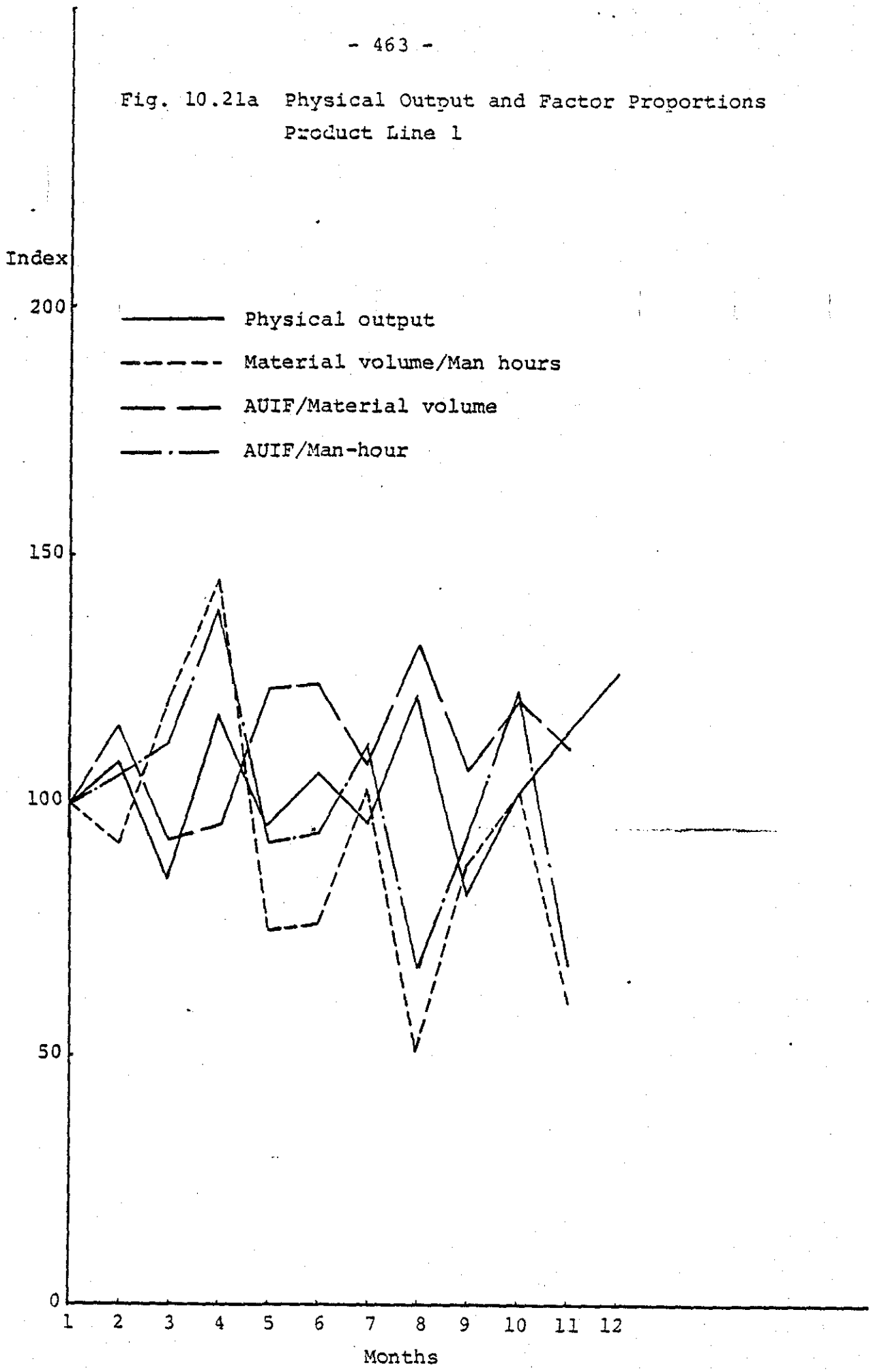


Fig. 10.21b Physical Output and Factor Proportions
Product Line 2

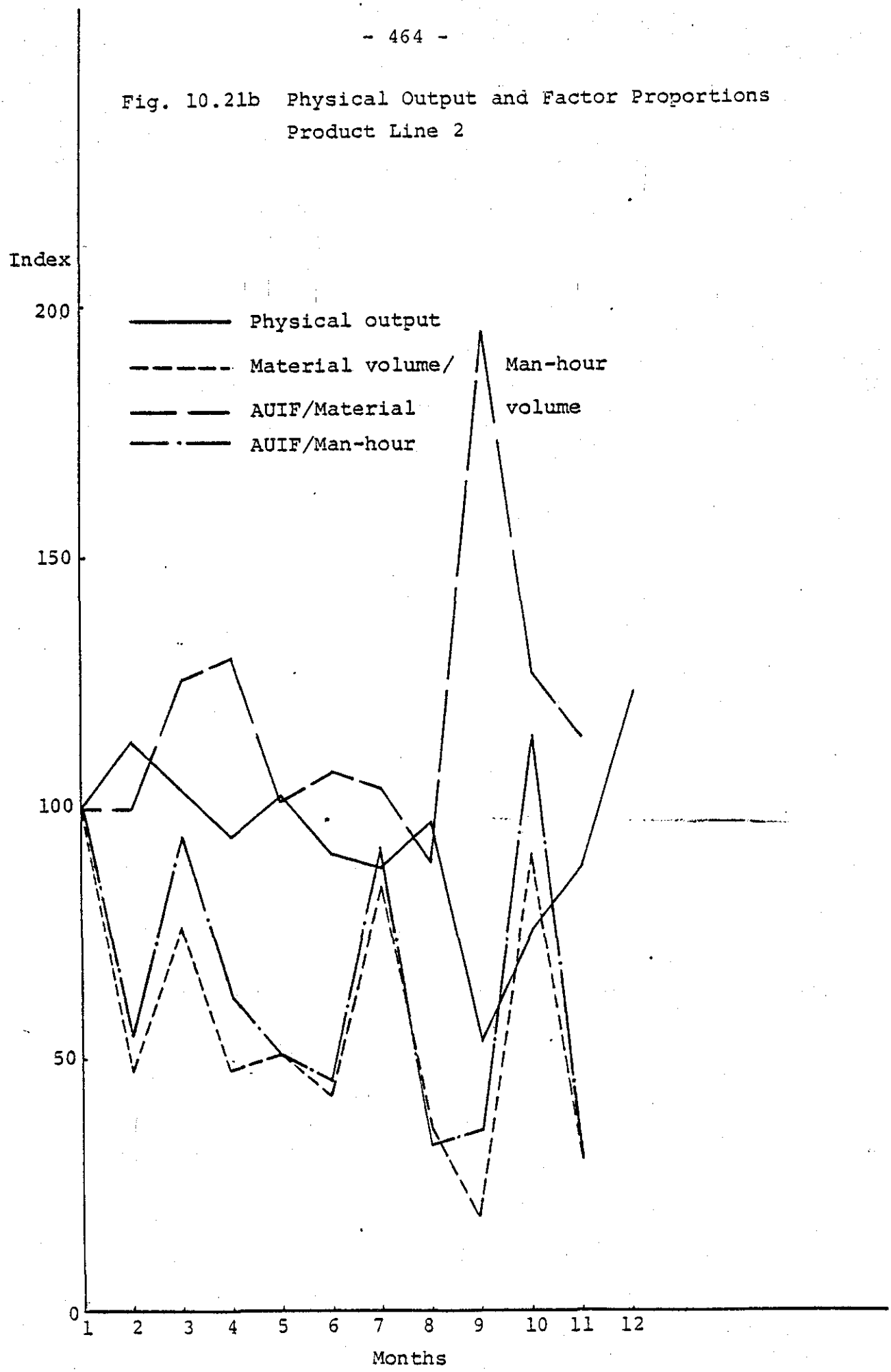


Fig. 10.21c Physical Output and Factor Proportions
Product Line 3

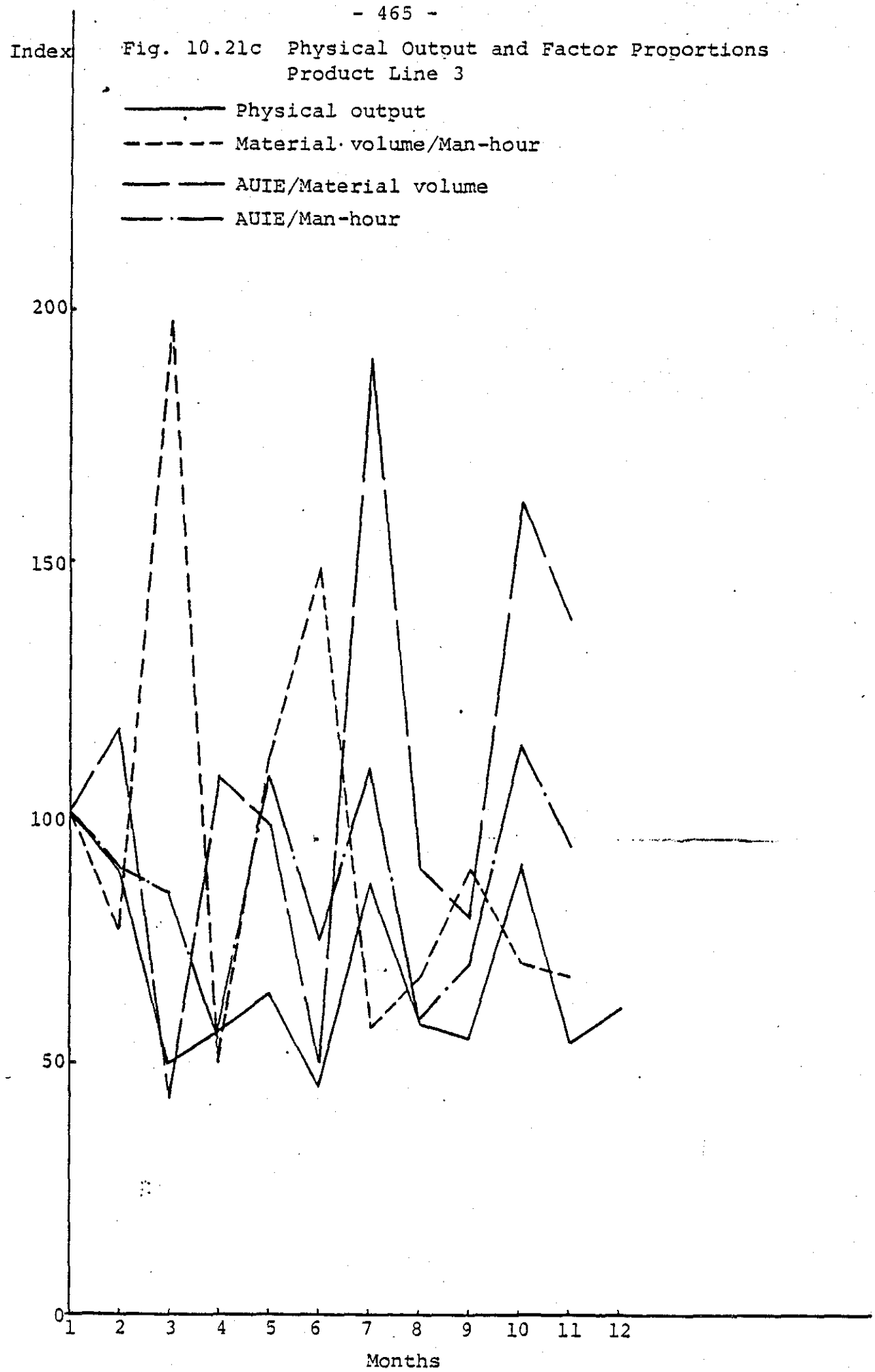


Fig. 10.21d Physical Output and Factor Proportions
Product Line 4

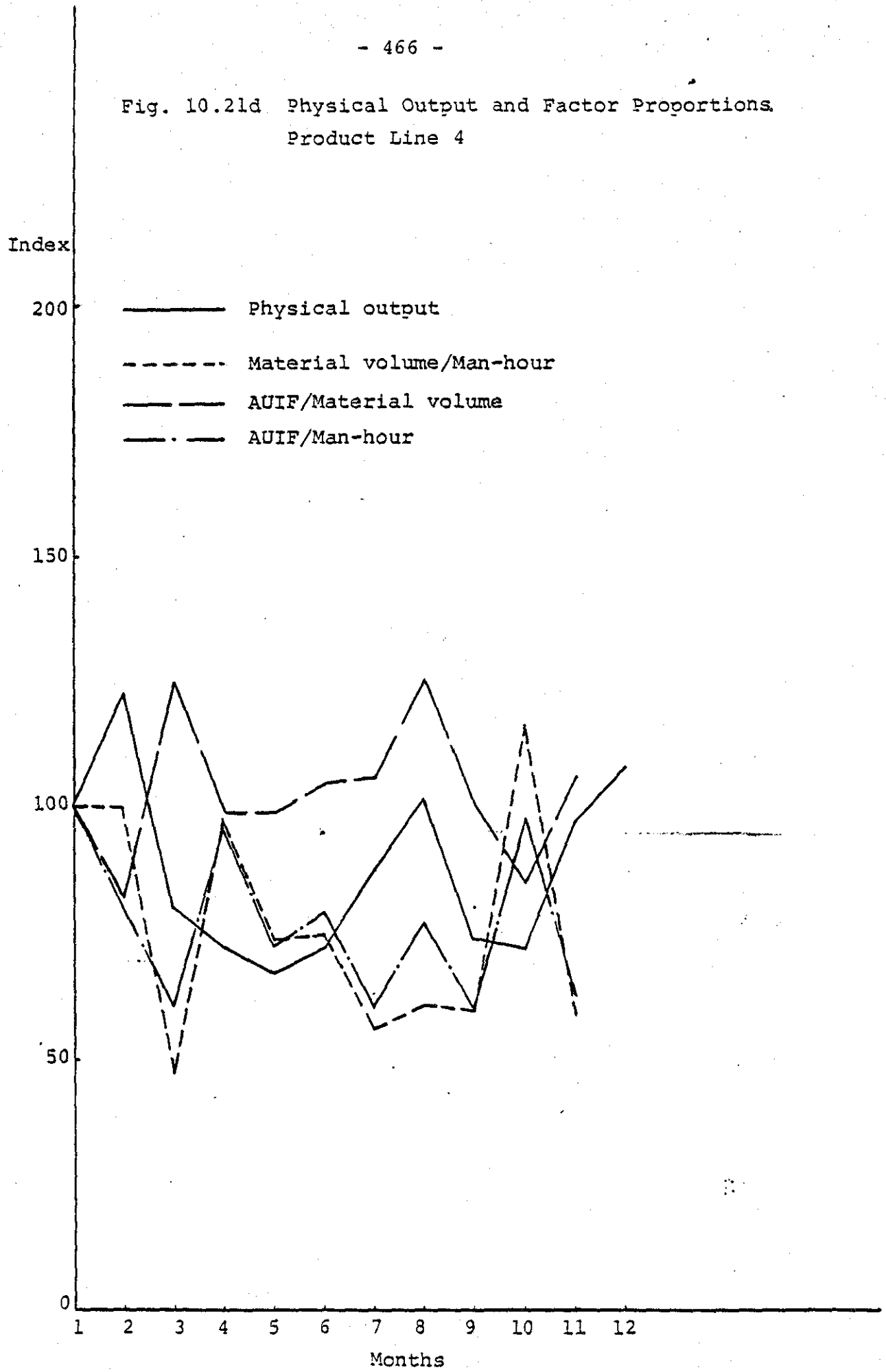


Fig. 10.22 Total Unit Costs and Its Components

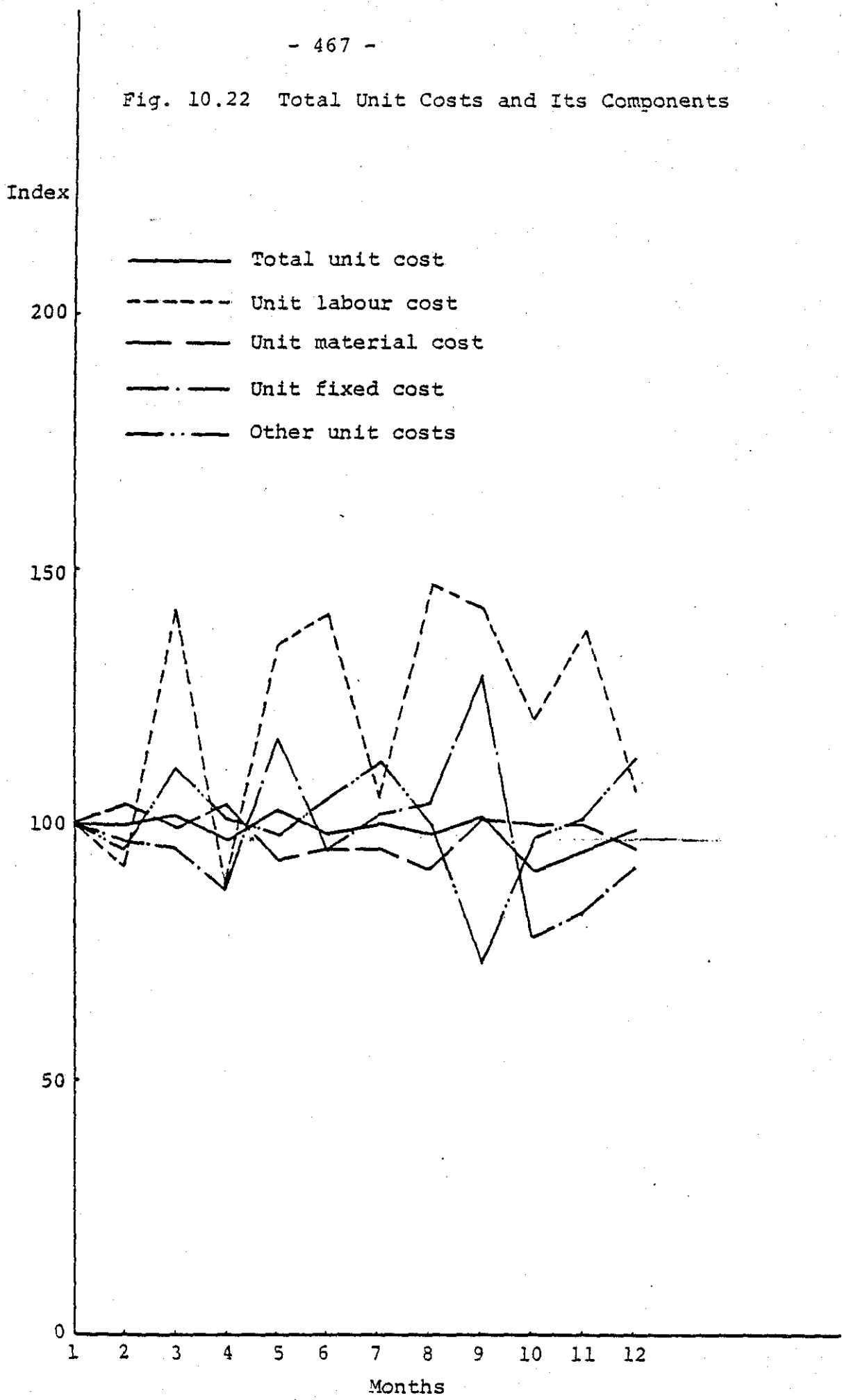


Fig. 10.23 Cost Proportions

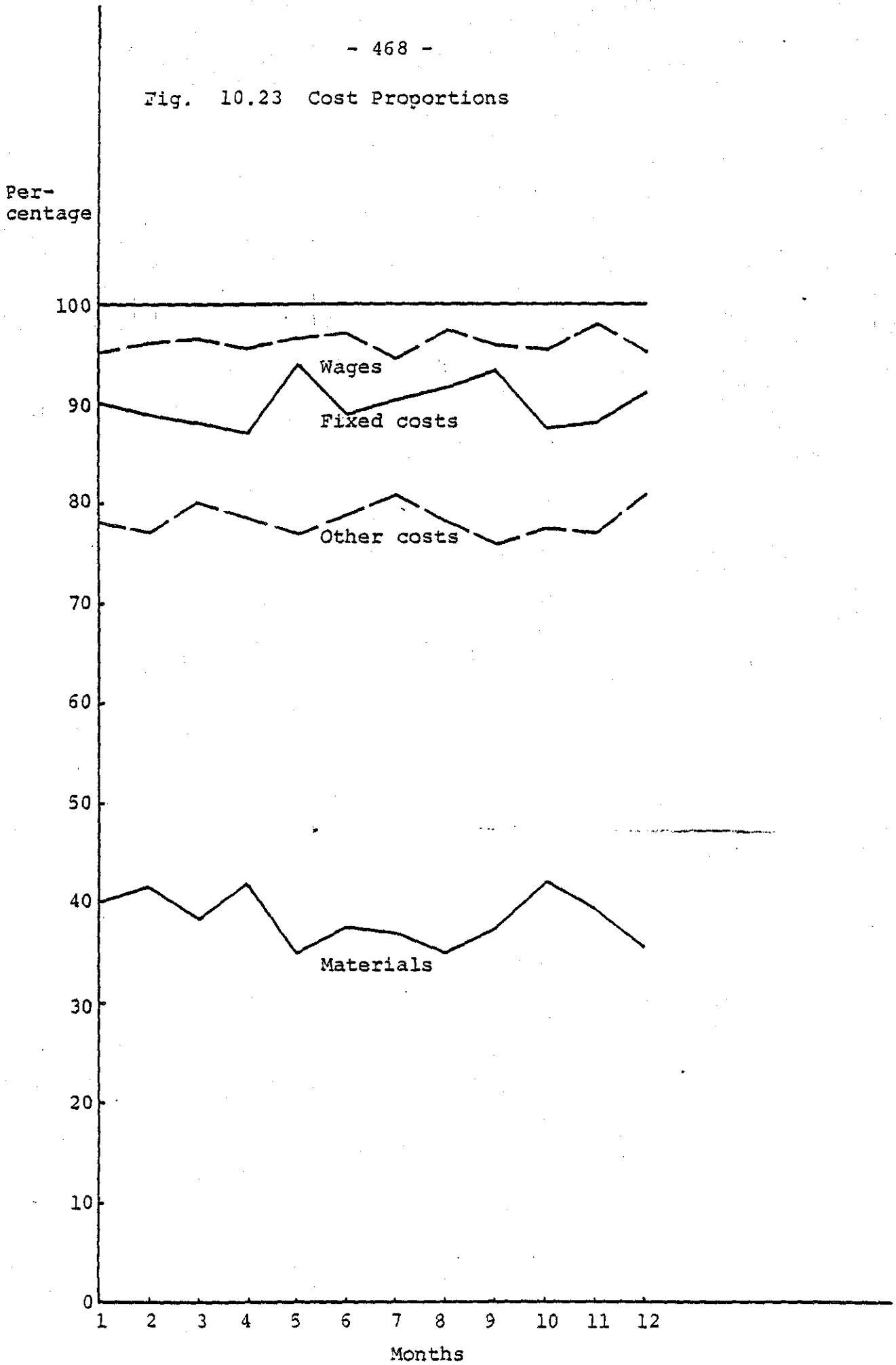


Fig. 10.24 The Calculation of Unit Profit

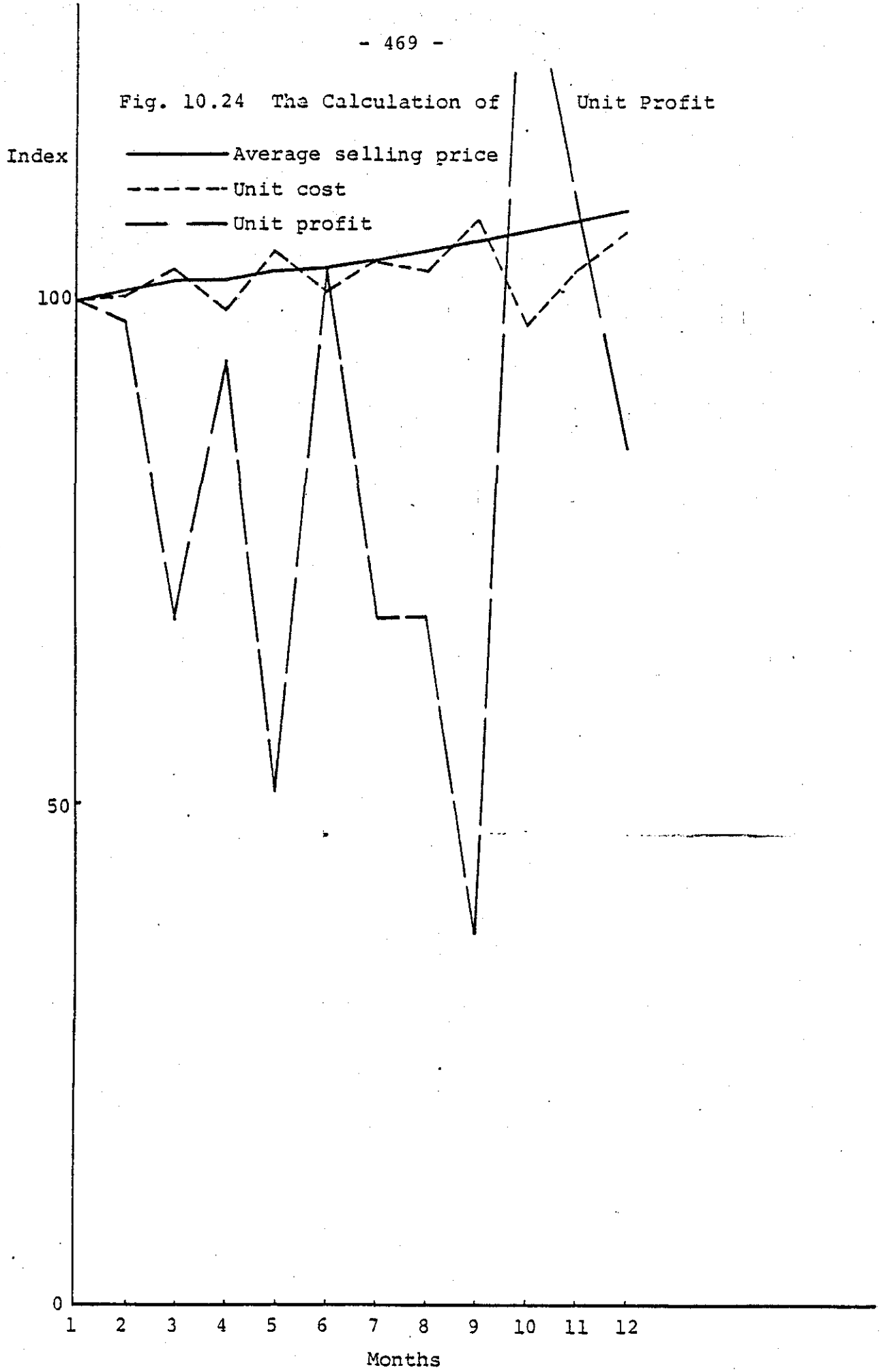


Fig. 10.25 Managerial Control Ratios

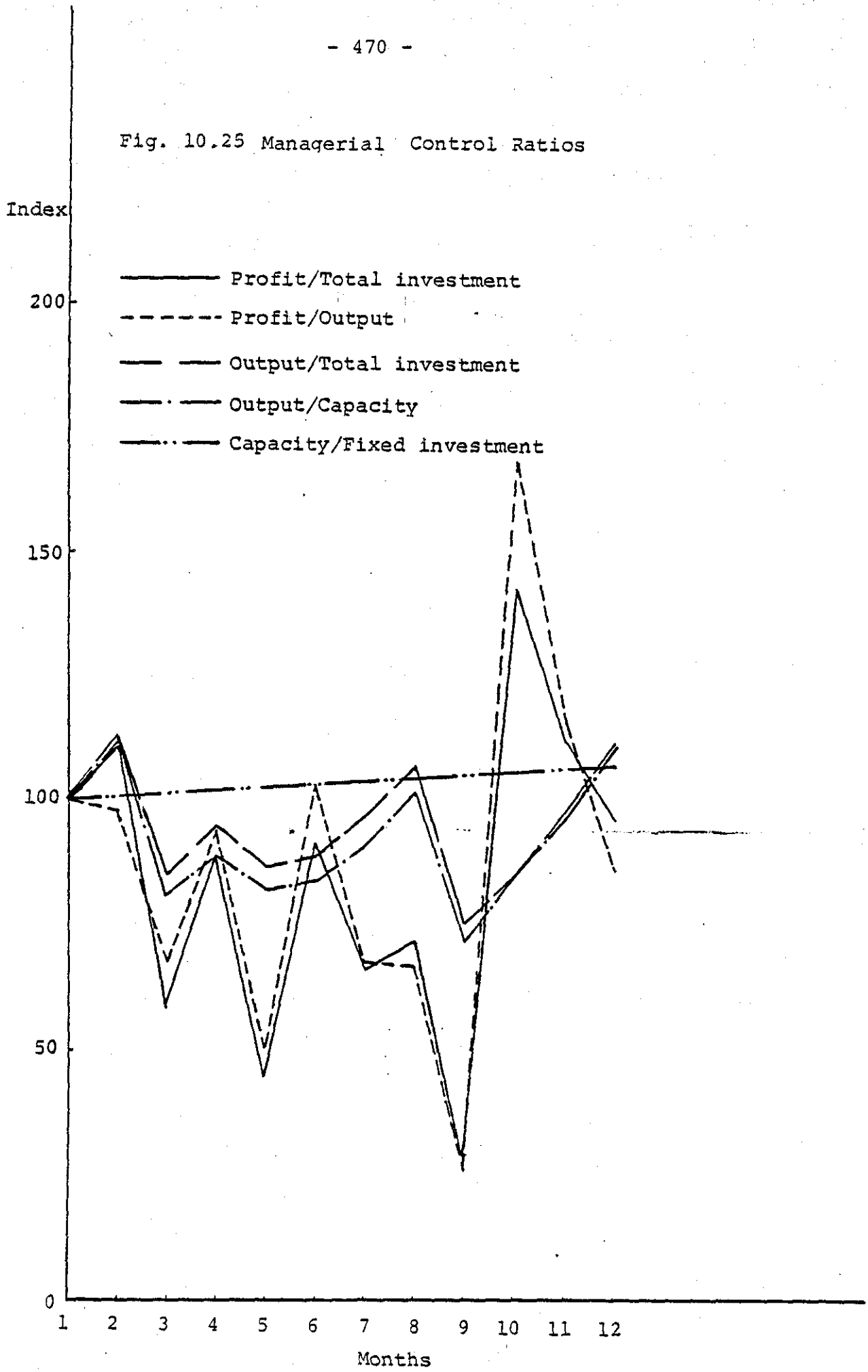


Fig. 10.26 Unit Profit versus Return on Capital Pattern Analysis

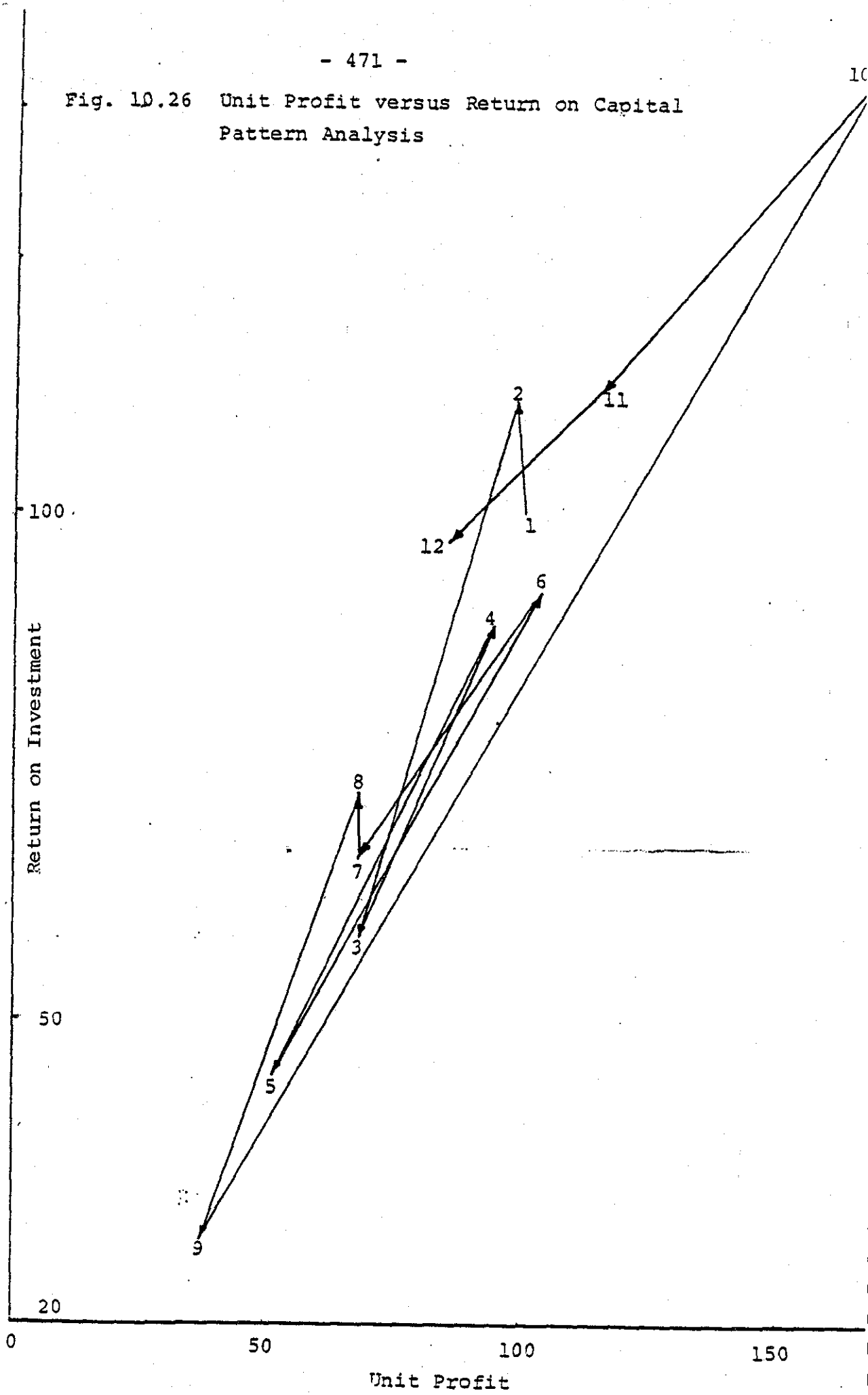


Fig. 10.27 The Relationship between Unit Cost and Output

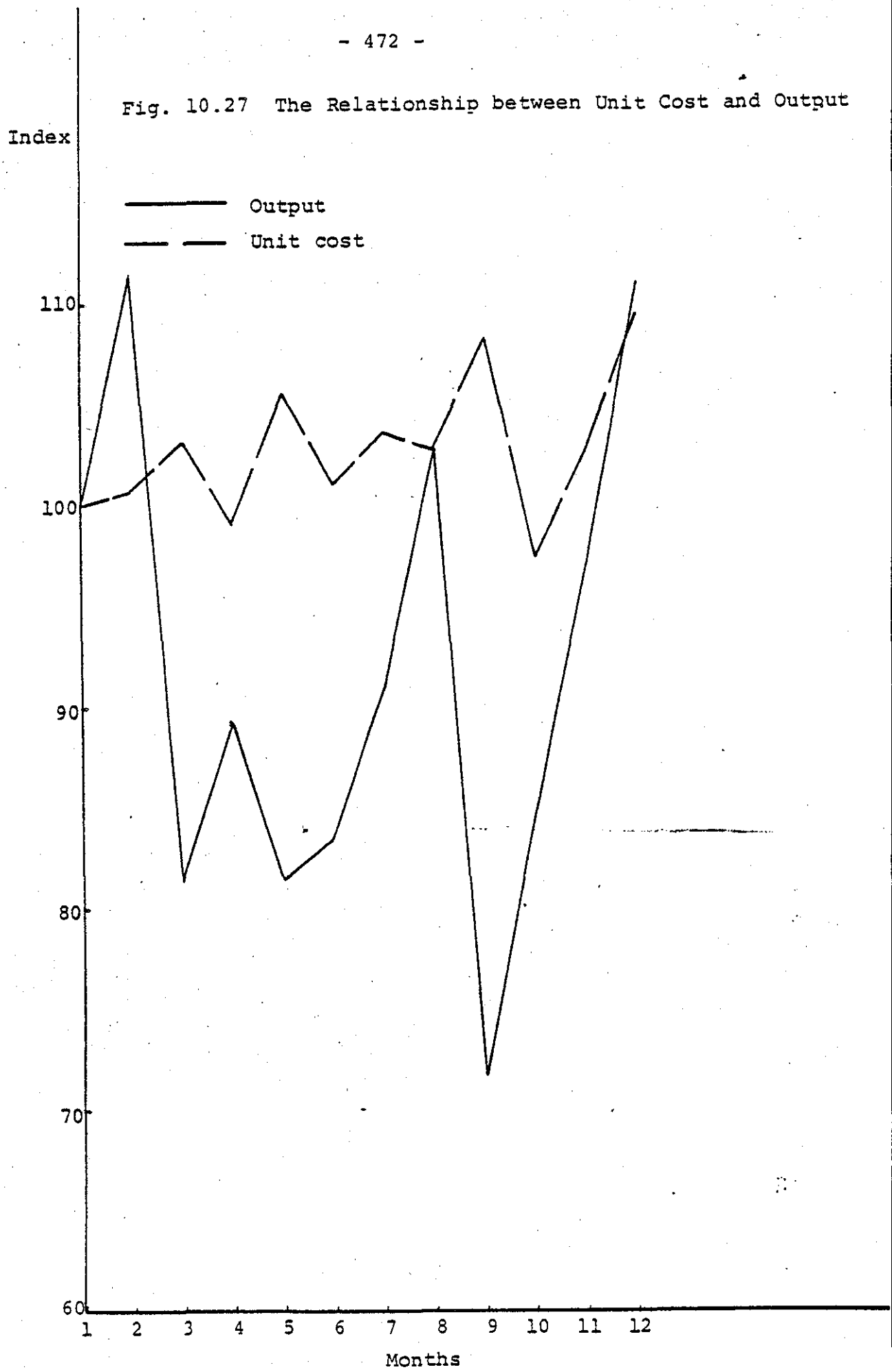
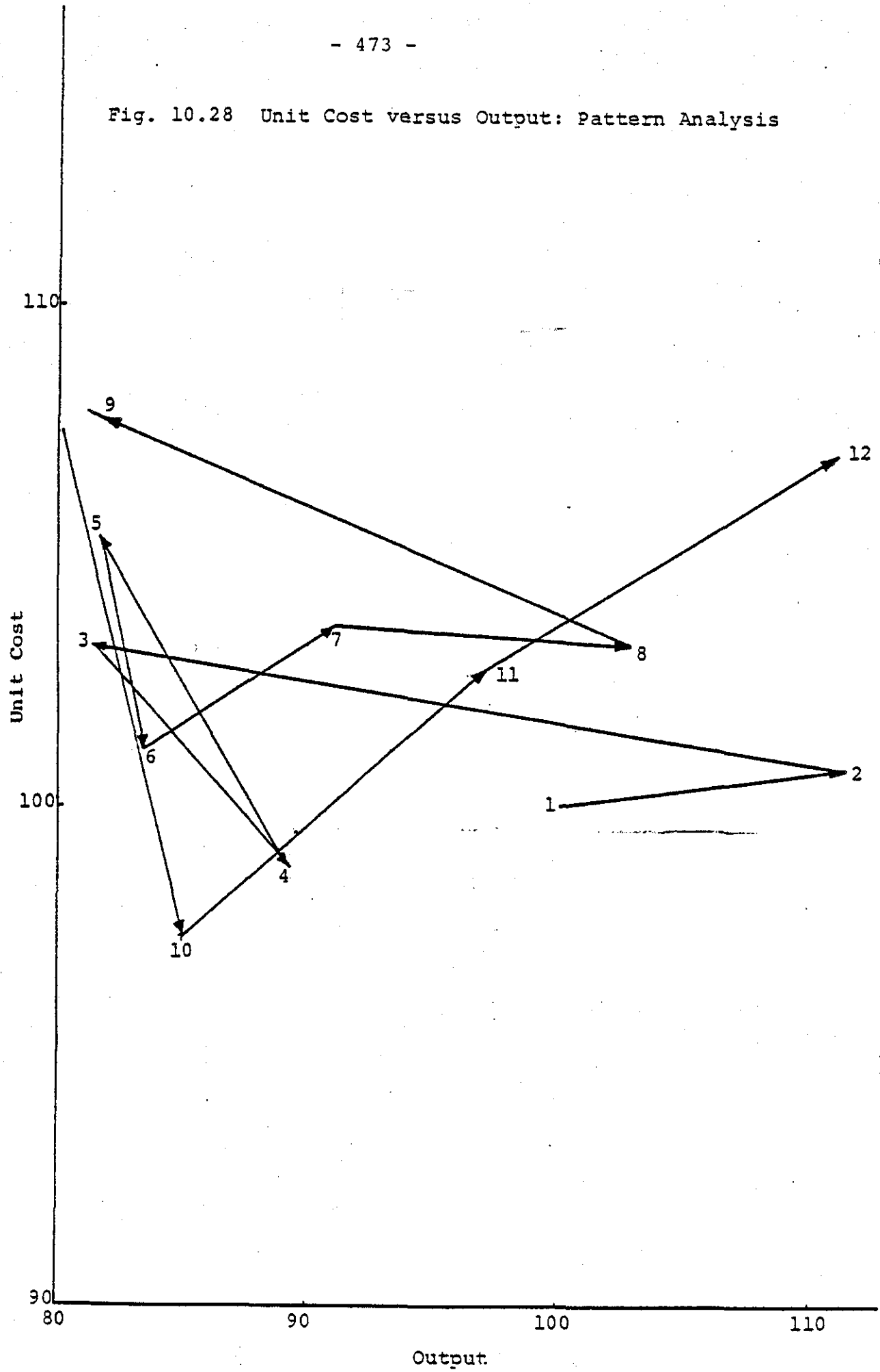


Fig. 10.28 Unit Cost versus Output: Pattern Analysis



REFERENCE

1. Gold, B. "Exploration in Management Economics". Macmillan, 1971.

CHAPTER ELEVEN

PRODUCTIVITY COSTING: CONCEPT, THEORY AND APPLICATION

11.1 Introduction

In this chapter we discuss the productivity-costing concept, and demonstrate its application, in the form of a case study, to the data collected from company A. The author has also devised a computer program in FORTRAN IV, which is capable of carrying out the analysis for a large number of products and productive equipment. The program is also capable of determining the optimum levels of a system's operations, using well-established linear programming techniques.

Productivity costing (Refs. 1, 2) is a systems-engineered method of integrated productivity measurement and conversion capacity-absorption cost accounting, derived from productivity measurement research and having direct or marginal costing features, in which system operation costs are allocated to each of the system's potentially-productive facilities (whether personnel or equipment) in proportion to their potential productiveness as measured in productive asset values, thereby facilitating effective management decision-making by providing:

(1) Minimal and stable costing rates for each facility, related to the maximum feasible facility capacity, which vary according to facilities, productive capacity and whether a facility is used for product-processing or is idle;

(2) Realistic product costs and related profits (or losses) which are unaffected by system activity variations because only a used facility has its cost (plus manning) charged to a product;

(3) Unit product, group product, and total system productivity indexes measured in terms of:

(a) Total earnings (or added value) and profit per unit of processing cost;

(b) Sales revenue and profit per unit of working capital investment;

(c) Conventional (profit after taxes) return on total capital investment; and

(4) A system-operating profit (or less) per period, identical to that for other cost-accounting methods, derived by deducting total idle facility costs from the total of product profits generated during the period:

Martin and Bahiri, the main protagonists of this approach, claim that it provides a common means of measuring productivity in industry and commerce, and that it is applicable to all types of work activities and thereby enables valid comparison of the efficiencies of widely-differing types of systems and subsystems.

11.2 Industrial-Commercial Systems Objectives

As has already been mentioned (Chapters 2 and 3), the appropriateness of a particular productivity concept, in measuring the effectiveness of a system, is a function of the goals to be pursued by an enterprise. Consequently, it is fundamental to understand the assumption made by Martin (Refs. 1, 2, 3) as to what constitutes the primary objective of an enterprise.

The productivity ratios developed by Martin (Refs. 1, 2, 3) are based upon the assumption that the primary objective of any industrial-commercial enterprise ~~is to~~ generate some desired total, implicit and explicit profit (Ref. 1). Martin (Ref. 3) claims that the above assumption is based on applied research in the measurement of productivity. He writes, "an industrial-commercial enterprise is a functional device which exists to achieve some definite purpose. To be able to measure the efficiency or productivity of the enterprise, its purpose, or primary objective, must be clearly-defined. Productivity measurement research has led to the conclusion that the primary objective of every industrial-commercial enterprise is to produce earnings for everyone who is directly and indirectly concerned in the conversion of basic materials into saleable products. The manufacture of the products has been found to be a secondary objective which is the means selected in particular cases for the realisation

of the (universal) primary objective. Recognition of this fundamental distinction was essential to the development of the desired universal method of measuring industrial-commercial productivity." Furthermore, he states (Ref. 3), "profit which is regarded by some macro-economists, as the primary objective of an industrial-commercial enterprise is directly related to 'total earnings'."

It is important to note that Martin is not alone in assuming that the primary objective of an enterprise is the generation of earnings (explicit and implicit profit); this view is held by other writers, notably Fox (Ref. 6) and Boyd (Ref. 7).

11.3 Output and Inputs of an Enterprise

As already mentioned in the previous section, "earnings" (implicit and explicit profit) are considered to be the primary output of any enterprise. In this section we define "total earnings" as used in the productivity-costing concept, and to discuss its measurement. Similarly, inputs to a system are specified and statistical techniques used in their measurement are described.

The "total earning" is defined (Ref. 2) as the value of sales minus the cost of production materials. Mathematically, the "total earning" concept can be stated as:

$$T = S - M$$

where T = Total earnings;
S = Sales revenue; and
M = Cost of production material.

The total of implicit and explicit profit corresponds to the economists' "added value". Added value is defined as the value of sales minus external expenses. From the definitions of "total earning" and "added value", it is clear that the two measures differ somewhat. The relation-

ship between "total earnings" (conversion output) and the economists' concept of "added value", expressed mathematically, is:

$$AV = S - X = T - C_x$$

where AV = Added value;
X = External expenditure; and
C_x = Cost of externally-purchased services and consumable materials.

Bahiri *et al.* (Ref. 4) maintain that "total earnings" is an acceptable approximation to the true total implicit and explicit profit (added value), the primary objective. The main advantage of using the "total earnings" approximation rather than the "added value" is that the former is easily determinable for particular products or for product-groups as well as for a total system.

Implicit in the nature of the "total earnings" concept, the primary output of an enterprise, is its measurement in monetary units. Because of the concept of productivity used by Martin (Refs. 1, 2, 3), it is necessary for both output and input to have a common unit of measurement. Hence, the input to an industrial-commercial system (or subsystem) is defined (Refs. 2, 3) as the whole cost of converting the materials into products sold; i.e., the cost of operating the system (or subsystem), excluding the cost of materials, which is a temporary throughput investment initiated at materials purchas and ended at payment for the sale of a product. The productivity concept adopted by Martin is discussed in the following section. Techniques used for the determination of conversion cost (inputs) are described in Section 11.6.1.

11.4 Productivity Measurement Indexes

Productivity costing uses a systems-engineering approach to productivity measurement which expresses all inputs and outputs in economic or money terms. The productivity of an enterprise in this system is defined

as the rate that input generates output (Refs. 3. 4).

Maximisation of "total earnings" in any industrial-commercial system is most easily attained by maximising the rate of generating total earnings or conversion output (T) per unit of operating or conversion input cost (C) (Ref. 4). There are, fundamentally, two productivity indexes which meet this requirement and which are universally applicable to all types of industrial-commercial enterprises (Ref. 3). They are:

(a) The Total earnings productivity, E_t (the Primary productivity index); and

(b) The Profit productivity, E_p (the Secondary productivity index),

and they are derived as follows:

$$\text{Total earning productivity,} \quad E_t = \frac{T}{C}$$

and

$$\text{Profit productivity,} \quad E_p = \frac{T - C}{C} = E_t - 1,$$

where

T = Total earnings = Net sales revenue - Materials (throughput) cost per unit period; and

C = Whole cost of operating the enterprise per unit period.

In maximising the primary productivity index, E_t, therefore, the secondary index of profit productivity, E_p, is also maximised, since it is always a unit less than the total earnings productivity, E_t.

11.4.1 Systems and subsystems productivity indexes

Productivity costing technique developes two parallel sets of productivity indexes which embrace the system and the subsystems. Subsystems of an enterprise are considered to be products or groups of products.

The major productivity indexes developed for assessing the productivity of a system and its subsystems (products) are (Refs. 3, 4):

$E_f = C_e/C_d \equiv C_e/C_f$ Processing facilities productivity (work productivity)

$E_d = T_d/C_e \equiv T_d/C_f \times E_f$ Product productivity characteristics

$E_{td} = T_d/C_d \equiv E_f \times E_d$ Product total earning productivity

$E_{pd} = P_d/C_d \equiv E_{td}-1$ Product profit productivity

$E_m = T_d - DL_d/C_f$ Contribution margin (cost) productivity

$E_{fs} = \Sigma C_e/\Sigma C_f+C_i \equiv \Sigma C_e/C_s$ Systems (total) facilities productivity

$E_{ds} = \Sigma T_d/\Sigma C_e \equiv T_s/\Sigma C_e$ Systems (total) product productivity characteristic

$E_{ts} = \Sigma T_d/\Sigma_{cf}+C_i \equiv T_s/C_s$ Systems (total) earning productivity

$E_{ps} = \Sigma T_d - (\Sigma C_f + C_i)/\Sigma C_f + C_i \equiv T_s - C_s/C_s$
or $T_s - 1$ Systems (total) profit productivity

$E_{ms} = (\Sigma T_d - \Sigma DL_d)/\Sigma C_f + C_i$
System (total) contribution margin productivity

$E_{cf} = C_f/C_u$ ($\equiv E_{cs} = \Sigma C_d/C_s$) Fixed facilities utilisation

where C_e = Cost of productive work (e.g., the work a facility is explicitly designed to do);

C_d ($\equiv C_f$) = Cost of facilities occupancy (includes C_e, i.e., product processing cost);

T_d = Total earnings (per product or group of products);

T_s = System's total earnings ($T_s = \Sigma T_d$);

C_s ($\equiv C_u$) = Total cost of operations for an industrial-commercial system ($C_s = \Sigma C_f + C_i$);

C_i = Idle (non-utilised) facilities cost;

P_d = Profit generated by a product or group of products;

P_s = System (total) operating profit;

DL_d = Direct labour cost per product or group of products;

C_f = Unavoidable (fixed) cost of facilities occupancy. Note that as it will be shown in the following section $C_f \equiv C_d$, i.e., C_f for normal range of systems output, is in fact the cost of facilities occupancy (product-prodcessing cost).

C_u = Unavoidable (fixed) cost of facilities (occupied plus idle). Note, as it will be shown in the following section, that $C_u \equiv C_s$; i.e., for the normal range of systems output, C_u is in fact the total cost of operations for an industrial-commercial system.

The costing system constructed for the measurement of inputs by Martin and Bahiri (Refs. 3, 4, 5) distinguishes the cost of productive work, C_e, from the cost of facilities occupancy, C_d (or C_f). Clearly, only the productive work cost kernel, C_e, of the product work cost, C_d, is directly incurred in adding value by the processing of materials. This, in fact, is an attempt to separate the truly productive work from auxiliary (non-productive) work. Truly productive work is defined (Refs. 2, 3) as:

> "Work which (whether done by a man or machine) actually changes the shape, physical characteristics or appearance of production materials; or which joins one material or product to another, or separates one material or product from another, during the process of converting throughput materials into saleable (or usable) products."

The product's total earning productivity, E_{td}, is a function of processing facilities productivity, E_f, and product productivity characteristics, E_d:

$$E_{td} = E_f \times E_d = C_e/C_d \times T_d/C_e = T_d/C_d$$

The facilities productivity index, E_f, is an engineering efficiency (or degree of utilisation of input) type measure of the proportion of the cost of operating a materials-processing system (or subsystem), C_d, that is actually incurred in accomplishing truly productive work, C_e, as defined above. The product-productivity characteristic, E_d, measures the total earnings per product (or product group) per unit of related productive work cost. Consequently, E_{td} reflects both the productiveness of products and of the facilities used in producing them.

Similarly, system total productivity, E_{ts}, is a function of total system facilities productivity, E_{fs}, and total system product productivity characteristics, E_{fs}. Mathematically, this can be stated as follows:

$$E_{ts} = E_{fs} \times E_{ds} = \Sigma C_e/C_s \times T_s/\Sigma C_e = T_s/C_s \ .$$

Maximisation of system total earning may be achieved by producing an optimum mix of products, i.e., optimal quantities of products having high total earnings productivity indexes, thereby utilising the maximum feasible capacity of a system's conversion facilities to their optimum extent.

The productivity indexes presented are based on processing costs. It is possible to derive a set of productivity indexes based on working capital investments. These indexes may be of use when working capital is a limiting factor.

The productivity indexes based on working capital investment for subsystems and systems are:

$E_{sw} = S_d/(M_d + I_d + C_f)$ Sales revenue/working capital productivity for a product or a group of products;

$E_{pw} = (S_d - M_d - I_d - C_f)/(M_d + I_d + C_f)$ Profit/working capital productivity for a product or group of products;

$E_{tw} = T_d/(M_d + I_d + C_f)$ Total earning/working capital productivity for a product or group of products;

$E_{mw} = (T_d - DL_d)/(M_d + I_d + C_f)$ Contribution margin/working capital productivity for a product or group of products

$E_{sws} = \Sigma S_d/(\Sigma M_d + \Sigma I_d + \Sigma C_f + C_i)$ System sales revenue/working capital productivity;

$E_{pws} = [\Sigma S_d - (\Sigma M_d + \Sigma I_d + \Sigma C_f + C_i)]/(\Sigma M_d + \Sigma I_d + \Sigma C_f + C_i)$

System profit/working capital productivity;

$E_{tws} = \Sigma T_d/(\Sigma M_d + \Sigma I_d + \Sigma C_f + C_i)$

System total earning/working capital productivity;

$E_{mws} = (\Sigma T_d - \Sigma DL_d)(\Sigma M + \Sigma I + \Sigma C_f + C_i)$

System contribution margin/working capital productivity

where

S_d = Sales revenue (per product or group of products);

M_d = Direct materials cost (per product or group of products); and

I_d = Interest charges (per product or group of products,

11.5 Costing Concepts

The relationship between various productivity-costing categories, introduced in the previous section, are summarised below:

C_u	C_i	$C_i + C_f = C_u$	= Unavoidable (facilities) costs
	C_f	$C_f + C_v = C_d$	= Product processing (facilities) cost
V	C_v	$C_u + C_v = C_s$	= Total system (facilities) costs
		$C_d + C_i = C_s$	= Total system (facilities) costs
	M	$M + C_v = V$	= Total variable expenses

where

C_v = Variable processing costs; and

M = Materials costs.

In developing costs (inputs to systems and subsystems), the basic assumption made (Refs. 3, 4) is that "an industrial system's operating costs (excluding materials costs but including direct labour costs) remains essentially stable (i.e., vary only randomly about a stable average value) over the whole normal range of variation of output from the system". Consequently, once the productive facilities have been identified, productivity can be measured by the total earnings of those productive facilities and the rate which each product generates profit.

In practice, the above assumption implies that the variable processing costs, C_v, will tend to approach zero within the normal range of a system's outputs. Consequently,

unavoidable (fixed) cost of facilities occupancy, C_f, approaches the product processing (facilities) costs, C_d, and unavoidable (fixed) cost of facility, C_u, approaches total cost of operations of the system, C_s. Mathematically, these can be stated as follows:

$$C_f + C_v = C_d ;$$

$$C_u + C_v = C_s ;$$

then as $C_v \rightarrow 0$,

$$C_f \equiv C_d \text{ and}$$

$$C_u \equiv C_s .$$

When the product processing cost, C_d, consists partly of fixed or unavoidable costs, C_u, and partly of variable processing costs, C_v, the ratio expressing that part of the fixed facilities occupancy cost, C_f, that is utilised in processing products, is the fixed facilities utilisation productivity, E_{cf}, or C_f/C_u. However, as C_v approaches zero, then the fixed facilities utilisation productivity, E_{cf}, will approach the total system facilities utilisation productivity, $E_{cs} = C_d/C_s$.

The product processing cost, C_f ($\equiv C_d$), in productivity costing is the cost of converting throughput materials into saleable products at the level of maximum feasible processing facilities utilisation. It represents a near-optimal allocation of per period system operating expenses to the system's material conversion facilities. This, in fact, is a refined form of conversion capacity-costing concept. Schlattar *et al.* (Ref. 8) list among the advantages of practical capacity-costing rates; constant and true unit costs, non-inflation of work-in-process and finished goods values during slack periods, isolation of idle capacity costs as a charge upon managements, and its importance in developing costing rates between those of absorption and marginal costing.

Figure 11.1 shows the breakeven model when variable processing costs $C_v \neq 0$; and Figure 11.2, the breakeven model when variable processing costs approach zero, i.e., $C_v = 0$.

As shown later, the cost of productive work, C_e, is computed by multiplying the productive work-hours as defined previously by the facility product costing rate. The facilities occupancy cost, C_f, is computed by multiplying the product-occupancy period per productive facility by the product-costing rate. The product-occupancy periods include not only the time required for productive work, but all the time required for processing the product. This includes preparing the machine for processing of the product, moving and fixing materials into their exact processing positions and removing them from the facility after the productive work has been completed. The idle facilities cost, C_i, is computed by multiplying the facilities (unoccupied) idle hours by the productive equipment-costing rates per hour. Idle hours are the difference between maximum feasible occupancy or work hours and the total product facilities occupancy hours. Finally, total facilities cost, C_s, is computed by multiplying the maximum feasible occupancy ~~hours by~~ the productive equipment costing rates. In other words, facilities occupancy cost, C_f, plus idle facilities cost, C_i. C_i.

The development of costing rates and the computation of various costs are demonstrated in the following sections by a means of a case study.

11.6 Productivity Measurement -- A Case Study

The use of the productivity-costing technique in the measurement of effectiveness of an enterprise is demonstrated here. The case study also helps to illustrate the development of costing rates necessary in the calculation of productivity indexes presented in Section 11.4.1.

The main products of the firm are bearings, which, broadly speaking, are divided into seven main groups. Each

product consists of two major components -- spindles and outers. Manufacture is organised along the orthodox batch method.

11.6.1 Development of costing rates

The development of productive (processing) facilities costing rates for the system under consideration is illustrated in Table 11.1. The first step in the development of a productivity-costing system was to identify the productive facilities of the system. Productive facilities are only those which qualify by virtue of the fact that they have the ability to, and may do, productive work as defined previously, during the process of converting "throughput" materials into products made and sold by the organisation.

The organisation's various production departments are shown on line 1 of Table 11.1. Line 3 shows the identified types of the potentially-productive facilities within the system.

The total nominal working hours per day (line 4 of Table 11.1) for each productive facility type was determined by multiplying the number of machine tools within each facility type by its relevant nominal working hours (as determined by management policy). As an example, consider the productive facility No. 1, which consists of three 4 Hi Conomatic machines. The nominal working hours for this group of machines were 8 hours per day, i.e., one shift. The total nominal working hours are then 24 hours (number of machines 3 x nominal working hours 8 = 24). Within the confines of the nominal working hours, maximum feasible (product-processing) occupancy hours were determined by using the data collected for the measurement of machine utilisation. The non-productive time for machine-grouping is collected weekly and machine-utilisation is computed every quarter. The data include the following items:

(a) Not used/No operator time;
(b) Set-up/Change-over time;
(c) Maintenance time;
(d) Waiting work time;
(e) Other categories time; and
(f) Total available hours.

In cases where no tangible measure of utilisation is available, it is possible to determine the maximum feasible occupancy hours by a detailed appraisal of the operating characteristics of each particular productive facility with respect to such capacity limiting factors such as maintenance needs, or known bottlenecks, conditions at productive facilities through which all products pass before being processed in the particular facility under consideration. The determination of maximum feasible occupancy hours is of the highest importance because, as will be seen later, it is used as divisor in computation of the facilities-costing rates, and may critically affect key management decisions with regard to product emphasis or de-demphasis. Therefore, top management should be involved in the determination of the maximum feasible occupancy period for each productive facility.

The productive facilities identified were used as the foundation of the productivity-costing system because, together they constitute the whole productive potential core of the organisation and are, therefore, the justification for all the expenses incurred within the system in converting "throughput" materials into saleable products. Therefore, it is logical that the operating expenses of the system be apportioned to the potentially-productive facilities core according to the relative productive potentials of the several productive units which constitute the potentially-productive core. As it is not possible to measure the productive potential of the productive facilities accurately, it is most convenient to infer that the present-day purchase value of each potentially-productive equipment unit provides a reasonably

accurate indication of its productive potential as compared to the remaining productive units (Refs. 1, 2, 3). It was possible to obtain the present-day purchase values of each productive unit by conferring with the industrial engineers. In cases where a particular machine had become obsolete, present purchase value of an equivalent machine was collected. The present-day purchase values were multiplied by the number of machines within each group to determine the productive potential of each group of machines, as shown on line 6 of table 11.1.

Expenses incurred by the organisation can be divided into two categories:

(a) Expenses incurred by individual departments or facilities such as the (direct) labour costs incurred in operating the facilities, depreciation reserves for specific maintenance, utilities costs, supervisory salaries, or non-operating (indirect) labour costs; and

(b) Expenses incurred by the organisation as a whole, such as staff and executive salaries, insurances, heating, lighting, etc.

From the Company's accounting records it was possible to extract readily the expenses incurred by individual departments and the organisation as a whole for the first nine months of the financial year 1980-81. These were divided by the number of working days for those nine months to obtain the average daily expenses for each department and the system. In the illustration, as shown in line 8 of Table 11.1, departmental expenses were apportioned between productive facilities within a particular department, in proportion to their relative present-day purchase values (i.e., the ratio of purchase value of a facility to total values of facilities within the particular department), and the total general expenses (£6,134.70 per day) were apportioned between the productive facilities in proportion to the relative present-day purchase value of each facility (i.e., the ratio of purchase value of a facility to the total values of facilities within the system).

In practice, it is possible to apportion the general system expenses to the departments using other criteria such as relative departmental staffing, area or volume. Apportionment of the general system expenses according to the above criteria, in terms of costing rate, proved not to be significantly different from that derived wholly from apportionment according to present-day purchase value.

Costing rates of each potentially-productive facility were derived by dividing all the operating expenses apportioned to the facility -- excluding operating (direct) labour -- by the maximum feasible occupancy hours for the facility, as illustrated in line 9 of Table 11.1. This rate was then used as a measure of the cost of the facility for each feasible occupancy hour whether or not the facility is in fact occupied productively in converting "throughput" materials into saleable products.

In order to compute the productive equipment costing rate it was necessary to determine the cost of direct labour required for the operational control of productive facilities. The direct labour cost for each department was readily available from the organisation's accounting records. For each department the total direct labour costs, including overtime, were determined for the first nine months of the financial year 1980-81. The average daily labour cost, line 10a of Table 11.1, was computed by dividing the total cost for the past nine months by the number of days worked. This labour cost, as illustrated in line 10a of Table 11.1, for a costing period of one day, was divided by the total maximum feasible occupancy hours within a given department, to obtain the manning labour cost per occupancy hour.

The product costing rate was computed (line 11 of Table 11.1) by adding labour cost and related productive facility costing rate per hour (line 9 + line 10b of Table 11.1). The product costing rate is charged to the products processed in the facility for each period of time they

occupy it. Such product occupancy periods include not only the time required for productive work as previously defined, but all the time that the need for processing the product's materials occupies the facility's potential productive capacity, such as preparing the machine for the processing of the product, moving and fixing materials into their exact processing position and removing them from the facility after the productive work has been completed.

11.6.2 Product costs and facilities productivities

During the period under consideration (i.e., the first nine months of the financial year 1980-81), 184 different products within the seven main products groups were produced. Because of the large number of products, application of productivity costing technique manually was laborious. A Pareto analysis of products was carried out, and products accounting for 50 per cent of output within each product group were selected, so as to demonstrate the development of products costs and product processing facilities productivities. These are illustrated in Table 11.2 for 20 different products. This technique could easily be applied to any number of products with the aid of a digital computer.

Productive work hours (as defined before) were obtained for each component of a given product by using the products flow chart and standard times used in loading the shops. The facilities occupancy hours defined in the previous section was obtained from the time-study data.

The facilities productivity, E_f, is the ratio of cost of productive work, C_e, to the total facilities occupancy cost, C_f, as defined in Section 11.4.1. The productive work cost, C_e, and facilities occupancy cost, C_f, were determined, respectively, by multiplying the product's productive work hours (line 12, 16, 20, etc., of Table 11.2) and the product's facilities occupancy hours (lines 13, 17, 21, etc., of Table 11.2) by the relative facilities product costing rate (line 11 of Table 11.1). The facilities

occupancy costs per product, per facility and in total are given in lines 15, 19, 23, etc., of Table 11.2 and in line 95 of Table 11.2.

As illustrated in lines 14, 18, 22, etc., of Table 11.2, the facilities productivity, E_f, for a given product at a particular productive facility was computed simply by dividing the productive work hours by the facility's occupancy hours, as the relative costing rate for the numerator and denominator of the above ratio for a given facility are the same and cancel each other out. The total facilities productivity for any given product was obtained by summing up the productive work hours and facilities occupancy hours at each productive facility, and dividing the two, as illustrated in the totals columns of Table 11.2, lines 14, 18, 22, etc. The total facilities productivity for all products combined is illustrated in line 94 of Table 11.2.

As is evident from Table 11.2, facilities productivities on the whole are high. The reasons for this are two-fold:

(a) In determining a facility's occupancy hours we assumed optimum batch scheduling which resulted in minimum set-up times; and

(b) Because of the high degree of mechanisation and the nature of the operations, material loading times were very low.

The utilisation and productivity of the potentially-productive facilities and the labour needed for their operational control for the total system are summarised in Table 11.3. These figures are based on an average daily production and costs of the system for the first eight months of the financial year 1980-81.

The idle facilities hours were determined by subtracting the total facility occupancy hour per facility (line 93 of Table 11.3) from the corresponding feasible occupancy hours (line 5 of Table 11.1). These idle

facility hours were then multiplied by the productive equipment costing rate per hour (line 9 of Table 11.1) so as to arrive at the idle facilities costs on line 97. Individual and total facilities utilisation are shown on line 98. Total facilities productivities, as illustrated on line 99, are the quotients of the total facility productive work hours per facility on line 92, divided by the maximum feasible occupancy hours (line 5), and the total facilities productivity for the whole system is stated in the totals column of line 99. This was derived by dividing the grand total cost of productive work achieved in all the facilities of the system by the grand total operating expenses for the whole system.

The low facilities utilisation and total facilities productivity can be partly attributed to the fact that not all the products made during the period under consideration were included in the analysis and partly because of falling demand. Taking the two above factors into consideration, it is still safe to conclude that an excess capacity exists in the case of some of the productive facilities, e.g., productive facility No. IV.

The operating labour cost not applied to product processing was determined by multiplying the idle labour hours by labour rates (line 10b of Table 11.1), as illustrated in line 101. The labour utilisation for each productive department is given in line 102 of Table 11.3.

11.7 Product Costing Comparison -- Conventional, Marginal, Productivity

In this section, profit and loss accounts are derived, based on absorption, marginal and productivity-costing concepts. We examine the differences and effects of using these concepts on management decisions.

11.7.1 Conventional costing

Products costs and profits, for individual products

and in total, as determined according to the overhead absorption costing procedure, are presented in Table 11.4. A break-even chart for the total system, based on the figures in the totals column of Table 11.4, is shown in Figure 11.3

The overhead expenses allocated to the products (line 3b) are based on the Company's accounting practices. Overheads such as rates, water rates, etc., are allocated to each department according to the floor space they occupy. The other fixed overheads such as electricity, gas, toolroom expenses, etc., are allocated according to the subjective estimates made of the proportion used by each department. The total fixed overhead within each department is then allocated to the machines within that department according to the maximum total standard hours of use. The product's fixed overhead rates are determined according to the standard processing hours.

Using overhead absorption costing procedures, all the overhead expenses have to be apportioned to all the products made during the accounting period. This requirement leads to apparent product profits or losses which are not strictly true. Comparison of the facilities occupancy costs of £562,574.1 (line 8 of Table 11.6) with the total operating expenses of £1,048,733.7 (line 8 + 10c of Table 11.6) indicates a difference of £486,159.6, representing the total idle capacity. This total idle capacity cost amounts to approximately 46 per cent of the total operating expenses, i.e. 46 per cent of the productive facilities, in terms of production equipment plus its operating labour, was not used during the period for processing products and is not, therefore, applicable to the products made during the period as a valid item of cost incurred in their actual production.

The relationships between the various total categories of cost tabulated in Table 11.4 are shown graphically in Figure 11.3. It also depicts the state of economic health

of the total industrial-commercial system by identifying the breakeven level of systems activity (in terms of sales revenue) at which revenue equals total costs and beyond which an operating profit will be realised.

11.7.2 Marginal (direct) costing

Products and total costs and profits, determined according to marginal (direct) costing principles, are shown in Table 11.5. The profit contributions margins versus sales revenue breakeven chart, based on Figures given in Table 11.5, is shown in Figure 11.4.

The products and total systems contribution margin was determined by subtracting the sales revenues from their related avoidable or direct costs as stated in line 3. This margin is the contribution made during a period by selling a product or a group of products in offsetting the unavoidable costs for the period, and any surplus becomes a direct contribution to the system operating profit.

The ratio of the contribution margin to its related sales revenue, provides a measure of the percentage of the product's sales revenue available for offsetting unavoidable period costs and contributing thereafter to operating profit as shown in line 4 of Table 11.5. It is appropriate to note that, according to overhead absorption costing, product 850 is a loss product; whereas, according to direct costing, it has a higher contribution margin rate per unit of sale (0.435) than product 14, which was a profitable product according to the overhead absorption costing. The essential difference between these two costing methods lies in the costs charged to specific products. The advantages and disadvantages of overhead absorption and marginal costings as a basis for management decision-making are covered in most accounting textbooks and are not repeated here.

The relationships between sales revenue, unavoidable period costs, individual and average product contribution

margin rates per unit of sales revenue, and operating profit (or loss) determined according to the marginal costing method are shown graphically in Figure 11.4. This form of breakeven chart shows clearly how, and at what rate, the individual and combined product contribution margins first act to offset the unavoidable costs and then act to provide operating profit in accordance with direct or marginal costing concepts.

11.7.3 Profit and loss account based on productivity costing

Costs and profits (or losses) for the individual products and in total, as determined according to productivity costing principles, are shown in Table 11.6. A system total earnings versus sales revenue breakeven chart based on figures given in Table 11.6 is shown in Figure 11.5.

Total earning levels for each product and for the system were determined by subtracting the avoidable costs (materials + interest as per line 2c) from the related sales revenue, as given in line 3. As has been discussed earlier, according to the basic concepts of productivity costing, the fundamental purpose of operating ~~the system~~ is to generate such total earnings. As such, they are considered to be the major basis of measuring the effectiveness of the operation of the system or the contribution that individual products can make to improving its operating effectiveness.

As stated previously, the productivity costing technique assumes that the operating labour costs are stable (i.e., vary only randomly about a stable average value) over the normal range of variation of output from the system, unless proved otherwise. This assumption holds true in this particular case.

Figure 11.6 is based on the data in Table 11.6. It depicts the relationship between sales revenue, direct

labour costs, overhead costs, materials costs and profits in (conventional) breakeven chart form for the first eight months of the financial year 1980-81. As is evident from Figure 11.6, the direct labour costs (monthly plottings of direct labour costs are identified by month numbers) did not vary in proportion to the level of activity but varied about a stable average value from a low monthly sales revenue level of approximately £95,000 to a high level of approximately £190,000 or over a two-to-one range of variation in sales revenue. It is evident, also, that there is no correlation between the magnitude of the weekly direct labour costs and the corresponding levels of sales revenue. This stability of direct labour costs supports the validity of "total earnings" concept referred to previously. It is important to point out at this stage that this assumption, although true in the majority of cases, may not be strictly true in all cases, particularly when viewed over the long range -- which may need to include periods of extremely low or zero output.

In Table 11.6, therefore, operating (direct) labour is not included as an avoidable (per product) cost under item 2. The products profits were arrived at by subtracting the facility-occupancy costs for products and in total from the related total earning amounts given in line 3 of Table 11.6 The total facility-occupancy costs per products computed in Table 11.2 were based on average numbers of units produced per day. These were multiplied by the number of working days (164) to arrive at facilities-occupancy costs, C_f, as illustrated in line 8 of Table 11.6. The system's operating profit (or loss) was derived by deducting the total product profits from the total of non-producing facilities costs (line 10c) as illustrated in line 11 of Table 11.6.

Figure 11.5 is a useful visual management aid. The divergence between the rate of generating total earning per product and in total (T/S) and the rate of incurring system operating costs per product and in total (C/S) provides a visual measure of the rate of generation of product profit or operating profit. Another feature of Figure 11.5 which is of value

to management is that it shows graphically the manner in which the idle capacity costs radically reduce the potential (total product) profit compared to the operating profit. It also shows clearly (a) how total earning comprises both product profits and product costs; and (b) how the system-operating (unavoidable) expenses are comprised of product cost plus idle capacity costs. This figure can also be used to determine the best way which the idle capacity may be utilised to achieve optimal utilisation of the industrial-commercial system. This is done by projecting various total earning and processing costs rates per unit of sales revenue and determining their effect on the system's operating profit.

11.7.4 Similarities and dissimilarities between the costing concepts

The productivity costing concept, as has been discussed, is based on the assumption that an industrial system's operating costs (excluding materials costs but including direct labour costs) remain essentially stable (i.e., vary only randomly about a stable average value) over the whole normal range of variation of output from the system. Since it is within this range that management decision-making needs to be effective, it is normally considered sound practice to regard direct labour costs as stable costs. This is indeed contrary to prevailing cost-accounting practice, as illustrated in Tables 11.4 and 11.5, which demonstrate absorption and marginal costing in which direct labour costs are treated as avoidable.

Productivity costing differs from conventional absorption costing methods mainly in the logic of its basis of apportionment. In productivity costing, the facilities costing rates are based on maximum feasible utilisation of all the facilities which comprise the potentially-productive system. Consequently, for any given manufacturing method, the product processing costs and their dependent product profits can be considered in a real sense to be optimal in terms of the maximum feasible utilisation of the

facilities comprising the system at prevailing product selling prices. Thus, in a certain sense, total non-producing facilities costs appearing under item 10 of Table 11.6 are the counterpart of the unabsorbed overhead expenses stated for the absorption costing case on line 5 of Table 11.4, except that, according to productivity costing concepts, the total non-producing facilities costs provide a measure of the degree to which the industrial system involved was not utilised optimally.

It is important to note that the total system's profit is the same for the costing methods used, Tables 11.4, 11.5 and 11.6, lines 6, 6 and 11, respectively. This is because the products produced within the nine months period were sold in that period. However, if the value of products sold differed significantly from the value of products produced during the period, the operating profit for the three different costing methods would have appeared to differ significantly, as the inventory valuation differs according to the method used.

Productivity costing is not incompatible with marginal costing as illustrated in Table 11.6. The total earning can, in fact, be viewed as a conservative marginal contribution for the short range, since it is based on the assumption that no direct labour costs will be avoided if the activity level of the system during an accounting period proves to be less than the anticipated maximum for which, normally, the system in manned.

11.8 Product Productivity Indexes

Table 11.7 presents two sets of product productivity costing data as per Table 11.6. One set is based on product processing costs and the other set is based on product working capital investments. So far, all the productivity indexes referred to have considered only the productivity of the funds invested in processing products. However, when management is faced with a tight working capital situation, decisions aimed at generating optimal utilisation of the system cannot ignore the effects thereof

on the demands for working capital required to support such optimal operations.

The derivation of product productivity indexes, listed under item 1 of Table 11.7, have been discussed previously and are not repeated here. If is important to note that the product productivity characteristics, shown in line 1d of Table 11.7, were derived in the reverse process by dividing their related total earnings (cost) productivity indexes, E_t, (line 1a) by the pertinent processing facility indexes, E_f, from line 1c of Table 11.7.

As another indication of the compatibility between marginal costing and productivity costing, groups of contribution margin productivity indexes are introduced on lines 1e and 2d of Table 11.7. They are the counterparts of the related total earning productivity indexes, as per lines 1a and 2c, except that they state the rates of generating marginal contribution (excluding direct labour costs) per unit of cost or investment, respectively, instead of stating the rates of generating "total earnings", which include direct labour costs.

It is pertinent to note that the first group of working capital-based productivity indexes is the group of sales revenue/working capital indexes on line 2a of Table 11.7. When considering the productivity of working capital, i.e., the rate of output per unit of working capital input, it appears most logical to regard the sales revenue generated from a given input of working capital as the true related output. This is not incompatible with the stated primary objective of the system. In fact, it follows logically that, having added material costs to the input denominator, they should also be added to the output numerator.

The product productivity indexes given in lines 1a, 1b, 1d and 1e on lines 2a and 2b of Table 11.7 are most relevant in terms of guidance for management decision-making concerning possible product emphasis or de-emphasis. The processing facilities productivities, on line 1c, each

provide only a measure of the effectiveness of utilisation for productive work of the processing subsystem involved in the manufacture of the particular product. The total earnings and contribution margin/working capital indexes on lines 2c and 2d, respectively, are considered to be less reliable guides to management decision-making because their output numerators are not strictly related to their input denominators in that their outputs and inputs do not both include the same factors of cost.

Product productivity characteristics bring into focus the importance of the product and process design functions in contributing towards optimal system operation. The total earnings numerator of the characteristic is the margin derived by deducting the materials investment cost from the sales revenue. The design function can influence this margin beneficially both by limiting the materials costs for a product and by designing into the product features that enhance its saleability, such as uniqueness, attractiveness, reliability, durability and serviceability. Similarly, the value of the productive work cost denominator of the characteristic is largely determined during the design process, for instance, by whether the design is more complex than is necessary or if it entails unnecessary expensive processing.

11.9 System Productivity Indexes

Two sets of system productivity indexes, parallel to those stated for the products in Table 11.7, are presented in Table 11.8. Essentially they differ from the productivity indexes for the product totals given in Table 11.7 to the extent that, in every case, the cost of idle capacity, C_i, is added to the input denominators. It will be noted that this causes a significant reduction in the productivity index value in all but the product productivity characteristic, which remains unchanged. This confirms the fact that this characteristic for a product or a given mix of products is essentially a constant. It remains constant as between Tables 11.7 and 11.8 by virtue of the

fact that the idle facilities cost, C_i, is introduced into its denominator as indicated on line 1d of Table 11.8, but also, in a compensative effect, into its numerator. The inclusion of the system total facilities productivity, E_{fs}, per line 1c as a divisor in the denominator of the productivity characteristic, E_{ds}, accomplishes this compensating effect because the idle facilities cost, C_i, is in turn a part of the denominator of the system total facilities productivity index as is shown in line 1c, and therefore, in effect becomes part of the numerator of the product productivity characteristic.

11.10 Comparative Product Rankings for Different Costing Methods

Comparative product rankings based on the cost data stated in Tables 11.4, 11.5 and 11.6 for absorption, marginal and productivity costing methods, respectively, are tabulated in Table 11.9 as an alternative basis of management decision-making concerning the relative merits of various products when seeking to achieve optimal operation of the system.

As shown in Table 11.9, absorption costing provides one index for management decision-making based on the apparent product profit or loss. The marginal costing method, meanwhile, provides two management decision-making indexes:

(a) Contribution margin; and
(b) Contribution margin per unit of sales revenue.

Finally, productivity costing method provides at least eight guides to management decision-making concerning with the relative merits of various products, which are not provided normally by either of the other two prevailing methods.

Based on the guidance provided by productivity indexes, i.e. rates of generating total earnings and profits, it is possible to conclude that any attempt to optimise the operation of the system while continuing to make and sell

the products listed in Table 11.9, should probably be based mainly on additional emphasis of products 47, 623, 621 and 138, but a more detailed appraisal of the problem is needed which takes into account the market situation and the possible output-dampening effects of production facilities bottlenecks.

11.11 Productivity Costing: A Program

The application of productivity costing technique, as is clear from Section 11.6, becomes extremely laborious, when a large number of products are involved. To overcome this difficulty, the author has devised a program in FORTRAN IV which is capable of carrying out the required analysis for a large number of products and productive facilities (equipment). The program, as well as carrying out the analysis outlined in Tables 11.1 to 11.9 has the capacity of optimising the system's "total earnings" using linear programming techniques. In the following sub-section we describe the program in more detail. The program listing is presented in Appendix II.

11.11.1 Description of the program

The program consists of a main segment and four subroutines. The inputs to the main segment of the program are:

OPTO = Optimisation subroutine marker. If OPTO = 0, then optimisation subroutine is not called. If OPTO $\geqslant$ 0, optimisation subroutine is called;

NPRO = Number of products produced by the enterprise for a given period;

NMAC = Number of system's productive equipments (facilities);

NDEP = Number of departments (productive stops) within the system;

NWH(J) = Nominal working hours for productive equipment J;

MFOH(J) = Maximum feasible occupancy hour for productive equipment J;

PEPV(J) = Present-day purchase value of productive equipment J;

NPED(K) = Number of productive equipments in department K;

DEPE(K) = Expenses incurred by department K;

GSE = General system expenses; and

DLHR(K) = Direct labour costs incurred by department K.

The main segment of the program calculates the productive equipment's costing rate per hour, PECR/H, and productive costing rate per processing hours, PCRPPH. Calculation steps are identical to those used for computation of data presented in Table 11.1, and these are described in detail in Section 11.6.1.

After performing the required calculations the main segment of the program calls subroutine PROC. The subroutine reads the following data from the data file:

PWH(I,J) = Productive work hours for product I, on productive equipment J; and

FoH(I,J) = Facility's occupancy hours for product I, on productive equipment J.

The subroutine then procedes to calculate the facility's occupancy cost, FOC, for each product and in total, individual products facility productivity, FP; and in total, facility's idle hours, FIH; idle facility's costs, IFC; facility's utilisation, FU; idle labour hours, ILH; idle labour cost, ILC; and operating labour utilisation. The outputs from this subroutine are identical to the data presented in Tables 11.2 and 11.3.

Subroutine ACCO calculates the system's profit or loss, according to conventional, marginal and productivity costing techniques. In addition, it computes the individual product's profit (determined according to conventional costing), contribution margin, quotient of sales revenue -- contribution margin (using marginal costing techniques), and various productivity costing indexes (based both on processing costs and working capital). From this subroutine the program calls sub-routine NRANK. The function of this subroutine is to rank the products according to criteria outlined in Section 11.10. These serve to assist in decisions regarding emphasis or de-emphasis of products. The output from sub-routine ACCO and NRANK are identical to the data presented in Tables 11.3 to 11.9. Following variables constitute the input to subroutine ACCO:

SR(I) = Sales revenue for product I;

PMC(I) = Production material cost for product I;

INT(I) = Interest, freight charges for product I;

ODL(I) = Operating (direct) labour expenses for product I;

OE(I) = Overhead expenses for product I;

UO = System's unabsorbed overheads; and

FC = System's fixed costs.

Subroutine OPSTE is called when the value of variable OPTO is equal or greater than unity. It solves the linear programming problem.

Minimise or maximise

$$Z = \sum_{j=1}^{n} C_j X_j \quad ,$$

subject to constraints:

$$\sum_{j=1}^{n} a_{ij} X_j R_i b_i$$

and

$$b_i \text{ and } X_j \geqslant 0 \quad ,$$

where

R_i is one of the symbols "$\leqslant$" or "="

$i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$

using the Simplex technique. The subroutine automatically sets up slacks variables for the "$\leqslant$" constraints and artificial variables for the "=". The subroutine reads the following variables from the data file:

A(I,J) = Coefficients of constraints a_{ij}
I = 1, 2, ... M and J = 1, 2, ... N;

A(I,N1) = Constraint bounds b_i ;

A(M+1,J) = Objective function coefficients C_j ;

MMM = First dimension of the array A.
MMM $\geqslant$ M + 2 ;

INEQ(I) = Indicates the type of constraints, i, as follows:

INEQ(I) = 0 a "$\leqslant$" constraints;

INEQ(I) = 1 a "=" constraints;

where

I = 1, 2, ... M ;

M = Number of constraints;

N = Number of variables;

N_1 = N + 1;

K = M + N ;

MINX = Specifies whether the objective function is to be maximised or minimised. Value of 1 specifies maximisation and -1 minimisation; and

MAXIT = Maximum number of iterations the subroutine is allowed to perform.

Integer IFAIL is an error indicator variable. It assumes one of the following five values: 0, 1, 2, 3 and 4. If the routine does not detect an error, IFAIL contains 0 on exit; otherwise, it would contain a value equal to any one of the other four values. These values refer to the following errors detected by the routine:

IFAIL = 1 The array INEQ has one, or more, elements set up incorrectly;

IFAIL = 2 One or more, of A(I,N1) (I = 1, 2, ... m) are negative.

IFAIL = 3 One, or more, of the following has been detected: $m < 1$, $N < 1$, $MAXIT < 1$, $MMM < M + 2$, $|MINX| \neq 1$, $N1 \neq N + 1$; and

IFAIL = 4 MAXIT iterations have been performed, but an optimal solution has not been found.

On exit, if IFAIL = 0, IPAR is set as follows:

IPAR = 0 : An optimal solution has been found;

IPAR = 1 : There is no feasible solution to the problem; and

IPAR = 2 : The constraint region for the problem is unbounded.

The subroutine calculates and prints the values of iterations, MAXIT; variables, X_j, s, in final basis; and the optimum value of objective function, Z. It then proceeds to recalculate the system, s; total earning productivity, ETS; profit productivity, EPS; product

productivity characteristics, EDS; contribution margin productivity, EMS; sales revenue/working capital productivity, ESWS; profit/working capital productivity, EPWS; total earning/working capital productivity, EMWS; and contribution margin/working capital productivity, EMWS, using the optimum value of the "total earning" and new levels of products output.

11.12 Industrial-Commercial System Optimisation

As we mentioned in the previous section, the productivity costing program is capable of determing the optimum levels of the system's operations. In this section we discuss in some detail two possible approaches to system optimisation. For reasons of clarity, we have devised an example to illustrate the issues involved in optimising the system's output. The organisation used in this particular example is assumed to produce three products, code-named 1, 2 and 3, and consisting of two departments, each having two productive equipments. Table 11.10 shows the computer output for this example. This table is, in fact, an equivalent of Tables 11.1 to 11.9 and shows the productive equipment costing rate per hour, PECRIH; product costing rate per processing hour, PCRPPH; products processing costs, FOC; facilities productivity, FP; idle facilities cost, IFC; facilities utilisation, FU; idle direct labour costs, ILC; operating labour utilisation, OLU; systems and products profits (using both absorption and productivity costing techniques); contribution margins, systems and products productivity indexes as determined by productivity costing techniques, and finally products rankings for alternative basis of management decision-making.

Optimisation of system's operations based upon maximisation of contribution margins (determined as the result of application of marginal costing techniques), subject to availability of time in various departments, is a well-established practice. However, adoption of

productivity costing concept in determination of a system's optimum operations has one very important advantage compared to the current practice. The advantage lies in the fact that restrictions (maximum feasible occupancy hour per departments; see the next two sub-sections for fuller explanations) are weighted financially compared to physical restrictions (numbers of machinery hours available) used as the result of application of marginal costing technique. Clearly weighting the available hours per processing equipment by an appropriate costing rate is closer to an "economically oriented concept of physical output".

11.12.1 System optimisation with no reductions of present product quantities

As the productivity costing technique is based on the assumption that the objective of any commercial-industrial organisation is generation of "total earnings", then any attempt to optimise the system should be concerned with maximising the system's "total earnings", subject to the stipulated constraints.

Mathematically, the system optimisation with no reduction of present product quantities can be formulated as follows:

$$\text{Maximise} \quad TE = \sum_{j=1}^{n} C_j X_j \,, \tag{11.1}$$

subject to constraints

$$\left.\begin{array}{r} \sum_{j=1}^{n} a_{ij} X_j < b_i \\ X_j \geqslant PX_j \\ b_i \text{ and } X_j \geqslant 0 \end{array}\right\} \quad i = 1, 2, 3, \ldots n \tag{11.2}$$

where

C_j = Total earnings of product j;

X_j = Quantity of product j ;

a_{ij} = Facility occupancy cost for productive equipment i, and product j ;

b_i = Maximum feasible occupancy cost, productive equipment i ; and

PX_j = Present quantity of product X_j.

Table 11.11 shows the values of the system's total earning productivity, ETS; profit productivity, EPS; total facilities productivity, EFS; product productivity characteristic, EDS; contribution margin productivity, EMS; sales revenue/working capital productivity, ESWS; profit/working capital productivity, EPWS; total earning/working capital productivity, ETWS; and contribution margin/working capital productivity, EMWS; prior and subsequent to optimisation of a system's total earning. The table also gives the value of variables in the final basis. Clearly, to achieve the maximum "total earnings" subject to the restrictions outlined in Equation 11.2, this company should produce the following quantities of of products 1, 2 and 3:

X_1 = 110 ;

X_2 = 105 ; and

X_3 = 90 .

Comparing these values with present levels of production, which are:

X_1 = 110 ;

X_2 = 70 ;

X_3 = 90 ,

reveals that an increase of 67 per cent in quantity of product 2 and no change in quantities of products 1 and 3

would lead to optimisation of a system's operations.

As mentioned in Section 11.4.1, a system's total productivity, ETS, is a function of total system productivity, EFS; and total systems product productivity characteristic, EDS. However, the product productivity characteristic, EDS, for a given mix of products is essentially constant (Section 11.9). Hence, an increase in quantity of products with high total earning productivity indexes would lead to a higher utilisation of the maximum feasible capacity of the system's conversion facilities.

From the results presented in 11.11, it is clear that optimisation of a system's operation can be realised by a 67 per cent increase in quantity of product 2, which has the highest total earning productivity, ETS = 1.9495 (from Table 11.10). Furthermore, the "total earning" increases from 2,085 to 2,406, an increase of 15.4 per cent; the total non-producing idle facilities cost reduces from 550.2 to 385.2, a reduction of 30 per cent, and operating profit increases from 262.4 to 583.4, an increase of 122 per cent. These results, in fact, support the hypothesis put forward above.

In formulating the restriction presented ~~in Equation~~ 11.2, we assumed that a market exists for increased volume of output of any of the products. This restriction could easily be removed by placing an upper and lower limit on quantities of products, X_j, to be produced. The lower limit compares with the minimum quantity of products, X_j, to be produced, and the upper limit represents the maximum magnitude of product, X_j, which market can absorb.

The lower limit represents the existing commitments of the organisation to supply its customers, while the upper limit represents the state of the market and the company's present market share and the opportunities for capturing a higher percentage share.

11.12.2 System optimisation based on the reduction of product variety

One of the major areas of management decision-making connected with optimal operation of industrial systems is concerned with control of the product assortment or variety upon which any attempt to optimise the system's output, in terms of total earnings or operating profit, is dependent. It is pertinent, therefore, to investigate whether a better optimal basis of operation of the system could be developed if some products were to be discontinued and optimal operation were to be generated from compensative increases in the output of the remaining products.

Assuming that a market exists for increased output in any of the three products, and the company is not bound by existing contracts to supply an agreed quantity of a product to its customers; then, the optimisation problem based on the reduction of product variety can be mathematically formulated as follows:

$$\text{Maximise} \quad TE = \sum_{j=1}^{n} C_j X_j \,, \tag{11.3}$$

subject to constraints $J = 1, 2, 3, \ldots, n$

$$\left.\begin{array}{l} \sum_{j=1}^{n} a_{ij} X_j < b_i \\ b_i \text{ and } X_j \geqslant 0 \end{array}\right\} \tag{11.4}$$

Coefficients C_j, a_{ij}, constant b_i and variable X_j were defined in Section 11.12.1.

Table 11.12 shows the quantities of products to be produced for the system's optimum operations. As is evident, products 1 and 3 should be discontinued and the output of product 2 increased from 70 units to 297, an increase of 324 per cent. This table also shows the system's productivity indexes for optimum and present levels of

outputs. By devoting the enterprise's production efforts to manufacture of product 2 with a total earning productivity of 1.9495 and profit productivity of 0.9495, the system's total productivity index, ETS, increases from 1.144 to 1.4971; and its profit productivity index, EPS, from 0.144 to 0.4971. This result confirms the statement made in Section 11.4.1 that maximisation of the system's total earning can be achieved by producing an optimal quantity of products having high total earnings productivities.

As a direct result of reductions in output varieties, the total earning increases from 2,085 to 2,728, an increase of 31 per cent. The product facilities occupancy costs changes from 1,272.3 to 1,397.1, the total non-producing (idle) facilities cost reduces from 550.2 to 425.4 and the system's operating profit increases from 262.4 to 905.5, an increase of 245 per cent.

It is interesting to contrast the present case with the one presented in Section 11.12.1. In that example, we attempted to optimise the enterprise's "total earning" by taking up some of the spare capacity. This leads to an increase of 122 per cent in the system's operating profit and a reduction of 30 per cent in total non-producing (idle) facilities cost. While reducing the system's product, variety leads to a much higher increase in profit (245 per cent) but a lower decrease in idle facilities cost (22 per cent). This shows that optimisation of the system's operations is a trade-off between maximisation of facilities productivity, E_{fs}, and product productivity characteristics, E_{ds}. Hence, maximisation of system's capacity utilisation would not in itself lead to optimisation of enterprise's operation.

11.13 Discussion

The application of productivity costing techniques was demonstrated using the data collected from company A. Based on the figures presented in Table 11.6, the relationships between all of the products in terms of sales

revenue, total earnings, processing cost and profits are shown in Figures 11.7, 11.8, 11.9 and 11.10, respectively. It should be noted that the distribution patterns shown in these figures are consistent in form. It is evident in all of them that a major part of the total sales revenue, total earnings, product cost or product profit, as the case may be, is generated from a minority of the products made and sold. The significance of these distribution patterns is not their consistency within this case. Their real significance is that they are all representative of the distribution patterns for the same phenomena found in every industrial-commercial system, no matter what the type of product made and sold. It is of vital importance, therefore, particularly from a management decision-making point of view concerning product emphasis or de-emphasis that the total processing cost per product, which is a major factor in determining a product's total earnings productivity or its profit productivity, be as realistic and stable as practicable. The costing rates developed using the productivity costing technique meet these requirements, since the product processing costs are based only on the periods during which products normally occupy their processing facilities during manufacture, and do not include any absorption of idle capacity cost. They are stable costs which do not tend to vary at different levels of total system output. To this extent, therefore, they are a stable basis for management decision-making.

The development of productivity costing indexes brings various aspects of the operation of an enterprise under scrutiny. The processing facilities productivity, E_f, provides the basis for standardisation and rationalisation of facilities design, while the product productivity characteristic, E_d, brings into focus the importance of the product and process design function, as discussed previously. The productivity costing rates could also provide the base for the development of standard costs.

Accepting that the primary objective of any industrial-commercial enterprise is to optimise its "total earnings". The productivity costing method provides the management with a rational tool for achieving this aim. The system optimisation could be achieved, either:

(a) By increasing the output of products with the highest total earnings productivity, E_t, or profit productivity, E_p, subject to the market and capacity constraints, e.g., in the foregoing case the firm's total earnings could be greatly improved by producing more of product 47 (E_t = 2.06 and E_p = 1.06); and

(b) By the reduction of product variety, e.g., products 133, JP14 and 850 have very low total earnings productivity and at first glance should be discontinued subject to various other considerations.

The system's optimisation, using the program devised by the author, and its effects on various productivity indexes, costs and profits were demonstrated and discussed in Section 11.12. The productivity costing method also provides useful management guidelines in determining the appropriate sales price for a product. As, ideally, the cumulative effect of the product pricing policy of an industrial-commercial enterprise should be the maximisation of the total earnings generated by the system during any given period. This, in turn, would of course, ensure maximisation of the system operating profit.

11.14 Conclusions

The productivity costing concept and its application to a batch manufacturing enterprise was discussed in previous sections. The technique emphasises the contribution to the productivity of a firm of individual products rather than the operating units or functional activities.

Productivity costing may be considered to be a conversion capacity-absorption costing method which differs from most conventional methods mainly in the logic of its basis of apportionment of system-operating expenses to the identified potentially-productive product-processing facilities. Because these apportionments are converted into product-processing cost rates based on the individually appraised maximum feasible utilisation of each potentially-productive facility, the resultant product costs and their dependent product profits can be considered to have stable and near-optional values.

The operating expenses of the system are apportioned to the productive facilities according to the present-day purchase value of equipments. The logic behind this method of apportionment is that the present-day purchase value provides an accurate indication of equipments productive potential. This inference appears to be only partially acceptable in the absence of more direct measures of productive potential of a productive facility. However, cases may exist in which the present-day purchase price is far from representing the productive potential of an equipment. As examples, consider the following two cases: (a) an equipment which is a key to productive efforts of an enterprise; and (b) where management of an enterprise has invested wrongly in an equipment.

The total earnings output concept, an inherent feature of productivity costing, is a marginal costing concept which differs from the normal practices of marginal (or direct) costing, mainly to the extent that direct labour costs are not accepted as avoidable costs, when products are not made, unless proved to be so. Consequently, productivity costing can, in a real sense, be considered a synthesis of both the absorption and marginal (or direct) costing methods. Its major value compared to the other two costing methods is the considerable number of decision-making bases concerned with industrial-commercial systems management it provides.

Considering the technique from a practical applications point of view, the data necessary for analysis were readily available from the company's accounting data. However, the data had to be manipulated in order to bring it into the desired format. In addition, some minor modifications were necessary, especially in the development of costing rates compared to the original technique formulated by Martin. It is the author's point of view that the productivity costing method would be extremely difficult to apply to smaller concerns, particularly those which do not possess a work measurement department and "jobbing shops" or manufacturers indulging in the production of small batches. The reason for this is the lack of dependable data concerning the productive work hours and product occupancy period, in such concerns. The determination of maximum feasible occupancy hours may also prove to be difficult in many enterprises.

The productivity costing technique highlights the factors bearing upon the costing of manufactured goods. The significance of the utilisation of productive capacity, and the impact of idle time on the effective cost of the product, are clarified and emphasised in this method of costing. The method provides the means for measuring industrial and commercial productivity in terms of how well a manager, at line (e.g., production) or higher supervisory level, measures up to his ultimate objective of generating, from the facilities at his disposal, the maximum practical or optimal output. It also enables the analyst to determine the contribution of individual products to productivity of the system, i.e., disaggregating systems productivity into its constituents.

As indicated by its designation as "productivity costing" the focus is entirely on cost (and revenue), ignoring underlying physical resource flows and input factor prices. Consequently, this approach reflects a conception less-closely associated with the physical connotation of "productivity" than with the prevailing business concepts of profit margins by product lines, and

and of allocation to specified cost categories. The technique does not provide a sound basis for comparing the effectiveness of an enterprise from period to period.

Table 11.1 Development of Productive Facilities Costing Rates for Productivity Costing

Industrial System Data

Item No.	Item Description	A Automative Shop			B General Shop				C Heat Treatment			Grinding			D			Shop	E Mould	F Press	Shop	G Assembly	TOTALS
1	Manufacturing Departments																						
2	Productive Facility No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	
3	Type of Productive Facility	Hi Cons	B&W	Work	Drilling Mach	Deep	Slotting Mach	Wrenches	Tool Head	Carlo	Wellen	Cincinnati	Churchill	Homoco	Heald	Cincinnati	Honing	Finishing	Moulding	Blanking	Ass Press	Mag Table	
4	Nominal Working Hours Per Day	24	96	480	40	8	24	8	24	72	24	112	32	128	192	176	32	16	32	32	56	420	
5	Maximum Feasible Occupancy or Work Hours	15.6	62.4	307.2	26	5.2	15.6	5.2	21.6	64.8	21.6	67.2	19.2	111.4	155.5	140.8	26.6	13.3	28.8	28.8	50.4	378	
6	Production Equipment, Present Day Purchase Values	180,000	90,000	2,345,000	11,000	1,000	5,000	1,000	85,000	90,000	115,000	576,000	160,000	560,000	1,200,000	785,000	150,000	15,000	80,000	100,000	100,000	130,000	6748000
7	Percentage of Total Equipment Values																						
	7a By Department	6.394	3.197	90.41	40.74	3.704	18.52	37.04	29.31	31.03	39.66	17.01	29.53	16.54	35.44	23.18	4.430	0.443	100	50	50	100	
	7b For Whole System	2.667	1.334	37.71	0.163	0.0148	0.0741	0.148	1.26	1.334	1.704	8.536	1.482	8.229	17.78	11.63	2.223	0.222	1.186	0.148	0.148	1.926	
8	Operating Expenses Apportioned to Productive Facilities Excluding Operating (Direct Labour)																						
	8a Departmental Expenses	32.99	16.5	466.5	38.7	3.52	17.59	35.19	84.41	89.38	114.2	158.1	27.45	153.7	329.5	215.5	41.18	4.12	0	49.50	49.50	865.7	2793.3
	8b General System Expenses	163.6	81.82	2314.0	10.0	0.909	4.546	9.091	7.727	81.82	104.5	523.6	90.91	509.1	1091.0	713.7	136.4	13.64	72.73	9.091	9.091	118.2	6134.7
	8c Totals	196.6	98.32	2780.5	48.7	4.428	22.14	44.28	161.7	171.2	218.8	681.8	118.4	662.8	1420.5	929.2	177.5	17.75	72.73	58.59	58.59	983.9	8928.0
9	Productive Equipment Costing Rates Per Hour (line 8c/line 5)	12.60	1.576	9.050	1.873	0.8515	1.419	8.515	7.486	2.642	10.13	10.15	6.165	5.950	9.134	6.599	6.675	1.335	2.525	2.034	1.163	2.603	
10	Direct Labour Cost																						
	10a Per Day	411.3			166.9				229.0			319.6							0	125.07		697.1	2009.0
	10b Per Working Hour	1.080	1.080	1.080	3.210	3.210	3.210	3.210	2.120	2.120	2.120	0.711	0.711	0.711	0.711	0.711	0.711	0.711	0	1.580	1.580	1.850	
11	Product Costing Rate Per Processing Hour (line 9 + line 10b)	13.68	2.656	10.13	5.083	4.061	4.629	11.72	9.606	4.762	12.25	10.86	6.876	6.661	9.845	7.310	7.386	2.046	2.525	3.614	2.743	4.453	142.9

Table 11.2 Productivity Costing Development of Product Processing Costs and Facilities Productivity (Sheet 1 of 4)

Item No.	Item Description	A Automatic	B Shop	C General	D Shop	E Heat Treatment						F Grinding		G Shop		H Mould	I Press	J Shop	K Assembly	TOTALS
1	Manufacturing Departments																			
2	Productive Facility No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	
							PRODUCT			PS104	Average		Production		Per	Day							
12	Productive Work Hours	4.307	0	10.77	0	0	0.8967	0	1.715	0	0.7183	0.583	0.4717	0	7.355	6.312	0	0.8083	0.2017	0.0391	2.092	17.48	53.80
13	Facility Occupancy Hours	4.913	0	11.49	0	0	1.248	0	1.885	0	0.7633	0.740	0.5617	0	7.560	6.663	0	0.9867	0.2217	0.0483	2.355	23.08	62.51
14	Facility Productivity 12/13	0.8765	0	0.9375	0	0	0.7183	0	0.9533	0	0.9410	0.7885	0.8398	0	0.9701	0.9562	0	0.8173	0.9048	0.6506	0.8869	0.7576	0.8607
15	Facility Occupancy Cost 13x11	67.24	0	116.4	0	0	5.779	0	18.11	0	9.349	8.034	3.862	0	74.43	48.71	0	2.019	0.5598	0.1620	6.457	102.8	463.9
	(for line 11 see Table 1)						PRODUCT			PS348	Average		Production		Per	Day							
16	Productive Work Hours	2.897	0	4.827	0	0	0.6033	0	0	4.343	1.917	0.9217	0.3167	0	4.932	4.283	3.017	0.5433	0.1367	0.0167	1.373	11.73	42.36
17	Facility Occupancy Hours	3.303	0	5.295	0	0	0.3283	0	0	6.613	1.992	0.9183	0.3767	0	5.083	4.480	3.183	0.6633	0.1500	0.0367	1.583	16.35	51.03
18	Facility Productivity 16/17	0.8769	0	0.9116	0	0	0.7384	0	0	0.6548	0.9623	0.8462	0.8407	0	0.9702	0.9561	0.9476	0.8191	0.9111	0.6511	0.8674	0.7509	0.8300
19	Facility Occupancy Cost 17x11	45.21	0	53.64	0	0	3.834	0	0	31.49	14.39	5.410	2.590	0	50.05	32.75	23.51	1.357	0.3788	0.1090	4.341	75.49	354.6
							PRODUCT			PS 14	Average		Production		Per	Day							
20	Productive Work Hours	1.552	0	5.545	0	0	0.3133	0	0	0	1.027	0.4767	0	0	2.643	2.295	0	0.2917	0.0733	0.0105	0.715	6.297	21.27
21	Facility Occupancy Hours	1.770	0	5.868	0	0	0.4533	0	0	0	1.067	0.550	0	0	2.725	2.402	0	0.3550	0.0800	0.0167	0.850	8.318	24.45
22	Facility Productivity 20/21	0.8766	0	0.9449	0	0	0.7132	0	0	0	0.9625	0.8667	0	0	0.9700	0.9556	0	0.8216	0.9167	0.6475	0.8647	0.7576	0.8697
23	Facility Occupancy Cost 21x11	24.22	0	59.45	0	0	2.099	0	0	0	13.06	5.971	0	0	26.83	17.56	0	0.7263	0.2026	0.0584	2.331	37.04	189.5
							PRODUCT			PS705	Average		Production		Per	Day							
24	Productive Work Hours	0	3.073	3.688	0	0.4150	0.3067	0	0.6150	0	0.2461	0.4533	0	0	2.513	2.182	1.537	0.2767	0.0667	0.010	0.700	5.985	22.06
25	Facility Occupancy Hours	0	3.288	3.933	0	0.4833	0.4283	0	0.6450	0	0.2617	0.5233	0	0	2.590	2.282	1.622	0.3383	0.0683	0.0153	0.803	7.907	25.19
26	Facility Productivity 24/25	0	0.9346	0.9377	0	0.8586	0.7160	0	0.9535	0	0.9427	0.8667	0	0	0.9704	0.9562	0.9476	0.8177	0.9824	0.6522	0.8678	0.7576	0.8758
27	Facility Occupancy Cost 25x11	0	8.733	39.85	0	1.963	1.983	0	6.176	0	3.205	5.682	0	0	25.50	16.68	11.98	0.6922	0.1726	0.0594	2.212	35.11	160.1
							PRODUCT			PS120	Average		Production		Per	Day							
28	Productive Work Hours	0	2.380	1.903	0	0.3217	0.2383	0	0	1.713	0.7550	0.1550	0.1250	0	1.945	1.630	1.190	0.2150	0.0533	0.0076	0.547	4.635	17.87
29	Facility Occupancy Hours	0	2.547	2.088	0	0.3756	0.3317	0	0	2.613	0.7850	0.1967	0.1483	0	2.005	1.767	1.255	0.2417	0.0583	0.0183	0.625	6.123	21.19
30	Facility Productivity 28/29	0	0.9346	0.9114	0	0.8578	0.7186	0	0	0.6550	0.9618	0.7881	0.8427	0	0.9701	0.9561	0.9482	0.8237	0.9143	0.6479	0.8667	0.7567	0.8432
31	Facility Occupancy Cost 29x11	0	6.763	21.46	0	1.523	1.535	0	0	12.44	9.614	2.135	1.020	0	19.34	12.91	9.269	0.5356	0.1473	0.0427	1.714	27.27	127.8
							PRODUCT			PS849	Average		Production		Per	Day							
32	Productive Work Hours	2.253	0	5.632	0	0	0.470	0	0.9383	0	0.3750	0.3050	0.2467	0	3.837	3.332	0	0.4233	0.0950	0.0153	1.068	9.140	28.14
33	Facility Occupancy Hours	2.570	0	6.008	0	0	0.6567	0	0.9850	0	0.4000	0.3867	0.2933	0	3.955	3.485	0	0.5167	0.1167	0.0233	1.232	12.07	32.70
34	Facility Productivity 32/33	0.8768	0	0.9373	0	0	0.7157	0	0.9524	0	0.9375	0.7888	0.8407	0	0.9701	0.9560	0	0.8161	0.9000	0.6515	0.8674	0.7576	0.8605
35	Facility Occupancy Cost 33x11	35.17	0	60.87	0	0	3.040	0	9.461	0	4.899	4.198	2.017	0	38.94	25.48	0	1.057	0.2946	0.0849	3.378	53.76	242.6

Table 11.2 Productivity Costing Development of Product Processing Costs and Facilities Productivity (Sheet 2 of 4)

Item No.	Item Description	A Automotive Shop		B General Shop					C Heat Treatment					D Grinding				E Mould Shop	F Press Shop	G Assembly	TOTAL
1	Manufacturing Departments																				
2	Productive Facility No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	
							PRODUCT			FPS811	Average		Production		Per	Day							
36	Productive Work Hours	0	0	7.987	0	3.5400	0.4000	0	0.7183	0	0.3200	0.2600	0.2100	0.5100	3.265	2.835	0	0.3600	0.0900	0.0130	0.1083	7.777	26.27
37	Facility Occupancy Hours	0	0	8.755	0	0.6283	0.5583	0	0.8383	0	0.3400	0.3300	0.2500	0.8283	3.365	2.965	0	0.4400	0.0783	0.2000	1.048	10.27	30.74
38	Facility Productivity 36/37	0	0	0.9122	0	0.8574	0.7164	0	0.9523	0	0.9412	0.7879	0.8400	0.6157	0.9703	0.9562	0	0.8182	0.9153	0.6500	0.8663	0.7576	0.8547
39	Facility Occupancy Cost 37x11	0	0	88.69	0	2.552	2.585	0	8.053	0	4.164	3.583	1.719	5.518	33.13	21.67	0	0.9002	0.2483	0.0722	2.875	45.75	221.5
	(for line 11 see Table 1)						PRODUCT			FPS730	Average		Production		Per	Day							
40	Productive Work Hours	0	0	10.13	0	0.6833	0.5067	0	1.013	0	0.4050	0.3300	0.2667	0.6333	4.142	3.597	2.533	0.4567	0.1133	0.0165	1.153	9.867	35.85
41	Facility Occupancy Hours	0	0	11.11	0	0.7983	0.7017	0	1.063	0	0.4300	0.4183	0.3167	1.052	4.268	3.762	2.673	0.5583	0.1250	0.0253	1.330	13.03	41.66
42	Facility Productivity 40/41	0	0	0.9122	0	0.8559	0.7221	0	0.9530	0	0.9419	0.7888	0.8421	0.6021	0.9703	0.9561	0.9476	0.8179	0.9067	0.6513	0.8671	0.7576	0.8605
43	Facility Occupancy Cost 41x11	0	0	112.5	0	3.242	3.248	0	10.21	0	5.266	4.542	2.177	7.005	42.02	27.50	19.74	1.142	0.3157	0.0415	3.648	58.01	300.7
							PRODUCT			FPS623	Average		Production		Per	Day							
44	Productive Work Hours	0	0	0.3333	0.1133	0.0233	0.0167	0	0.0333	0	0.0133	0.0250	0	0.0217	0.1367	0.1183	0	0.0150	0.0030	0.00055	0.0033	0.3250	1.218
45	Facility Occupancy Hours	0	0	0.3700	0.1283	0.0267	0.0227	0	0.0350	0	0.0142	0.0283	0	0.0035	0.1400	0.1233	0	0.0183	0.0042	0.0083	0.0041	0.4283	1.419
46	Facility Productivity 44/45	0	0	0.9009	0.8831	0.8750	0.7353	0	0.9524	0	0.9412	0.8834	0	0.6190	0.9762	0.9595	0	0.8182	0.8800	0.6600	0.8890	0.7583	0.3583
47	Facility Occupancy Cost 45x11	0	0	3.748	0.6533	0.1083	0.1049	0	0.3362	0	0.1735	0.3076	0	0.2331	1.378	0.9016	0	0.0375	0.0105	0.0030	0.1188	1.907	10.02
							PRODUCT			FPS 1	Average		Production		Per	Day							
48	Productive Work Hours	0	0	2.720	0	0.1833	0.1367	0	0.2717	0	0.1083	0.0883	0.0717	0.1700	1.112	0.9650	0	0.1217	0.0317	0.0045	0.3100	2.648	8.742
49	Facility Occupancy Hours	0	0	3.020	0	0.2150	0.1882	0	0.2850	0	0.1150	0.1117	0.0950	0.2783	1.147	1.010	0	0.1500	0.0337	0.0068	0.3560	3.448	10.51
50	Facility Productivity 48/49	0	0	0.9007	0	0.8517	0.7263	0	0.9532	0	0.9420	0.7910	0.7544	0.6108	0.9695	0.9554	0	0.8111	0.9107	0.6583	0.8691	0.7576	0.8508
51	Facility Occupancy Cost 49x11	0	0	30.59	0	0.8732	0.8710	0	1.738	0	1.408	1.212	0.6532	1.854	11.19	7.383	0	0.3069	0.0850	0.0241	0.9782	15.58	75.85
							PRODUCT			FPS 56	Average		Production		Per	Day							
52	Productive Work Hours	0	1.845	3.430	0	0	0.2000	0	0	1.440	0.7900	0.2550	0	0	2.160	1.420	0	0.1300	0.020	0.0075	0.4550	3.845	16.07
53	Facility Occupancy Hours	0	1.975	3.770	0	0	0.2800	0	0	2.178	0.7900	0.2950	0	0	2.245	1.485	0	0.2200	0.025	0.0115	0.5450	5.145	18.76
54	Facility Productivity 52/53	0	0.9342	0.9098	0	0	0.7143	0	0	0.6550	0.9875	0.8644	0	0	0.9621	0.9562	0	0.8182	0.9000	0.6522	0.8667	0.7576	0.8483
55	Facility Occupancy Cost 53x11	0	5.245	38.19	0	0	1.246	0	0	10.47	9.476	3.203	0	0	22.10	10.86	0	0.4501	0.0631	0.0416	1.440	22.91	125.9
							PRODUCT			FPS654	Average		Production		Per	Day							
56	Productive Work Hours	0	0.7017	1.303	0	0	0.0767	0	0	0.5467	0.2967	0.0967	0	0	0.8200	0.5400	0.3800	0.0683	0.0017	0.0028	0.0175	1.490	6.338
57	Facility Occupancy Hours	0	0.7500	1.433	0	0	0.1083	0	0	0.8533	0.3000	0.1117	0	0	0.8533	0.5650	0.4017	0.0833	0.0013	0.0043	0.2000	1.955	7.629
58	Facility Productivity 56/57	0	0.9356	0.9093	0	0	0.7071	0	0	0.6400	0.9887	0.8651	0	0	0.9607	0.9558	0.9461	0.8200	0.8214	0.6538	0.8667	0.7576	0.8308
59	Facility Occupancy Cost 57x11	0	1.992	14.52	0	0	0.5015	0	0	4.064	3.674	1.212	0	0	8.401	4.130	2.967	0.1705	0.0232	0.0157	0.5483	8.705	50.93

Table 11.2 Productivity Costing Development of Products Processing Costs and Facilities Productivity (Sheet 3 of 4)

Item No.	Item Description																					
1	Manufacturing Departments	Automatic	Automatic	Shop	General		Shop		Heat	Treatment			Grinding			Shop		Mould	Press	Shop	Assembly	TOTALS
2	Productive Facility No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	
							PRODUCT			FPS850	Average		Production		Per	Day						
60	Productive Work Hours	0	0	15.37	0	0.7417	0.5300	0.8883	1.033	0	0.7950	0.8483	0	8.348	4.333	3.763	2.650	0.9267	0.1850	0.0200	1.418	11.81	53.66
61	Facility Occupancy Hours	0	0	17.41	0	0.8617	0.7367	1.167	1.087	0	0.8217	0.9667	0	9.077	4.465	3.935	2.797	1.047	0.1883	0.0300	1.630	15.42	61.35
62	Facility Productivity 60/61	0	0	0.8828	0	0.8607	0.7195	0.7614	0.9507	0	0.9675	0.8776	0	0.9198	0.9705	0.9569	0.9476	0.8854	0.9328	0.6667	0.8701	0.7810	0.8747
63	Facility Occupancy Cost 61x11	0	0	176.4	0	3.500	3.410	13.68	10.44	0	10.06	10.49	0	60.46	43.96	28.77	20.66	2.141	0.5007	0.1084	11.410	67.32	456.3
	(for line 11 see Table 1)						PRODUCT			FPS 47	Average		Production		Per	Day						
64	Productive Work Hours	0	0	3.017	0	0.1400	0.1033	0.1750	0.2033	0	0.1567	0.1667	0	1.638	0.8500	0.7383	0.5200	0.1817	0.0367	0.0038	0.2783	2.317	10.53
65	Facility Occupancy Hours	0	0	3.417	0	0.1633	0.1433	0.2283	0.2133	0	0.1617	0.1900	0	1.782	0.8767	0.7717	0.5483	0.2050	0.0400	0.0060	0.3200	2.967	12.03
66	Facility Productivity 64/65	0	0	0.8829	0	0.8571	0.7209	0.7669	0.9531	0	0.9691	0.8772	0	0.9196	0.9696	0.9568	0.9483	0.8862	0.9167	0.6337	0.8698	0.7807	0.8747
67	Facility Occupancy Cost 65x11	0	0	34.61	0	0.6634	0.6635	2.677	2.049	0	1.980	2.063	0	11.87	8.631	5.641	4.050	0.4194	0.1010	0.0217	0.8776	13.21	81.53
							PRODUCT			FPS779	Average		Production		Per	Day						
68	Productive Work Hours	0	0	0.1550	0	0.0717	0.0533	0.0970	0.0103	0	0.0080	0.0833	0	0.0833	0.0433	0.0383	0.0267	0.0013	0.0018	0.0020	0.0143	0.1183	0.5330
69	Facility Occupancy Hours	0	0	0.1750	0	0.0833	0.0750	0.1167	0.0100	0	0.0833	0.0967	0	0.0916	0.0450	0.0400	0.0283	0.0050	0.0020	0.0030	0.0163	0.1517	0.6173
70	Facility Productivity 68/69	0	0	0.8857	0	0.8600	0.7111	0.7714	0.9374	0	0.9600	0.8713	0	0.9091	0.9630	0.9583	0.9412	0.8889	0.9167	0.6667	0.8776	0.7803	0.8732
71	Facility Occupancy Cost 69x11	0	0	1.773	0	0.0338	0.0347	0.1368	0.1057	0	0.1021	0.1049	0	0.6106	0.4436	0.2924	0.2093	0.0215	0.0050	0.0010	0.0449	0.6750	4.594
							PRODUCT			FPS 825	Average		Production		Per	Day						
72	Productive Work Hours	0	0	0.8700	0	0.0417	0.0300	0.0500	0.0583	0	0.0450	0.0483	0	0.4733	0.2450	0.2133	0.1500	0.0533	0.0105	0.0013	0.0800	0.6623	3.038
73	Facility Occupancy Hours	0	0	0.9850	0	0.0483	0.0417	0.0667	0.0617	0	0.0467	0.0550	0	0.5133	0.2533	0.2333	0.1583	0.0600	0.0113	0.0012	0.0917	0.8567	3.475
74	Facility Productivity 72/73	0	0	0.8832	0	0.8621	0.7200	0.7500	0.9459	0	0.9643	0.8788	0	0.9221	0.9671	0.9552	0.9474	0.8889	0.9165	0.6538	0.8727	0.7802	0.8744
75	Facility Occupancy Cost 73x11	0	0	1.978	0	0.1963	0.1727	0.7816	0.5923	0	0.5716	0.5971	0	3.419	2.494	1.633	1.167	0.1228	0.0286	0.0063	0.2514	3.815	15.85
							PRODUCT			FPS 621	Average		Production		Per	Day						
76	Productive Work Hours	0	0	1.160	0	0.0533	0.0400	0.0667	0.0783	0	0.0600	0.0633	0	0.6300	0.3267	0.2833	0.2000	0.0700	0.0140	0.0015	0.1067	0.8817	4.045
77	Facility Occupancy Hours	0	0	1.313	0	0.0633	0.0567	0.0883	0.0817	0	0.0617	0.0733	0	0.6850	0.3367	0.2967	0.2117	0.0783	0.0150	0.0023	0.1333	1.142	4.619
78	Facility Productivity 76/77	0	0	0.8832	0	0.8421	0.7059	0.7547	0.9582	0	0.9730	0.8631	0	0.9197	0.9703	0.9551	0.9449	0.8931	0.9333	0.6429	0.8649	0.7810	0.8739
79	Facility Occupancy Cost 77x11	0	0	13.30	0	0.2517	0.2623	1.036	0.7845	0	0.7553	0.7762	0	4.563	3.315	2.167	1.563	0.1603	0.0378	0.0084	0.3382	5.084	34.43
							PRODUCT			FPS 138	Average		Production		Per	Day						
80	Productive Work Hours	0	0	1.215	0	0.0600	0.0450	0.0750	0.0867	0	0.0667	0.0717	0	0.7033	0.3650	0.3167	0.2233	0.0783	0.0157	0.0016	0.1200	0.9750	4.511
81	Facility Occupancy Hours	0	0	1.468	0	0.0700	0.0650	0.0983	0.0917	0	0.0700	0.0817	0	0.7650	0.3767	0.3317	0.2350	0.0883	0.0167	0.0025	0.1367	1.275	5.172
82	Facility Productivity 80/81	0	0	0.8320	0	0.8571	0.6923	0.7627	0.9455	0	0.9514	0.8776	0	0.9194	0.9690	0.9545	0.9504	0.8868	0.9400	0.6667	0.8784	0.7804	0.8737
83	Facility Occupancy Cost 81x11	0	0	14.87	0	0.2843	0.3007	1.153	0.8865	0	0.8513	0.9866	0	5.096	3.708	2.415	1.736	0.1807	0.0421	0.0070	0.3741	5.677	38.41

TABLE 11.2: PRODUCTIVITY COSTING DEVELOPMENT OF PRODUCT PROCESSING COSTS AND FACILITIES PRODUCTIVITY (sheet 4 of 4)

Item No.	Item Description																					TOTALS
1	Manufacturing Departments	Automative Shop			General		Shop		Heat Treatment				Grinding			Shop		Mould	Press Shop	Assembly		
2	Productive Facility No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	
							PRODUCT		FPS133		Average		Production		Per	Day						
84	Productive Work Hours	1.335	0	4.330	0	0.4050	0.2883	0	0.5767	0	0.5050	0.4767	0	0	2.887	2.050	1.443	0	0.0650	0.0093	0.6567	8.688	23.77
85	Facility Occupancy Hours	1.580	0	4.605	0	0.4683	0.3967	0	0.5917	0	0.5200	0.5417	0	0	2.958	2.143	1.523	0	0.0711	0.0145	0.8883	14.53	26.83
86	Facility Productivity 84/85	0.8766	0	0.9403	0	0.8643	0.7269	0	0.9746	0	0.9712	0.8800	0	0	0.9758	0.9565	0.9475	0	0.9070	0.6431	0.7372	0.3251	0.8857
87	Facility Occupancy Cost 85x11	21.62	0	46.65	0	1.902	1.836	0	5.683	0	6.369	5.881	0	0	29.13	15.67	11.25	0	0.1810	0.0524	2.436	46.31	195.5
	(for line 11 see Table 1)						PRODUCT		JP14		Average		Production		Per	Day							
88	Productive Work Hours	0	0	12.13	0	0	0.2483	0	0.9050	0	0.5833	0.9550	0.1433	0	3.317	2.585	0	0	0	0	0	8.097	28.97
89	Facility Occupancy Hours	0	0	13.37	0	0	0.3500	0	0.9550	0	0.6083	1.017	0.1867	0	3.410	2.678	0	0	0	0	0	7.647	32.22
90	Facility Productivity 88/89	0	0	0.9077	0	0	0.7095	0	0.9416	0	0.9583	0.9393	0.7679	0	0.9724	0.9652	0	0	0	0	0	0.8313	0.8991
91	Facility Occupancy Cost 89x11	0	0	135.4	0	0	1.620	0	9.173	0	7.451	11.04	1.283	0	33.57	19.58	0	0	0	0	0	42.36	262.1
							PRODUCTS				TOTALS												
92	Productive Work Hours	12.39	8.000	96.60	0.1133	3.616	5.465	1.264	8.417	8.043	7.181	6.088	1.852	13.21	47.21	39.62	13.87	5.018	1.226	0.1749	12.02	115.8	409.3
93	Facility Occupancy Hours	14.14	8.560	105.9	0.1283	4.210	7.603	1.660	8.829	12.28	9.556	7.125	2.228	15.11	48.66	41.41	14.64	6.081	1.345	0.2680	14.16	150.5	474.3
94	Facility Productivity 92/93	0.8767	0.9346	0.9124	0.8831	0.8588	0.7188	0.7614	0.9533	0.6551	0.9608	0.8540	0.8310	0.8746	0.9702	0.9567	0.9476	0.8351	0.9109	0.6529	0.8481	0.7698	0.8628
95	Facility Occupancy Cost 93x11	193.5	22.73	1073.0	0.6523	17.10	35.20	19.46	84.81	58.47	117.0	77.35	15.32	100.6	477.1	302.7	108.1	12.44	3.398	0.9688	38.84	670.1	3430.0

TABLE 11.3: PRODUCTIVITY COSTING - PRODUCT PROCESSING FACILITIES AND LABOUR SUMMARY

System Utilisation Summary

Item No.	Item Description																					
1	Manufacturing Departments	Automatic	A Shop		General		B Shop		Heat	C Treatment			Grinding		D Shop			E Mould	F Press	Shop	G Assembly	TOTALS
2	Productive Facility No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	
92	Productive Work Hours	12.39	8.0	96.60	0.1133	3.616	5.465	1.264	8.417	8.043	9.181	6.088	1.852	13.21	47.21	39.62	13.87	5.078	1.226	0.1749	12.02	115.8	409.3
93	Total Productive Facility Occupancy Hours	14.14	8.560	105.9	0.1283	4.210	7.603	1.660	8.829	12.28	9.556	7.125	2.228	15.11	48.66	41.41	14.64	6.081	1.345	0.2680	14.16	150.5	474.3
94	Total Productive Facilities Productivity	0.8767	0.9346	0.9124	0.8831	0.8588	0.7188	0.7614	0.9533	0.6551	0.9608	0.8546	0.8310	0.8746	0.9702	0.9567	0.9476	0.8351	0.9109	0.6525	0.8486	0.7698	0.8628
95	Total Productive Facility Occupancy Costs	193.5	22.73	1073.0	0.6523	17.10	35.20	19.46	84.81	58.47	117.0	77.35	15.32	100.6	479.1	302.7	108.1	12.44	3.398	0.9688	38.84	670.1	3430.0
											Idle	Facilities											
96	Facility (unoccupied) Idle Hours (5 - 93)	1.463	53.84	201.3	25.87	0.990	7.997	3.540	12.77	52.52	12.04	60.08	16.97	96.29	106.8	99.39	11.96	7.219	27.45	28.53	36.24	227.5	1091.0
97	Idle Facility Cost (96 x 9)	18.45	84.83	1822.0	48.46	0.8430	11.35	30.14	95.60	138.8	122.0	609.5	104.6	573.0	975.9	655.9	79.85	9.638	67.33	58.05	42.13	512.2	6413.0
											Facilities			Summary									
8c	Total Facilities Costs	196.6	98.32	2780.0	48.70	4.428	22.14	44.28	161.7	171.2	218.8	681.8	118.4	662.8	1420.0	929.2	177.5	17.75	72.73	58.59	58.59	983.9	8928.0
98	Facilities Utilisation ($\frac{8c - 97}{8c}$)	0.9062	0.1372	0.3447	0.0049	0.8096	0.4874	0.3192	0.4088	0.1895	0.4424	0.1060	0.1161	0.1356	0.3129	0.2941	0.5563	0.4572	0.0461	0.0093	0.2810	0.3781	0.3120
3	Maximum Feasible Occupancy Hours	15.60	62.40	307.2	26.0	5.20	15.60	5.20	21.60	64.80	21.60	67.20	19.20	111.4	155.5	140.8	26.60	13.30	28.80	28.80	50.40	378.0	1565.0
99	Total Facilities Productivity (92/3)	0.7944	0.1282	0.3145	0.0043	0.6953	0.3503	0.2431	0.3897	0.1241	0.4251	0.0906	0.0964	0.1186	0.3034	0.2814	0.5214	0.3818	0.0415	0.0060	0.2381	0.3064	0.2615
											Non-Operating			Labour									
100	Operating Labour Hours Not Applied to Product Processing	1.463	53.84	201.3	25.87	0.990	7.997	3.540	12.77	52.52	12.04	60.08	16.97	96.29	106.8	99.39	11.96	7.219	0	28.53	36.24	227.5	1091.0
101	Operating Labour Costs Not Applied to Product Processing (100 x 10b)	1.580	58.15	217.4	83.05	3.178	25.67	11.36	27.07	111.3	25.53	42.71	12.07	68.46	75.96	70.67	8.506	5.133	0	45.08	57.26	420.9	1371.0
											Operating	Labour		Summary									
10a	Total (Operating) Labour Costs		411.3			166.9				229.0					379.6				0		125.7	697.1	2009.0
102	Operating Labour Utilisation ($\frac{10a - 101}{10a}$)	0.3261	0.3261	0.3261	0.2615	0.2615	0.2615	0.2615	0.284	0.284	0.284	0.2531	0.2531	0.2531	0.2531	0.2531	0.2531	0.2531	0	0.1818	0.1818	0.3162	0.3175

TABLE 11.4: PRODUCT COSTS AND PROFITS (OR LOSSES) AS DETERMINED BY CONVENTIONAL (OVERHEAD ABSORPTION) COSTING

Item No.		Products																					
		104	348	14	705	120	849	811	730	623	1	56	654	850	47	779	825	621	138	133	JP14		TOTALS
1	Sales Revenue (S)	161813	142859	77514	61694	46733	87288	82586	105203	4430	29739	40543	14202	157412	45821	1717	9973	15372	15730	57311	90637		1242576
2	Less Avoidable (Product) Costs:																						
	(a) Product Materials (M)	64528	46784	32828	22011	16672	32828	27966	34459	1163	9622	10909	3998	60548	12130	575	3468	4515	5232	25477	42133		457848
	(b) Interest (I)	11850	10462	5677	4518	3422	6393	6048	7705	324	2178	2969	1040	11089	3356	126	730	1126	1152	4197	6638		91000
	(c) Total Avoidable Costs (M + I)	76378	57246	38505	26529	20094	39221	34014	42164	1487	11800	13878	5038	71637	15486	701	4198	5641	6384	29674	48771		548848
3	Less System Operating Expenses:																						
	(a) Operating (Direct) Labour (D)	13422	11054	5695	5208	4213	6967	6883	9763	337	2342	3782	1481	13904	2683	127	753	1025	1158	6892	7148		104837
	(b) Overhead Expenses (O)	57706	50390	25017	24399	20311	29990	32669	47070	1527	11108	18793	7263	67031	12982	612	3636	4964	5600	34033	37003		492104
	(c) Total Operating Expenses (D + O)	71128	61444	30712	29607	24524	36957	39552	56833	1864	13450	22575	8744	80935	15665	739	4389	5989	6758	40925	44151		596941
4	Products Profit (S - M - I - D - O)	14307	24169	8297	5558	2114	11110	9020	6206	1079	4489	4040	420	-1160	14670	277	1386	3742	2588	-1329	-2285		96787
5	Less Unabsorbed Overhead (U)																						451794·6
6	System Operating Profit (S - M - I - D - O - U)																						-355007·6

TABLE 11.5: PRODUCT CONTRIBUTION MARGINS AND SYSTEMS OPERATING PROFIT AS DETERMINED BY DIRECT OR MARGINAL COSTING

Item No.	Description	Products																					TOTALS
		104	348	14	705	120	849	811	730	623	1	56	654	850	47	779	825	621	138	133	JP14		
1	Sales Revenue (S)	161813	142859	77514	61694	46732	87288	82586	105203	4430	29739	40543	14202	151412	45821	1717	9973	15372	15730	57311	90637		1242576
2	Less Avoidable (Product) Costs																						
	(a) Product Materials (M)	64528	46784	32828	22011	16672	32828	27966	34459	1163	9622	10909	3998	60548	12130	575	3468	4515	5232	25479	42133		457848
	(b) Interest (I)	11850	10462	5677	4518	3422	6393	6048	7705	324	2178	2969	1040	11089	3356	126	730	1126	1152	4197	6638		91000
	(c) Direct (Operating) Labour (D)	13422	11054	5695	5208	4213	6967	6883	9763	337	2342	3782	1481	13904	2683	127	753	1025	1158	6892	7148		104837
	(d) Total Avoidable Costs (M + I + D)	89800	68300	44200	31737	24307	46188	40897	51927	1824	14142	17660	6519	85541	18169	828	4951	6666	7542	36568	55919		653687
3	Contribution Margin (S - M - I - D) = CM	72013	74559	33314	29957	22425	41100	41689	53276	2606	15597	22883	7683	65871	27652	889	5022	8706	8138	20743	34718		588891.6
4	Contribution Margin / Sales Revenue = (S-M-I-D)/S = CM/S	0.4450	0.5219	0.4298	0.4856	0.4799	0.4701	0.5048	0.5064	0.5883	0.5245	0.5644	0.5410	0.4350	0.6035	0.5178	0.5036	0.5664	0.5205	0.3619	0.3830		0.4739
5	Less Unavoidable (Fixed) Costs (U)																						943338.6
6	System Operating Profit (Loss)																						-355007.6

TABLE 11.8: PRODUCT EARNINGS, CONTRIBUTION MARGINS, COST AND PROFITS AS DETERMINED BY PRODUCTIVITY COSTING

Ten. No.		Products																					TOTALS
		104	348	14	705	120	849	811	730	623	1	56	654	850	47	779	825	621	138	133	JP14		
1	Sales Revenue (S)	161813	142859	77514	61694	46732	87288	82584	105203	4430	29739	40543	14202	151412	45821	1717	9973	15372	15730	57311	90637		1242576
2	Less Avoidable (Product) Costs																						
	(a) Product Materials (M)	64528	46784	32828	22011	16672	32828	27966	34457	1163	9622	10909	3998	60548	12130	575	3468	4515	5232	25477	42133		457848
	(b) Interest (I)	11850	10462	5677	4518	3422	6393	6048	7705	324	2178	2969	1040	11089	3356	126	730	1126	1152	4177	6638		91
	(c) Total Avoidable Costs (M + I)	76378	57246	38505	26529	20094	39221	34014	42164	1487	11800	13878	5038	71637	15486	701	4198	5641	6384	29676	48771		548848
3	Total Earnings (or Short Range Contribution Margin) (S - M - I - I)	85435	85613	39009	35165	26638	48067	48570	63039	2943	17939	26665	9164	79775	30335	1016	5775	9731	9346	27635	41866		693728
4	Total Earnings / Sales Revenue = I / S	0.5280	0.5993	0.5033	0.5700	0.5700	0.5507	0.5881	0.5992	0.6643	0.6032	0.6577	0.6453	0.5269	0.6620	0.5917	0.5791	0.6330	0.5942	0.4827	0.4619		0.5583
5	Less Operating (Direct) Labour (D)	13422	11054	5695	5208	4213	6967	6883	9763	337	2342	3782	1481	13904	2683	127	753	1025	1158	6392	7148		104837
6	Long Range Contribution Margin (I - D) = CM	72013	74559	33314	29957	22425	41100	41689	53276	2606	15597	22883	7683	65871	27651	889	5022	8706	8188	20243	34718		588891
7	Contribution Margin / Sales Revenue = I - D / S = CM / S	0.4450	0.5219	0.4298	0.4856	0.4799	0.4709	0.5048	0.5064	0.5883	0.5245	0.5644	0.5410	0.4350	0.6035	0.5178	0.5036	0.5664	0.5205	0.3619	0.3830		0.4739
8	Less Product Processing (Facilities Occupancy) Costs (C_f)	76072.5	58146.4	31085.6	26256.7	20962.5	39793.4	36327.3	49318.6	1643.5	12439.1	20654.4	8351.7	74838.6	14081.4	753.4	4239.3	5647.4	6311.6	32069.3	42986.9		562574.1
9	Product Profit (I - C_f)	9362.5	27448.6	7923.4	8908.3	5675.5	8274.0	12244.7	13720.4	1299.5	5499.9	6010.6	812.3	4936.4	5652.6	262.6	1535.7	4083.7	3034.4	-4434.5	-1114.9		131153.9
10	Less Non-Producing Facilities Cost																						
	(a) Idle Facilities Cost																						399586.0
	(b) Non-applied Operating Labour Costs																						86573.6
	(c) Total Non-producing Facilities Cost (C_i)																						486159.6
11	System Operating Profit (Loss) (I - C_f - C_i)																						-355005.6

TABLE 11.7: PRODUCT PRODUCTIVITY INDEXES AS DETERMINED BY PRODUCTIVITY COSTING

Item No.		PRODUCTS																				TOTALS
		104	348	14	705	120	849	811	730	623	1	56	654	850	47	779	825	621	138	133	JP14	
1	Based on Processing Cost:																					
	(a) Total Earnings (/Cost) Productivity, $E_e = \frac{I}{C_f}$	1.1231	1.4724	1.2549	1.3393	1.2707	1.2019	1.3371	1.2782	1.7707	1.4412	1.2910	1.0973	1.0660	2.0661	1.3481	1.3623	1.7232	1.4808	0.8611	0.9741	1.2331
	(b) Profit (/Cost) Productivity, $E_p = \frac{I - C_f}{C_f}$	0.1231	0.4724	0.2549	0.3393	0.2707	0.2019	0.3371	0.2782	0.7707	0.4412	0.2910	0.0973	0.0660	1.0661	0.3481	0.3623	0.7232	0.4808	-0.1389	-0.0259	0.1331
	(c) Processing Facilities Productivity, $E_f = \frac{C_p}{C_f}$	0.8607	0.8300	0.8697	0.8758	0.8431	0.8605	0.8547	0.8605	0.8583	0.8508	0.8483	0.8308	0.8741	0.8747	0.8733	0.8744	0.8737	0.8737	0.8857	0.9911	0.8628
	(d) Product Productivity Characteristic, $E_c = \frac{I}{C_f + E_f}$	1.3049	1.7737	1.4428	1.5292	1.5070	1.4038	1.5643	1.4855	2.0862	1.6951	1.5219	1.3207	1.2187	2.3619	1.5444	1.5579	1.9717	1.6949	0.9729	1.0834	1.4272
	(e) Contribution Margin Cost Productivity $E_m = \frac{I - D}{C_f}$	0.9466	1.2823	1.0717	1.1409	1.0698	1.0328	1.1476	1.0802	1.5856	1.2539	1.1079	0.9199	0.8802	1.8833	1.1800	1.1846	1.5417	1.2973	0.6468	0.8072	1.0468
2	Based on Working Capital Investment																					
	(a) Sales Revenue Working Capital Productivity, E_{sw} $E_{sw} = \frac{S}{W + I + C_f}$	1.0614	1.2380	1.1139	1.1688	1.1382	1.1047	1.1741	1.1500	1.4151	1.2269	1.1741	1.0607	1.0337	1.5188	1.1806	1.1820	1.3618	1.2390	0.9282	0.9378	1.1180
	(b) Profit Working Capital Productivity, E_{pw} $E_{pw} = \frac{S - W - I - C_f}{W + I + C_f}$	0.0614	0.2380	0.1139	0.1688	0.1382	0.1047	0.1741	0.1500	0.4151	0.2269	0.1741	-0.0607	0.0337	0.5188	0.1806	0.1820	0.3618	0.2390	-0.0718	-0.0122	0.1180
	(c) Total Earnings Working Capital Productivity, E_{tw} $E_{tw} = \frac{I}{W + I + C_f}$	0.5604	0.7419	0.5605	0.6662	0.6488	0.6083	0.6905	0.6891	0.9401	0.7401	0.7722	0.6844	0.5446	1.0055	0.6786	0.6845	0.8621	0.7362	0.4476	0.4562	0.6242
	(d) Contribution Margin Working Capital Productivity, E_{mw} $E_{mw} = \frac{I - D}{W + I + C_f}$	0.4724	0.6461	0.4787	0.5675	0.5462	0.5202	0.5927	0.5824	0.8325	0.6435	0.6627	0.5738	0.4497	0.9166	0.6113	0.5952	0.7713	0.6419	0.3359	0.3734	0.5299

TABLE 11.8: SYSTEM PRODUCTIVITY INDEXES AS DETERMINED BY PRODUCTIVITY COSTING

Item No.	Description	Index
1	Based on Processing Cost:	
	(a) Total Earning (/Cost) Productivity, $E_{te} = \frac{T}{\Sigma C_f + C_l}$	0.6615
	(b) Profit (/Cost) Productivity, $E_{pp} = \frac{T - (\Sigma C_f + C_l)}{\Sigma C_f + C_l}$	-0.3385
	(c) Total Facilities Productivity, $E_{fe} = \frac{\Sigma C}{\Sigma C_f + C_l}$	0.4628
	(d) Product Productivity Characteristic, $E_{de} = \frac{T}{E_{fe}(\Sigma C_f + C_l)}$	1.4292
	(e) Contribution Margin Productivity, $E_{me} = \frac{T - \Sigma D}{\Sigma C_f + C_l}$	0.5615
2	Based on Working Capital Investment:	0.7778
	(a) Sales Revenue / Working Capital Productivity, $E_{svw} = \frac{S}{\Sigma H + \Sigma I + \Sigma C_f + C_l}$	
	(b) Profit / Working Capital Productivity, $E_{pvw} = \frac{S - (\Sigma H + \Sigma I + \Sigma C_f + C_l)}{\Sigma H + \Sigma I + \Sigma C_f + C_l}$	-0.221
	(c) Total Earnings / Working Capital Productivity, $E_{twp} = \frac{T}{\Sigma H + \Sigma I + \Sigma C_f + C_l}$	0.4342
	(d) Contribution Margin / Working Capital Productivity, $E_{mvw} = \frac{T - D}{\Sigma H + \Sigma I + \Sigma C_f + C_l}$	0.3681

TABLE 11.8: COMPARATIVE PRODUCT RANKINGS FOR ALTERNATIVE BASIS OF MANAGEMENT DECISION- MAKING

	Absorption Costing		Direct or Marginal Costing				Productivity Costing															
Product Number	Net Profit	Profit Rank No.	Contribution Margin (T - D)	Contribution Margin (T - D) / Sales Ratio	Contribution Margin (T - D) Rank No.	Contribution Margin (T - D) / Sales Ratio Rank No.	Profit Productivity $\varepsilon_p = \frac{S - C_t - M}{C_t}$	Profit Productivity Rank No.	Total Earning Productivity $\varepsilon_t = \frac{(S - M)}{C_t}$	Total Earning Productivity Rank No.	Contribution Margin Ex (/Cost) Productivity	ε_m Rank No.	Sales Revenue / Working Capital Productivity ε_{sw}	ε_{sw} Rank No.	Profit / Working Capital Productivity ε_{pw}	ε_{pw} Rank No.	Total Earnings / Working Capital Productivity ε_{tw}	ε_{tw} Rank No.	Contribution Margin / Working Capital Productivity ε_{mw}	ε_{mw} Rank No.	Product Productivity Characteristic $\varepsilon_d = \varepsilon_{mw}^{\alpha}$	ε_d Rank No.
106	14307	3	72013	2	0.4450	16	0.1331	16	1.1331	16	0.9416	16	1.0414	16	0.0614	16	0.5601	17	0.4714	17	1.3041	17
348	31169	1	74559	1	0.5119	7	0.4724	5	1.4724	5	1.2823	5	1.2380	5	0.2380	5	0.7419	5	0.6461	5	1.7739	4
14	8297	6	33344	8	0.4398	18	0.2549	14	1.2549	14	1.0717	13	1.1137	14	0.1137	14	0.5605	16	0.4737	16	1.4033	14
703	5559	8	39457	9	0.4850	13	0.3313	9	1.3313	9	1.1407	10	1.1888	11	0.1888	11	0.6662	13	0.5675	13	1.5816	10
120	2404	13	32425	12	0.4771	14	0.2707	13	1.2707	13	1.0698	14	1.1382	13	0.1382	13	0.6488	14	0.5462	14	1.5013	12
849	11110	4	41100	6	0.4709	15	0.2071	15	1.2071	15	1.0338	15	1.1847	15	0.1847	15	0.6083	15	0.5205	15	1.4035	15
811	9010	5	41639	5	0.5048	11	0.3311	10	1.3311	10	1.1416	9	1.1741	9	0.1741	9	0.6705	9	0.5127	10	1.5643	7
730	6136	7	53216	4	0.5069	10	0.2182	12	1.2182	12	1.0801	12	1.1500	12	0.1500	12	0.6891	10	0.5824	11	1.4355	13
623	1079	15	2606	19	0.5583	2	0.7707	2	1.7707	2	1.5850	2	1.4151	2	0.4151	2	0.9401	2	0.8325	2	2.0842	2
1	4487	9	15511	14	0.5145	6	0.4933	6	1.4933	6	1.2531	6	1.2261	6	0.2261	6	0.7401	6	0.6135	7	1.6151	5
56	4040	10	11883	11	0.5644	4	0.2910	11	1.2910	11	1.0971	11	1.1141	10	0.1141	10	0.7221	9	0.6221	9	1.5814	11
654	410	16	7683	17	0.5410	5	0.0773	17	1.0773	17	0.9199	17	1.0607	17	0.0607	17	0.6894	12	0.5735	12	1.3201	16
850	-1160	18	65871	3	0.4350	17	0.0660	18	1.0660	18	0.8501	18	1.0337	18	0.0337	18	0.5440	18	0.4497	18	1.1157	18
47	14610	2	27652	10	0.6035	1	1.0661	1	2.0661	1	1.8833	1	1.5188	1	0.5188	1	1.0055	1	0.9164	1	1.3619	1
179	277	17	889	20	0.5178	9	0.3481	8	1.3481	8	1.1800	8	1.1506	9	0.1506	8	0.6781	8	0.6183	8	1.5044	9
825	1386	14	5022	18	0.5011	12	0.3428	7	1.3428	7	1.1846	7	1.1820	7	0.1820	7	0.6845	11	0.5151	9	1.5571	8
621	3742	11	8206	15	0.5664	3	0.7233	3	1.7233	3	1.5407	3	1.3618	3	0.3618	3	0.8621	3	0.7733	3	1.9717	3
138	2588	12	8189	16	0.5205	8	0.4808	4	1.4808	4	1.2173	4	1.2310	4	0.2310	4	0.7302	7	0.6407	6	1.6149	6
132	-13290	20	20743	13	0.3619	20	-0.1853	20	0.8147	20	0.6468	20	0.9282	20		20	0.4416	20	0.3551	20	0.9721	20
1016	-2285	19	30718	7	0.3830	13	-0.0251	19	0.9741	19	0.8018	19	0.9878	19	-0.0122	19	0.4513	19	0.3734	19	1.0831	19

Table 11.10 Productivity Costing Analysis:A Hypothetical Case

SUMMARY OF SYSTEM EXPENSES

TOTAL DEPARTEMENTAL OPERATING EXPENSES	600.0
TOTAL GENERAL SYSTEM OPERATING EXPENSES	650.0
TOTAL OPERATING SYSTEM EXPENSES	1250.0
TOTAL DIRECT LABOUR COST PER DAY	286.0
PROD COSTING RATE PER PROCESSING HOUR OF SYSTEM	37.3

DEVELOPMENT OF PRODUCTIVE FACILITIES COSTING RATE FOR PRODUCTIVITY COSTING

PFN	MFOH	PEVD	PEVS	DEAPE	SEAPE	TOEAPE	PECR/H	DLC/H	PCRPPH
1	6.600E+01	4.603E+01	2.959E+01	1.735E+02	1.923E+02	3.658E+02	5.543E+00	2.810E+00	8.353E+00
2	6.800E+01	5.397E+01	3.469E+01	2.035E+02	2.255E+02	4.290E+02	6.308E+00	2.810E+00	9.118E+00
3	3.200E+01	5.660E+01	2.022E+01	1.262E+02	1.314E+02	2.576E+02	8.051E+00	2.970E+00	1.102E+01
4	3.400E+01	4.340E+01	1.550E+01	9.678E+01	1.008E+02	1.976E+02	5.810E+00	2.970E+00	8.780E+00

AVERAGE PRODUCTION PER DAY FOR PRODUCT 1

PFN	PWH	FOH	FP	FOC
1	4.000E+00	1.600E+01	2.500E-01	1.337E+02
2	7.000E+00	2.000E+01	3.500E-01	1.824E+02
3	8.000E+00	1.000E+01	8.000E-01	1.102E+02
4	9.000E+00	1.200E+01	7.500E-01	1.054E+02
TOTAL	2.800E+01	5.800E+01	4.828E-01	5.316E+02

AVERAGE PRODUCTION PER DAY FOR PRODUCT 2

PFN	PWH	FOH	FP	FOC
1	5.000E+00	1.000E+01	5.000E-01	8.353E+01
2	8.000E+00	1.200E+01	6.667E-01	1.094E+02
3	4.000E+00	6.000E+00	6.667E-01	6.613E+01
4	6.000E+00	8.000E+00	7.500E-01	7.024E+01
TOTAL	2.300E+01	3.600E+01	6.389E-01	3.293E+02

AVERAGE PRODUCTION PER DAY FOR PRODUCT 3

PFN	PWH	FOH	FP	FOC
1	8.000E+00	1.600E+01	5.000E-01	1.337E+02
2	6.000E+00	1.600E+01	3.750E-01	1.459E+02
3	2.000E+00	4.000E+00	5.000E-01	4.409E+01
4	8.000E+00	1.000E+01	8.000E-01	8.780E+01
TOTAL	2.400E+01	4.600E+01	5.217E-01	4.114E+02

Table 11.10 Continued

****
PRODUCTS TOTALS
****

PFN	PWH	FOH	FP	FOC
1	1.700E+01	4.200E+01	4.048E-01	3.508E+02
2	2.100E+01	4.800E+01	4.375E-01	4.377E+02
3	1.400E+01	2.000E+01	7.000E-01	2.204E+02
4	2.300E+01	3.000E+01	7.667E-01	2.634E+02
TOTAL	7.500E+01	1.400E+02	5.357E-01	1.272E+03

PRODUCTIVITY COSTING-PRODUCT PROCESSING

FACILITIES AND LABOUR SUMMARY

SYSTEM UTILISATION SUMMARY

PFN	PWH	FOH	FP	FOC
1	1.700E+01	4.200E+01	4.048E-01	3.508E+02
2	2.100E+01	4.800E+01	4.375E-01	4.377E+02
3	1.400E+01	2.000E+01	7.000E-01	2.204E+02
4	2.300E+01	3.000E+01	7.667E-01	2.634E+02
TOTAL	7.500E+01	1.400E+02	5.357E-01	1.272E+03

IDLE FACILITIES SUMMARY

PFN	FIN	IFC
1	2.400E+01	1.330E+02
2	2.000E+01	1.262E+02
3	1.200E+01	9.662E+01
4	4.000E+00	2.324E+01
TOTAL	6.000E+01	3.791E+02

FACILITIES SUMMARY

PFN	TFC	FU	MFOH	TFP
1	3.658E+02	6.364E-01	6.600E+01	2.576E-01
2	4.290E+02	7.059E-01	6.800E+01	3.088E-01
3	2.576E+02	6.250E-01	3.200E+01	4.375E-01
4	1.976E+02	8.824E-01	3.400E+01	6.765E-01
TOTAL	1.250E+03	6.968E-01	2.000E+02	3.750E-01

LABOUR (OPER AND NON OPER) SUMMARY

PFN	ILH	ILC	OLU
1	2.400E+01	6.744E+01	3.423E-01
2	2.000E+01	5.620E+01	3.423E-01
3	1.200E+01	3.564E+01	5.151E-01
4	4.000E+00	1.188E+01	5.151E-01
TOTAL	6.000E+01	1.712E+02	4.015E-01

Table 11.10 Continued

SYSTEMS PROFITS(OR LOSSES) AS DETERMIND BY CONVENTIONAL (OVERHEAD ABSORPTION) COSTING

SALES REVENUE (SR)	4670.0
LESS AVOIDABLE COSTS :	
A)PRODUCT MATERIALS COST (PMC)	2396.0
B)INTEREST CHARGES (INT)	189.0
C)TOTAL AVOIDABLE COST (TAC)	2585.0
LESS SYSTEM OPERATING EXPENSES :	
A)OPERATING (DIRECT) LABOUR (ODL)	543.2
B)OVERHEAD EXPENSES (OE)	1126.5
C)TOTAL OPERATING EXPENSES (TOE)	1669.8
PRODUCT PROFIT (PP)	415.3
LESS UNABSORBED OVERHEAD (UO)	152.9
SYSTEM OPERATING PROFIT (SOP)	262.4

PRODUCTS PROFITS(OR LOSSES) AS DETERMIND BY CONVENTIONAL (OVERHEAD ABSORPTION COSTING)

		LESS AVOIDABLE COSTS			LESS SYSTEMS OPERATING EXPENSES			
PT	SR	PMC	INT	TAC	ODL	OHE	TOE	PP
1	830.0	126.0	22.0	148.0	253.8	507.6	761.3	-79.3
2	1090.0	410.0	38.0	448.0	113.8	267.6	381.4	260.6
3	2750.0	1860.0	129.0	1989.0	175.7	351.3	527.0	234.0

SYSTEMS CONTRIBUTION MARGINS AND OPERATING PROFIT DETERMIND BY MARGINAL COSTING

SALES REVENUE (SR)	4670.0
LESS AVOIDABLE PRODUCT COSTS :	
A)PRODUCT MATERIALS COST (PMC)	2396.0
B)INTEREST CHARGES (INT)	189.0
C)OPERATING (DIRECT) LABOUR (ODL)	543.2
D)TOTAL AVOIDABLE COST (TAC)	3128.3
CONTRIBUTION MARGIN (CM)	1541.8
CONTRIBUTION MARGIN/SALES REVENUE (CMSR)	.3301
LESS FIXED COSTS (FC)	1279.4
SYSTEM OPERATING PROFIT (SOP)	262.3

PRODUCTS CONTRIBUTION MARGINS AS DETERMINDBY MARGINAL COSTING

		LESS AVOIDABLE (PRODUCT) COST					
PT	SR	PMC	INT	ODL	TAC	CM	CM/SR
1	830.0	126.0	22.0	253.8	401.8	428.2	.5159
2	1090.0	410.0	38.0	113.8	561.8	528.2	.4846
3	2750.0	1860.0	129.0	175.7	2164.7	585.3	.2128

Table 11.10 Continued

TOTAL EARNINGS,CONTRIBUTION MARGINS,COSTS AND PROFITS AS DETERMIAND BY PRODUCTIVITY COSTING

SALES REVENUE (SR)	4670.0
LESS AVOIDABLE (PRODUCT) COSTS :	
A)PRODUCT MATERIALS COST (PMC)	2396.0
B)INTEREST CHARGES (INT)	189.0
C)TOTAL AVOIDABLE COST (TAC)	2585.0
TOTAL EARNING (TE)	2085.0
TOTAL EARNING/SALES REVENUE (TE/SR)	.4465
LESS OPERATING (DIRECT) LABOUR COST (ODL)	543.2
CONTRIBUTION MARGIN (LONG RANGE) (CMLR)	1541.8
CONTIBUTION MARGIN (CMLR)/SALES REVENUE	.3301
PRODUCT FACILITES OCCUPANCY COSTS (FOC)	1272.3
PRODUCT PROFIT (PP=TE-FOC)	812.7
LESS NON-PRODUCING FACILITES COST :	
A)IDLE FACILITES COST (IFC)	379.1
NON APPLIED OPERATING LABOUR COSTS (NALC)	171.2
,C)TOTAL NON-PRODUCING FACILITES COST (TNPFC)	550.2
SYSTEM OPERATING PROFIT (SOP)	262.4

PRODUCTS EARNINGS,CONTRIBUTION MARGINS,COSTAND PROFITS AS DETERMIND BY PRODUCTIVITY COSTING

		LESS AVOIDABLE COSTS									
PT	SR	PMC	INT	TAC	TE	TE/SR	LODL	CM	CM/SR	LFOC	PP
1	830.0	126.0	22.0	148.0	682.0	.8217	253.8	428.2	.5159	531.6	150.4
2	1090.0	410.0	38.0	448.0	642.0	.5890	113.8	528.2	.4846	329.3	312.7
3	2750.0	1860.0	129.0	1989.0	761.0	.2767	175.7	585.3	.2128	411.4	349.6

PRODUCT PRODUCTIVITY INDEXES AS DETERMIND BY PRODUCTIVITY COSTING

****
(A)BASED ON PROCESSING COST
****

PT	ET	EP	EF	ED	EM
1	1.2829	.2829	.4828	2.6575	.8055
2	1.9495	.9495	.6389	3.0513	1.6039
3	1.8496	.8496	.5217	3.5452	1.4227
TOTAL	1.6387	.6387	.5357	3.0589	1.2117

****
(B)BASED ON WORKING CAPITAL INVESTMENT
****

PT	ESW	EPW	ETW	EMW
1	1.2213	.2213	1.0035	.6301
2	1.4023	.4023	.8259	.6795
3	1.1456	.1456	.3170	.2438
TOTAL	1.2107	.2107	.5405	.3997

Table 11.10 Continued

SYSTEM PRODUCTIVITY INDEXES AS DETERMIND BY PRODUCTIVITY COSTING

****
(A) BASED ON PROCESSING COST
****

TOTAL EARNING (/COST) PRODUCTIVITY (ETS)	1.1440
PROFIT (/COST) PRODUCTIVITY (EPS)	.1440
TOTAL FACILITIES PRODUCTIVITY (EFS)	.3750
PRODUCT PRODUCTIVITY CHARACTRISTIC (EDS)	3.0507
CONTRIBUTION MARGIN PRODUCTIVITY (EMS)	.8459

****
(B) BASED ON WORKING CAPITAL INVESTMENT
****

SALES REVENUE/WORKING CAPITAL PRODUCTIVITY (ESWS)	1.0595
PROFIT/WORKING CAPITAL PRODUCTIVITY (EPWS)	.0595
TOTAL EARNING/WORKING CAPITAL PRODUCTIVITY (ETWS)	.4731
CONTRIBUTION MARGIN/WORKING CAPITAL PRODUCTIVITY (EMWS),	.3498

COMPARATIVE PRODUCT RANKING FOR ALTERNATIVE BASES OF MANGEMENT DECISION MAKING

RAPP		RACM		RACM/SR		RAET		RAEP		RAEM		RAED	
-79.3	3	428.2	3	.5159	1	1.2829	3	.2829	3	.8055	3	2.6575	3
260.6	1	528.2	2	.4846	2	1.9495	1	.9495	1	1.6039	1	3.0513	2
234.0	2	585.3	1	.2128	3	1.8496	2	.8496	2	1.4227	2	3.5452	1

RANKING OF VARIABLES CONTINUED

RAESW		RAEPW		RAETW		RAEMW	
1.2213	2	.2213	2	1.0035	1	.6301	2
1.4023	1	.4023	1	.8259	2	.6795	1
1.1456	3	.1456	3	.3170	3	.2438	3

TABLE II.11 PRODUCTIVITY INDEXES PRIOR AND SUBSEQUENT TO SYSTEM OPTIMIZATION WITH NO REDUCTION IN PRESENT PRODUCT QUANTITIES

SYSTEM PRODUCTIVITY INDEXES AS DETERMIND BY PRODUCTIVITY COSTING

(A) BASED ON PROCESSING COST

TOTAL EARNING (/COST) PRODUCTIVITY (ETS)	1.1440
PROFIT (/COST) PRODUCTIVITY (EPS)	.1440
TOTAL FACILITIES PRODUCTIVITY (EFS)	.3750
PRODUCT PRODUCTIVITY CHARACTRISTIC (EDS)	3.0507
CONTRIBUTION MARGIN PRODUCTIVITY (EMS)	.8459

(B) BASED ON WORKING CAPITAL INVESTMENT

SALES REVENUE/WORKING CAPITAL PRODUCTIVITY (ESWS)	1.0595
PROFIT/WORKING CAPITAL PRODUCTIVITY (EPWS)	.0595
TOTAL EARNING/WORKING CAPITAL PRODUCTIVITY (ETWS)	.4731
CONTRIBUTION MARGIN/WORKING CAPITAL PRODUCTIVITY (EMWS),	.3498

SYSTEM OPTIMIZATION WITH NO REDUCTION OF PRESENT PRODUCT QUANTITIES

NUMBER OF ITERATIONS 4

,X 7=,	158.66149159
,X 8=,	127.68151856
,X 9=,	99.18045601
,X 5=,	34.99925256
,X 1=,	110.00000000
,X 2=,	104.99925256
,X 3=,	90.00000000

OPTIMUM VALUE OF TOTAL EARNING = 2405.99369494

SYSTEM,S OPTIMUM PRODUCTIVITY INDEXES

(A) BASED ON PROCESSING COST

TOTAL EARNING (/COST) PRODUCTIVITY (ETS)	1.3201
PROFIT (/COST) PRODUCIVITY (EPS)	.3201
TOTAL FACILITIES PRODUCTIVITY (EFS)	.4325
PRODUCT PRODUCTIVITY CHARACTRISTIC (EDS)	3.0523
CONTRIBUTION MARGIN PRODUCTIVITY (EMS)	1.0220

(B) BASED ON WORKING CAPITAL INVESTMENT

SALES REVENUE/WORKING CAPITAL PRODUCTIVITY (ESWS)	1.1306
PROFIT/WORKING CAPITAL PRODUCTIVITY (EPWS)	.1306
TOTAL EARNING/WORKING CAPITAL PRODUCTIVITY (EMWS)	.5216
CONTRIBUTION MARGIN/WORKING CAPITAL PRODUCTIVITY (EMWS),	.4038

TABLE 11.12 PRODUCTIVITY INDEXES PRIOR AND SUBSEQUENT TO SYSTEM OPTIMIZATION WITH REDUCTION IN PRODUCT VARIETY

SYSTEM PRODUCTIVITY INDEXES AS DETERMIND BY PRODUCTIVITY COSTING

(A) BASED ON PROCESSING COST

TOTAL EARNING (/COST) PRODUCTIVITY (ETS)	1.1440
PROFIT (/COST) PRODUCTIVITY (EPS)	.1440
TOTAL FACILITIES PRODUCTIVITY (EFS)	.3750
PRODUCT PRODUCTIVITY CHARACTRISTIC (EDS)	3.0507
CONTRIBUTION MARGIN PRODUCTIVITY (EMS)	.8459

(B) BASED ON WORKING CAPITAL INVESTMENT

SALES REVENUE/WORKING CAPITAL PRODUCTIVITY (ESWS)	1.0595
PROFIT/WORKING CAPITAL PRODUCTIVITY (EPWS)	.0595
TOTAL EARNING/WORKING CAPITAL PRODUCTIVITY (ETWS)	.4731
CONTRIBUTION MARGIN/WORKING CAPITAL PRODUCTIVITY (EMWS),	.3498

SYSTEM OPTIMIZATION BASED ON REDUCTION OF PRODUCT VARIETY

NUMBER OF ITERATIONS 1

,X 4=,	196.22465523
,X 5=,	155.04023719
,X 6=,	71.63082507
,X 2=,	297.49957645

OPTIMUM VALUE OF TOTAL EARNING = 2728.49654047

SYSTEM,S OPTIMUM PRODUCTIVITY INDEXES

(A) BASED ON PROCESSING COST

TOTAL EARNING (/COST) PRODUCTIVITY (ETS)	1.4971
PROFIT (/COST) PRODUCIVITY (EPS)	.4971
TOTAL FACILITIES PRODUCTIVITY (EFS)	.4887
PRODUCT PRODUCTIVITY CHARACTRISTIC (EDS)	3.0631
CONTRIBUTION MARGIN PRODUCTIVITY (EMS)	1.1990

(B) BASED ON WORKING CAPITAL INVESTMENT

SALES REVENUE/WORKING CAPITAL PRODUCTIVITY (ESWS)	1.2340
PROFIT/WORKING CAPITAL PRODUCTIVITY (EPWS)	.2340
TOTAL EARNING/WORKING CAPITAL PRODUCTIVITY (EMWS)	.7268
CONTRIBUTION MARGIN/WORKING CAPITAL PRODUCTIVITY (EMWS),	.5821

Fig. 11.1 Productivity Costing, Break Down of Components cv ≠ 0.

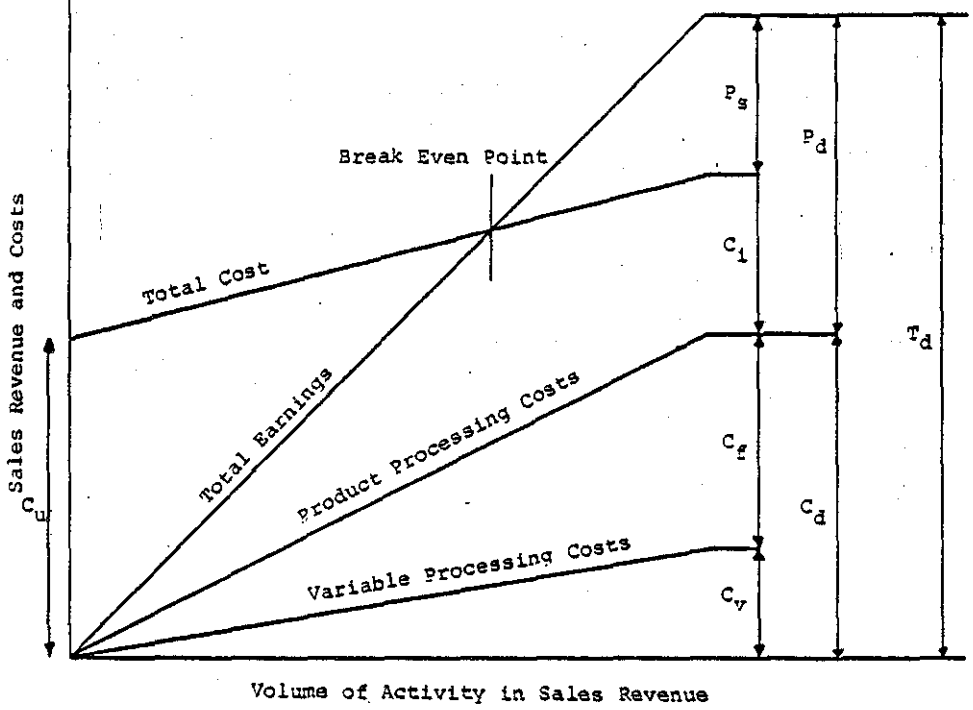


Fig. 11.2 Productivity Costing, Break Down of Components $C_v = 0$

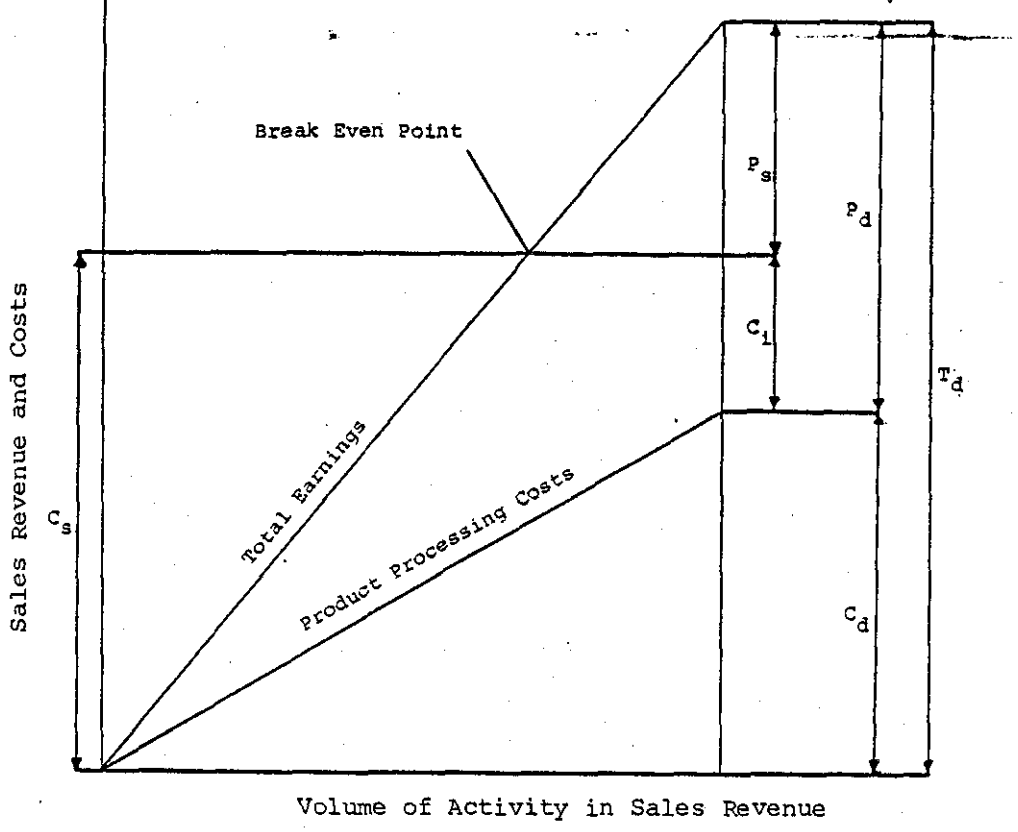


Fig. 11.3 System Break Even Chart Based on Absorption Costing

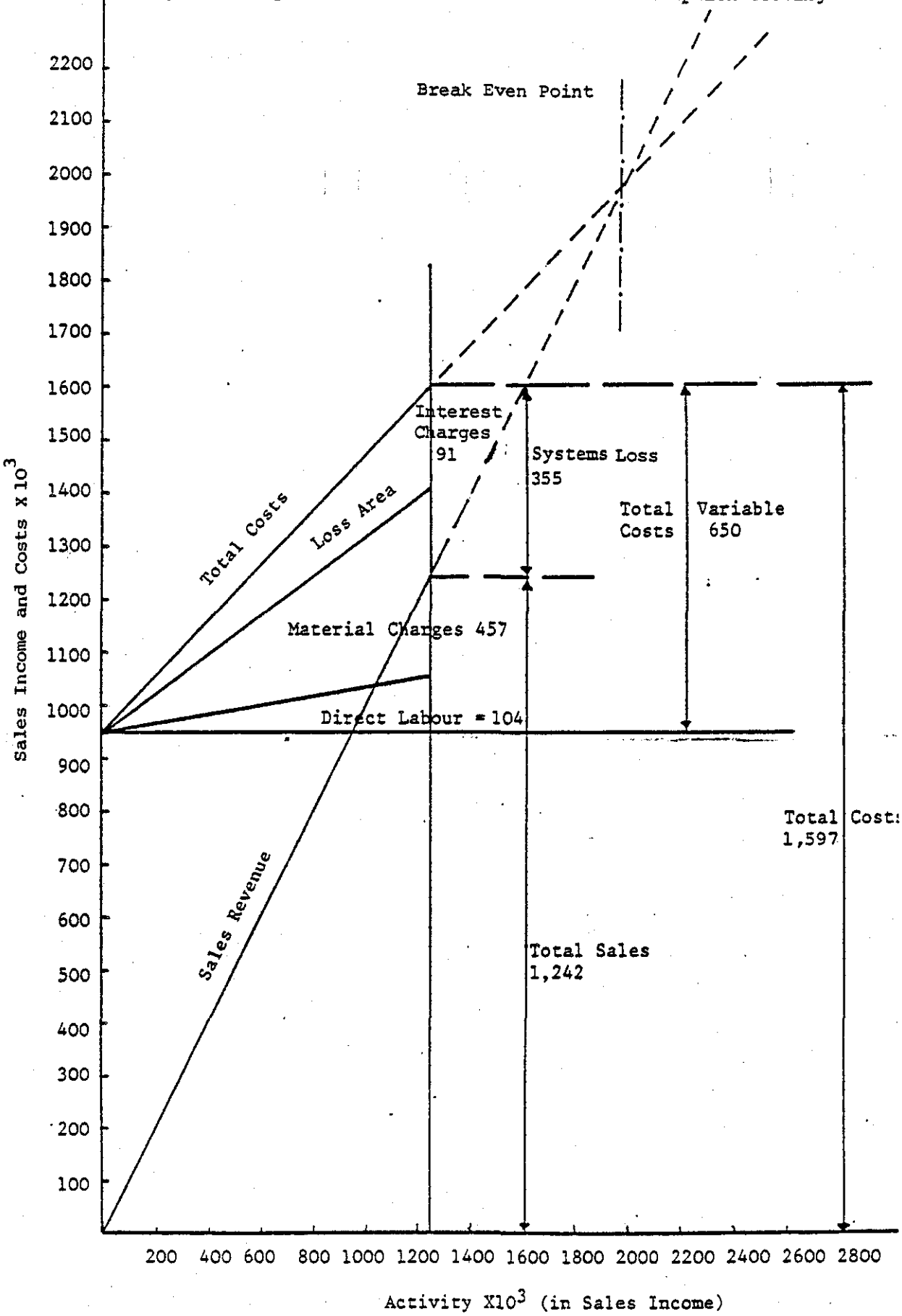


Fig. 11.4 System Profit Contribution Margin -- Sales Revenue Break Even Chart Based on Marginal Costing

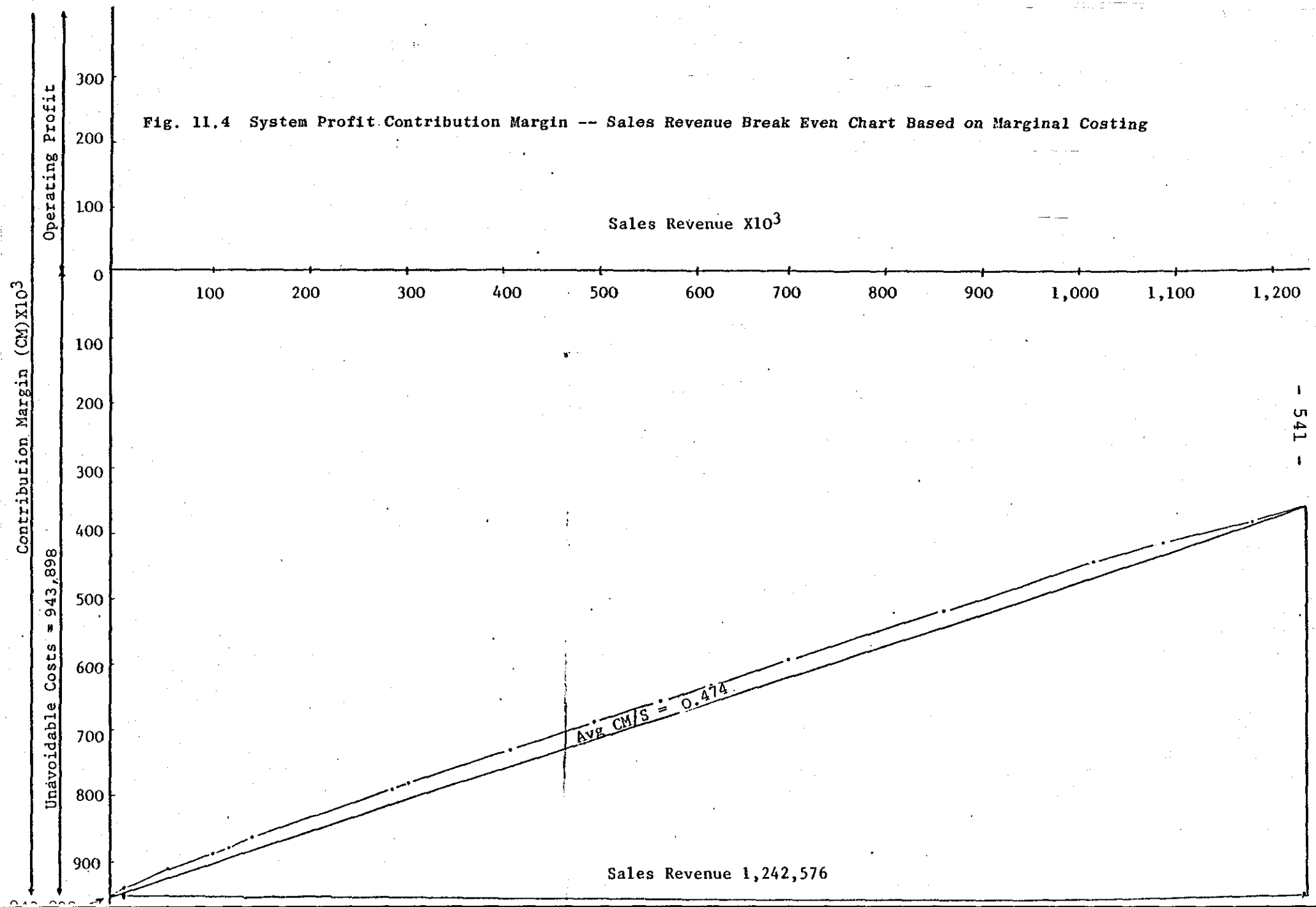


Fig. 11.5 System Total Earnings -- Sales Revenue Break-Even Chart Based on Productivity Costing

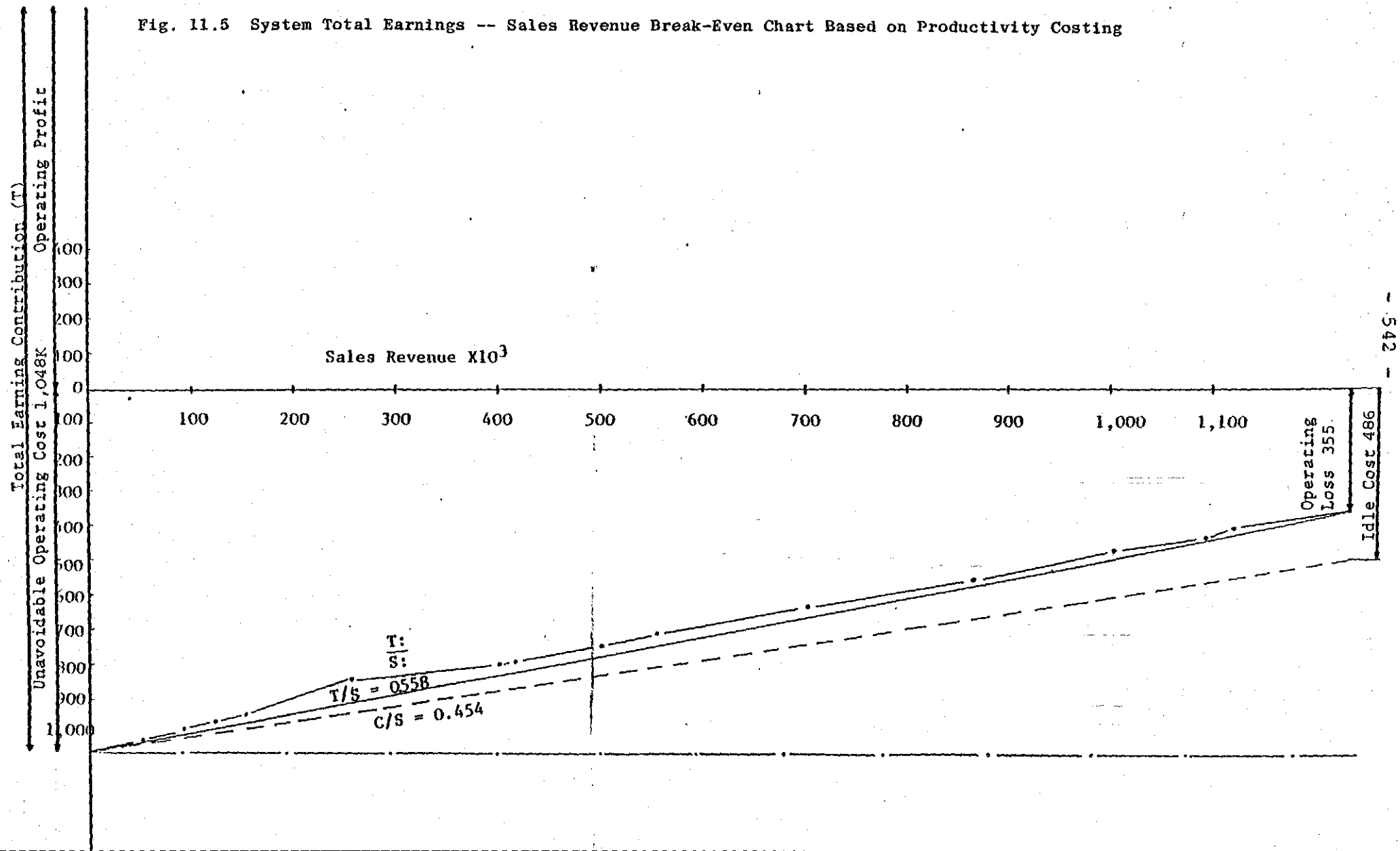


Fig. 11.6 Monthly Break Even Chart Based on 8 Months

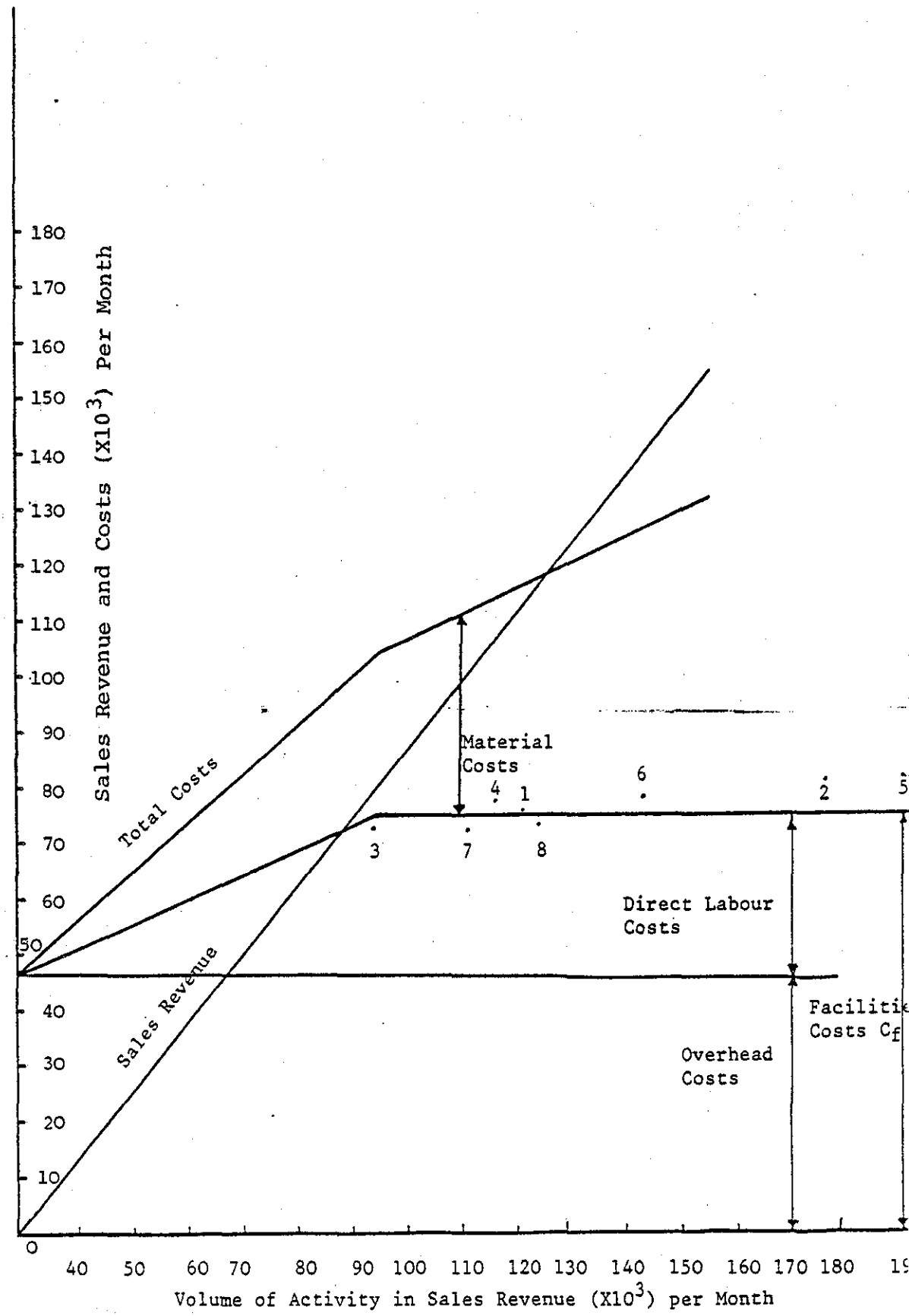


Fig. 11.7 Product Sales Revenue Distribution Chart

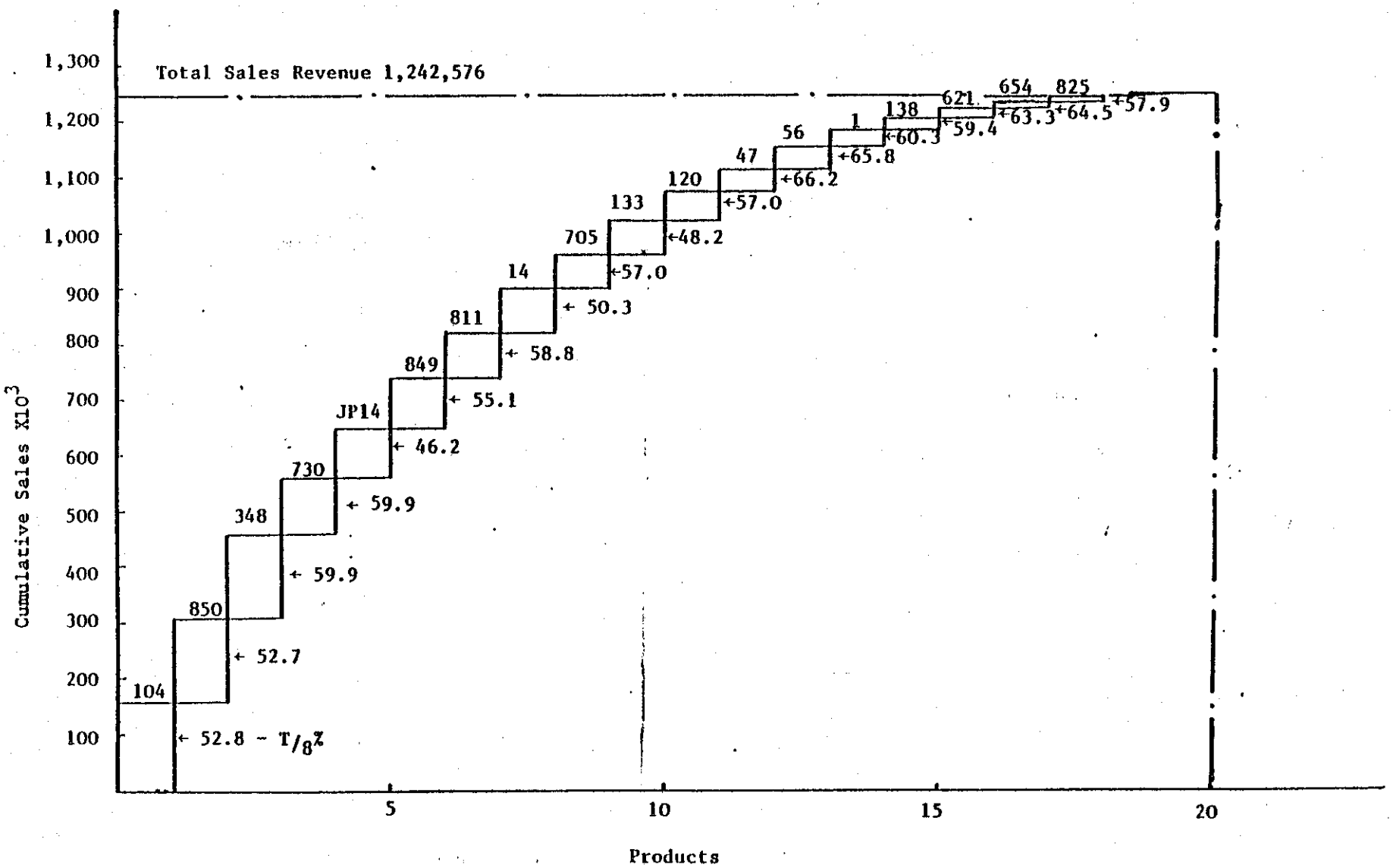


Fig. 11.8 Product Total Earnings in Distribution Chart

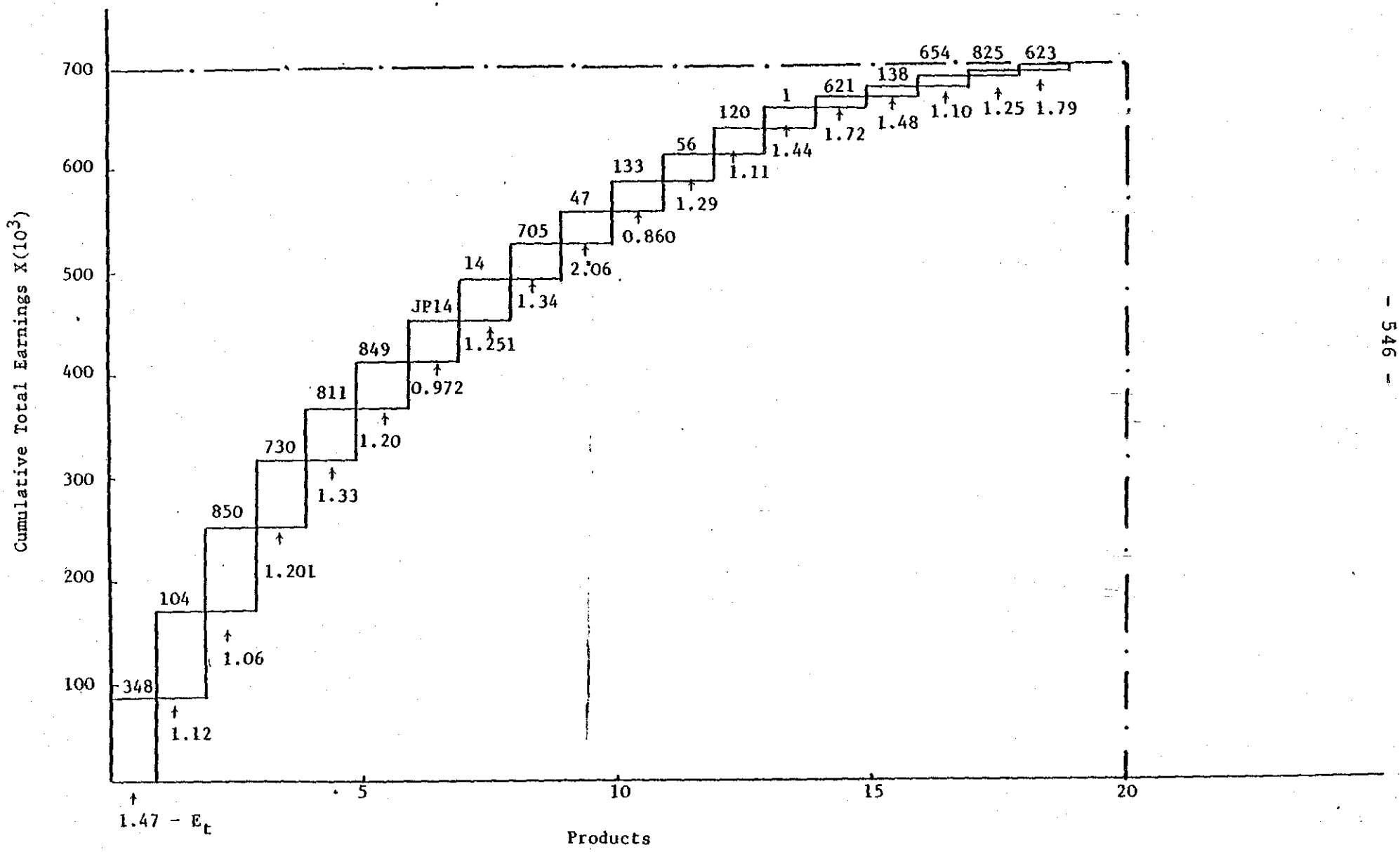


Fig. 11.9 Product Cost Distribution Chart

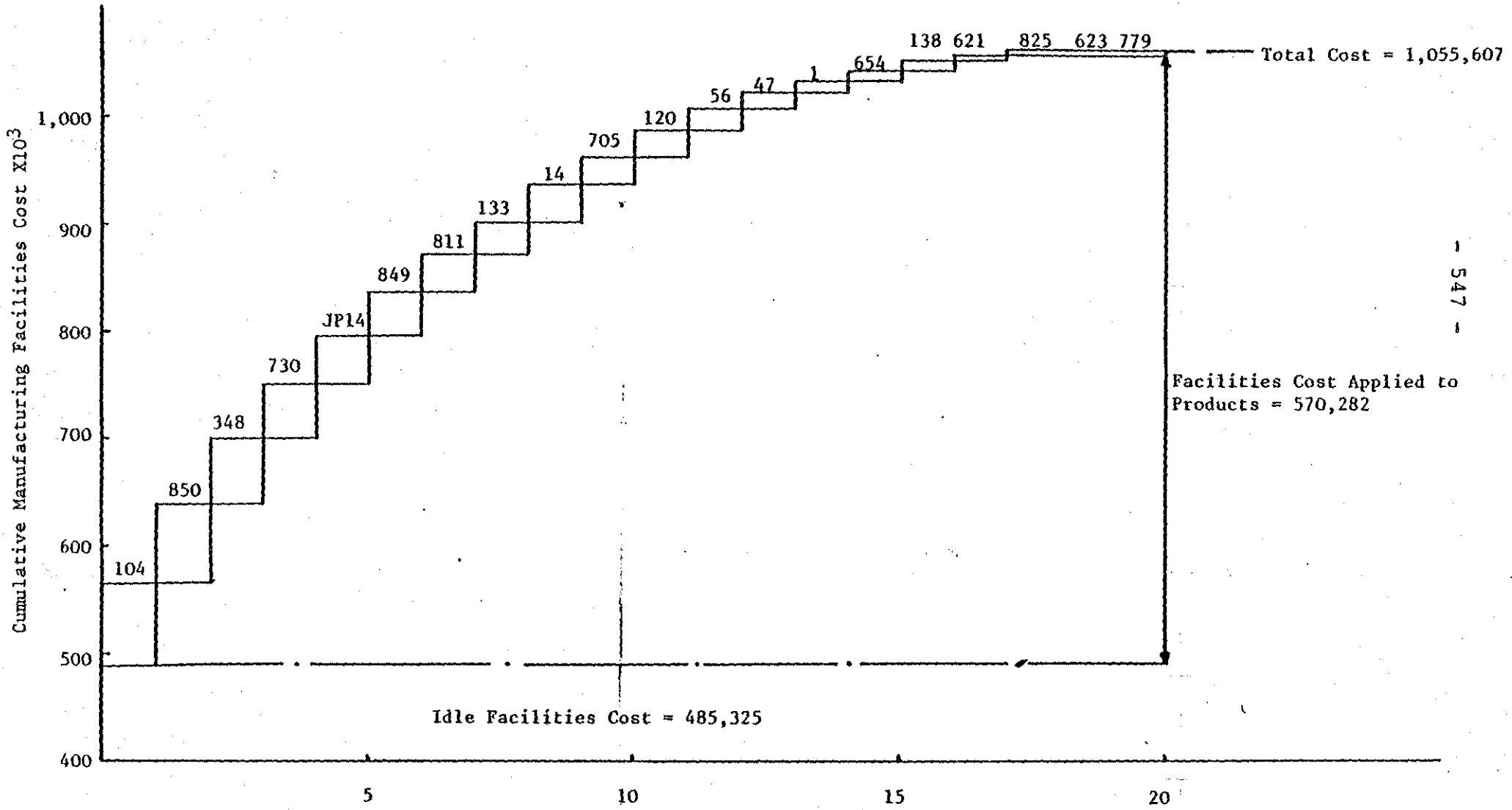
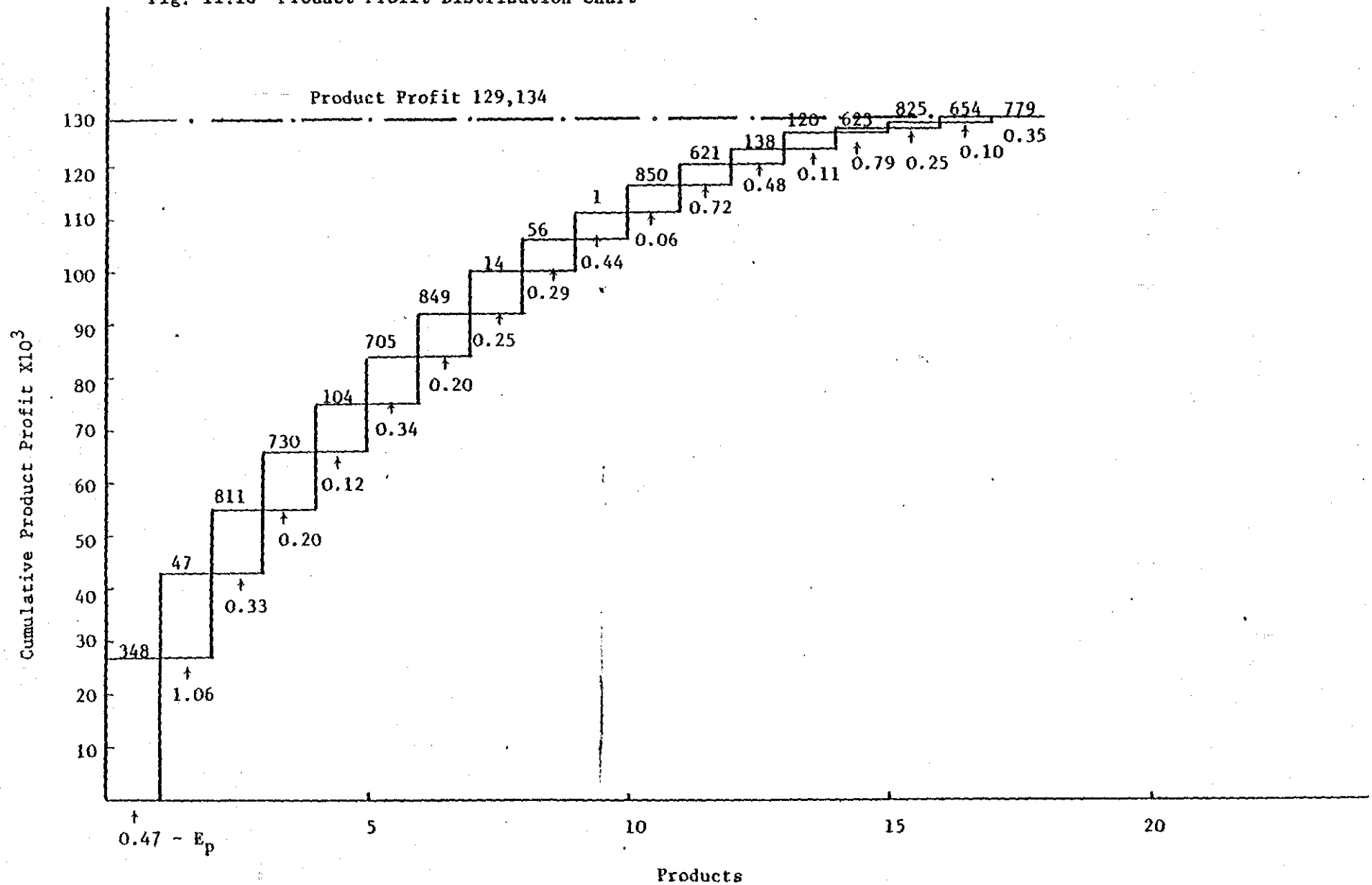


Fig. 11.10 Product Profit Distribution Chart



REFERENCES

1. Martin, H.W. "Towards a Common Measure of Productivity". Productivity Measurement Review, No. 19, November 1959, OECD.

2. Martin, H.W. "Productivity Measurement and Control". Productivity Measurement Review, No. 37, May 1960, OECD.

3. Martin, H.W. "Productivity Costing and Control" Productivity Measurement Review, No. 37, May 1964, OECD.

4. Bahiri, S. and Martin, H.W. "Effective Management through Productivity Costing". Industrial and Commercial Technique Ltd., London, 1968.

5. Bahiri, S. "Evaluating and Developing Productivity Costing Models". M.Sc. thesis, University of Birmingham, 1967.

6. Fox, A. "Industrial Sociology and Industrial Relations". HMSO, London, 1966.

7. Boyd, J.M. "Is Industrial Democracy Compatible with Efficiency". The Production Engines, January 1968.

8. Schlatter, C.F. and Schlatter, W.J. "Cost Accounting" John Wiley, 1960.

CHAPTER TWELVE

AN ECONOMETRIC APPROACH TO MEASUREMENT OF PRODUCTIVITY; PRODUCTION FUNCTION: CONCEPT AND THEORY

12.1 Introduction

In this chapter we discuss econometric approaches to measurement of productivity. These types of approach are generally used by economists, for making inferences at a macro-level about: the impact of productivity growth upon the rate of industrial employment (manpower planning); the distribution of higher productivity among factors of production; main sources of growth; etc. (Refs. 1, 2, 3).

The application of these techniques is not, of course, restricted to studies at a macro-level. Indeed, Bosworth (Ref. 4) states that

> "At macro level the problems of aggregation can result in the failure of aggregate production functions to reflect the underlying technology of production. Such fears give micro studies much of their appeal. At a very low level of aggregation, extraneous influences should be less important and estimates should directly reflect the micro technologies. Despite the potential insights about the technology of production that research at this level promises to yield, few studies of production have worked at such a detailed level. There are two main causes for this lack of interest: first, there are severely restrictive data constraints at the micro level; and, secondly, the good empirical performance of aggregate functions has detracted from the incentive to carry out more detailed studies."

Subject to data problems, these techniques are applicable to studies of single machines or processes, and they are most useful at this level of application.

As mentioned, the engineering concept of efficiency reflects the relationship between the actual and the potential output of a process. This concept could be applied to productive systems, if one could define the potential of the system. The aim of this chapter is to discuss two possible methods of defining functions which specify the potential output of an enterprise and which demonstrate their use in determining the productive efficiency of a firm.

12.2 Production Function

Production function describes the relationship between output and factors of production, e.g., labour and capital. The output is generally defined as the net output (i.e., value added). The reason for this is to avoid double counting; this point was fully discussed in Chapter 7. However, it is possible to define production functions which relate the total output of a firm or industry to all relevant input factors.

Use of a simple diagrammatic example makes the above definition of the production function simpler to comprehend. Consider the combination of labour and capital which would be needed to produce a given output, say P. Then each combination of labour, L, and of capital, C, for a given output, P, can be represented as a point on the scatter diagram, as shown in Figure 12.1.

Each point in Figure 12.1 represents a combination of L and C which may be used to produce the given output, P. Technique X_A requires L_A labour and C_A capital, and technique X_B requires L_B labour and C_B capital.

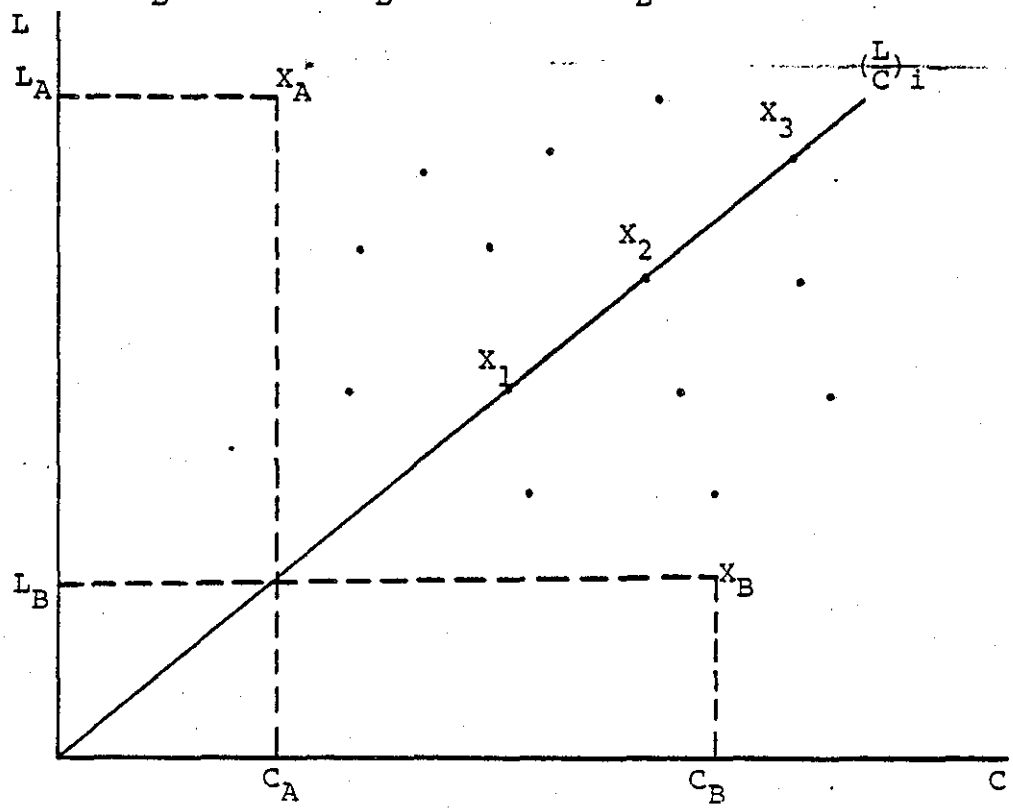


Fig. 12.1 Two-Dimensional Scatter Diagram of Factors of Production (Labour and Capital)

Considering a fixed labour/capital ratio, say $(\frac{L}{C})_i$ (represented by the solid line in Figure 12.1), we see three possible techniques, X1, X2 and X3, each of which uses the same factor proportion $(\frac{Li}{Ci})$ and each of which produces the same output (P). Clearly, X1 is preferred to X2 or X3 since less of each factor is needed to yield the given output. X1 is the most efficient of the processes X1, X2 and X3.

If this is repeated for every possible set of factor proportions $(\frac{Lj}{Cj})$, then by choosing the most efficient technique at each $(\frac{Lj}{Cj})$, we trace out the south-west boundary of the set of all possible techniques.

Such a boundary is called an "isoquant" since it represents the most efficient combinations of factors for a fixed quantity of output. The general shape of boundary assumed here (convex to origin) is implied if we assume diminishing returns. Diminishing returns are in turn suggested by the "law of diminishing returns", which states that "as more of one factor is added to a fixed quantity of other factors, then the change in output due to a change in the variable factor will eventually diminish" (Ref. 5).

The production function describes the slope and the position of the isoquants. The problem in practice is to define this function. We discuss two methods for this purpose. The first is the method proposed by Farrell (Ref. 6), and the second is the production function defined by Cobb and Douglas (Ref. 7). There are other production functions such as Constant Elasticity of Substitution, CES (Ref. 8) and those suggested by Johansen (Ref. 9). However, these are not considered in this chapter.

12.3 The Measurement of Productive Efficiency

In this section we discuss the method put forward by Farrell (Ref. 6) for measurement of efficiency. Efficiency in the present context is defined as the

ability of a firm to produce as large as possible an output from a given set of inputs. This definition is synonymous with the engineer's concept of efficiency. This means comparison of the observed performance of a firm with some postulated standard of perfect efficiency, so that each of the measures has, in general corresponding to each postulated standard, a different value and a different significance.

From the above it is evident that two different kinds of efficient production functions are possible - a theoretical function specified by engineers and an empirical function based on the best results observed in practice. The former would be a very natural concept to choose. After all, should not a postulated standard of perfect efficiency represent the best that is theoretically attainable. However, although the concept is reasonable enough and there have been attempts to define such functions for a single production process (Ref. 10), there are considerable objections to its application to anything so complex as a typical manufacturing firm.

This is due to a number of simplifying assumptions required, and difficulties attached to, *a priori* estimates of plant's needs, e.g., indirect labour. Consequently, in this study we adopted the second approach, i.e., comparing performances with the best actually achieved.

12.3.1 Statement of the method

Consider, for the sake of simplicity, a firm employing two factors of production to produce a single product, under conditions of constant returns to scale. Constant returns to scale means that output increases or decreases in the same proportions as to the factors of production, e.g., doubling labour, L, and capital, C, together will double the output. This point will be discussed further in Section 12.3.3. Suppos the efficient production function is known; that is, the output that a perfectly efficient firm could obtain from any given

combination of inputs.

In Figure 12.2, the point, P, represents the input of the two factors, per unit of output, that the firm is observed to use. The isoquant SS' represents the various combinations of the two factors that a perfectly efficient firm might use to produce a unit output.

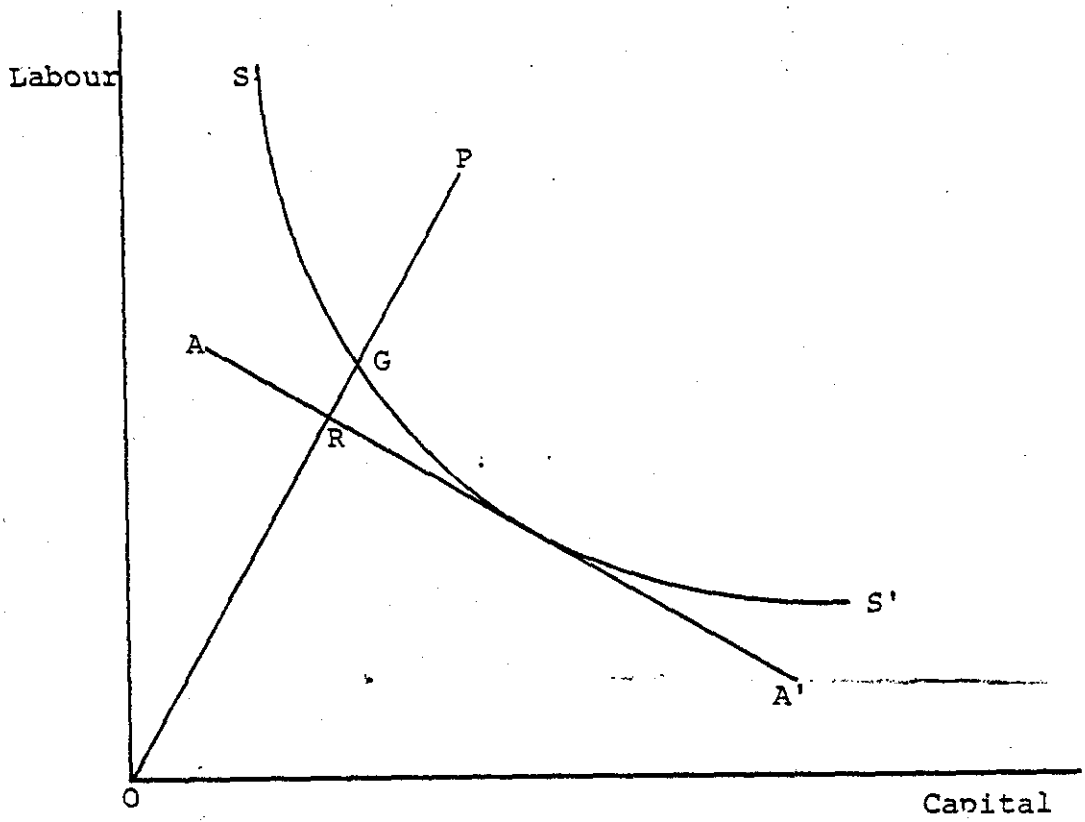


Fig. 12.2 Efficient production isoquant

Now the point Q represents an efficient firm using the two factors in the same ratio as P. It can be seen that it produces the same output as P, using only a fraction OQ/OP as much as each factor. It could also be thought of as producing OP/OQ times as much output from the same inputs. It thus seems natural to define OQ/OP as the technical efficiency of the firm P.

This ratio takes the value of unit y (or 100 per cent) for a perfectly efficient firm, and will become infinitesimally small if the amounts of inputs per unit

become infinitely large. Moreover, so long as SS' has a negative slope, an increase in the input per unit of output of one factor will, *ceteris poribus,* imply lower technical efficiency.

However, one also needs a measure of the extent to which a firm uses the various factors of production in the best proportions, in view of their prices. Thus in 12.2, if AA' has a slope equal to the ratio of the prices of the two factors, Q' and not Q, is the optimal method of production; for, although both points represent 100 per cent technical efficiency, the costs of production at Q' will only be a fraction OR/OQ of those at Q. It is natural to define this ratio as the price efficiency of Q.

Further, if the observed firm were to change the proportions of its inputs until they were the same as those presented by Q', while keeping its technical efficiency constant, its costs would be reduced by a factor OR/OQ, so long as factor prices did not change. It is therefore reasonable to let this ratio also measure the price efficiency, P, of the observed firm. This argument is not entirely conclusive, as it is impossible to say what will happen to the technical efficiency of a firm as it changes the proportions of its inputs, but, with this qualification, it seems the best measure available. It also has the desirable property of giving the same price efficiency to firms using the factors in the same proportions.

If the observed firm was perfectly efficient, both technically and in respect of prices, its costs would be a fraction, OR/OP, of what they in fact are. It is convenient to call this ratio the overall efficiency of the firm, and one may note that it is equal to the product of technical and price efficiencies.

12.3.2 Estimation of efficient isoquant

The method described in Section 12.3.1 requires estimation of the efficient isoquant from the scatter diagram. To estimate this isoquant Farrell (Ref. 6) makes the following assumptions: that the isoquant is convex to the origin and has nowhere a positive slope; and that the curve SS', Figure 12.3, is the most conservative (or pessimistic) estimate of it. This simply means that SS' is the least-exacting standard of efficiency that is consistent with the observed points and which satisfies these two assumptions. The convexity supposition amounts to assuming that if two points are attainable in practice, then so is any point representing a weighted average of them. The assumption "constant returns to scale" merely requires that the processes represented by the two points can be carried on without interferring with each other. The supposition that the slope of the isoquant is nowhere positive means that increased applications of both factors would not result in reduced output.

In the case of one output and two inputs, Figure 12.3, the curve SS' may be defined geometrically as follows: It is composed of the line segments joining certain pairs of points, chosen from a set A of points consisting of the observed points plus the two points $(0, \infty)$ and $(\infty, 0)$. The two points at infinity are added to give the parts of SS' parallel to axis. The pairs of points chosen are those for which the line joining them satisfies the two conditions:

(1) That its slope is not positive; and

(2) That no observed points lie between it and the origin.

These two conditions can conveniently be expressed as the single condition -- that no point of A lies on the same side of the line as the origin.

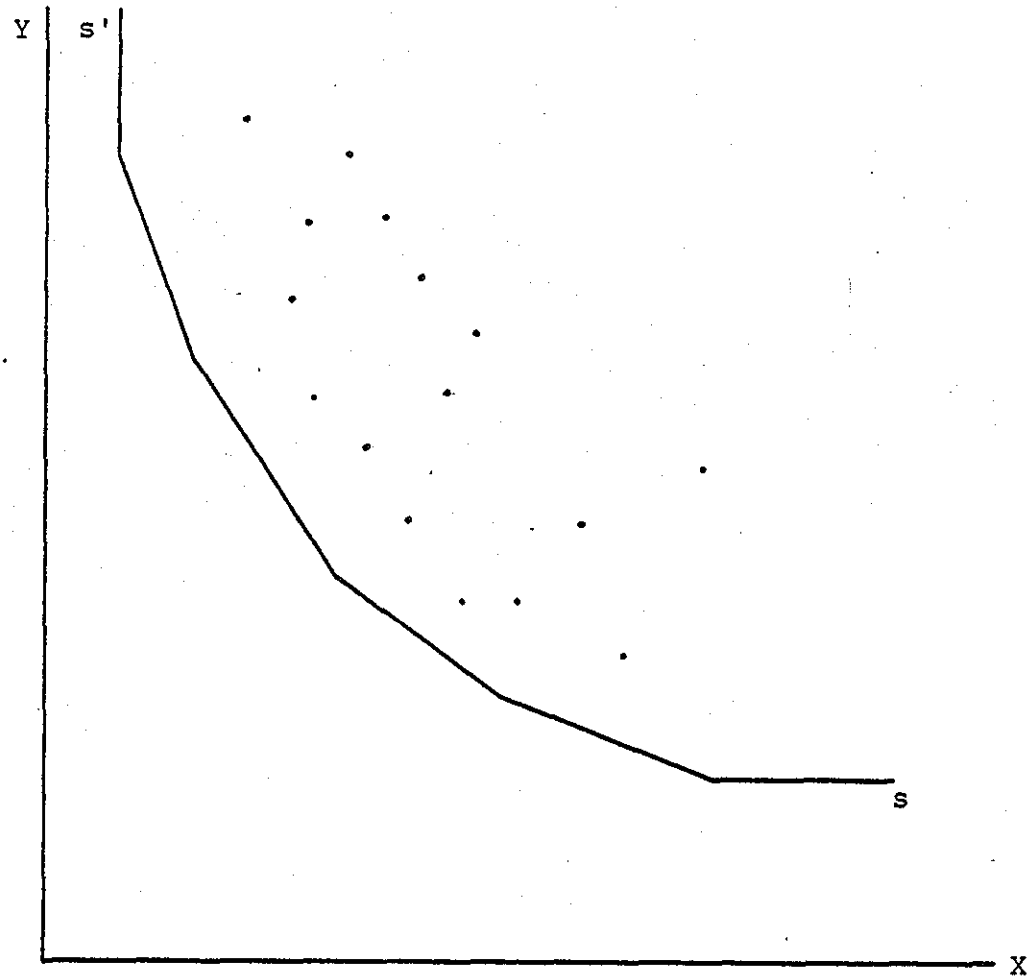


Figure 12.3 Graphical Representation of Two-Dimensional Efficient Production Isoquant

This is equivalent to the following algebraic definition:

Write any point in the form Pi = (x_{i1}, x_{i2}) and let λ_{ijk}, μ_{ijk} be the solution of the equations

$$\lambda x_{i1} + \mu x_{j1} = x_{k1} \quad \text{and} \quad \lambda x_{i2} + \mu x_{j2} = x_{k2} \qquad (12.1)$$

where P_i, P_j and P_k are points in A. Then the line-segment joining P_i and P_j is part of SS' if, and only if,

$$\lambda_{ijk} + \mu_{ijk} \geqslant 1 \quad \text{for all} \quad P_k \quad \text{in A} . \qquad (12.2)$$

It is perhaps worthwhile to elaborate a little. Any point on the line $P_i\ P_j$ can be written as $(\lambda x_{i1} + \mu x_{j1}, \lambda x_{i2} + \mu x_{j2})$, where $\lambda + \mu = 1$; and for points between Pi and Pj, $\lambda, \mu \geqslant 0$. Hence, if Pi Pj lies between Pk and the origin, $\lambda_{ijk} + \mu_{ijk} > 1$; and if OP_k cuts Pi Pj internally, $\lambda_{ijk}, \mu_{ijk} \geqslant 0$. Thus, the Equations (12.1) may be used to determine the technical efficiency of any point P_k.

It is first necessary to find which segment of SS' is intersected by OP_k -- that is, to find the segment Pi Pj of SS' for which $\lambda_{ijk}, \mu_{ijk} \geqslant 0$. Then the technical efficiency of

$$P_k = \frac{1}{\lambda_{ijk} + \mu_{ijk}}$$

An equivalent but more elegant definition (and one which is useful in computations) is that the technical efficiency of P_k is the maximum of

$$\frac{1}{\lambda_{ijk} + \mu_{ijk}}$$

for all segments Pi Pj of SS'. The convexity of SS' ensures that this expression reaches its maximum, where $\lambda, \mu \geqslant 0$. The generalisation to permit n inputs, while retaining the assumption of a single product and constant returns, is straightforward. Each observed firm is now represented by a point in n-dimensional space, written typically as a column vector x_i. The set A is constructed by adding to the observed points n points:

$$(\infty, 0, \ldots, 0), (0, \infty, \ldots, 0) \ldots, (0, 0, \ldots, \infty)$$

Just as in two dimensions where pairs of points in A defined lines and line segments, so now sets of n points in A define hyperplanes and "facets". Here "facet" is used to describe that part of a hyperplane the points of which can be expressed as weighted averages, with non-negative weights, of the n defining points. The efficient

isoquant is now a surface S in n dimensions, composed of such facets.

To the Equations (12.1) there corresponds the matrix equation

$$[x_i, x_{i+1}, \ldots x_{i+n-1}]\lambda = x_k \qquad (12.3)$$

whose solution is the column vector λ, and the facet defined by n points $P_i, P_{i+1}, \ldots P_{i+n-1}$, is part of S, if and only if,

$$\lambda' u \geqslant 1 \quad \text{for all } P_k \text{ in } A \qquad (12.4)$$

where u is a unit column vector. As before, the technical efficiency of P_k may be defined either as $1/\lambda' u)$ for that facet intersected by OP_k, or as the maximum of $1/_{(\lambda' u)}$ for all facets of S.

The relaxation of the single product assumption is slightly more complex. Since output is no longer a scalar quantity, it is no longer possible to reduce the observations to points on an isoquant diagram by dividing inputs by output. Instead, each observed firm has a vector X_i of outputs and a vector x_i of inputs and must be represented by a point in (n + m)-dimensional space. The efficient surface S is now composed of facets determined by sets of n+m points, chosen from a set A including, besides the observed points and the points at infinity, the origin. As the constant returns are still assumed, the definition of a facet is changed to permit the origin a negative weight. It follows that the origin appears in every efficient facet. The counterpart of Equations (12.1) and (12.3) is now the matrix equations

$$\left.\begin{aligned} [X_i, X_{i+1}, \ldots X_{i+m+n-2}, 0]\lambda &= (\lambda' u) X_k \\ [x_i, x_{i+1}, \ldots, x_{i+m+n-2}, 0]\lambda &= x_k \end{aligned}\right\} \qquad (12.5)$$

equivalent to n + m linear equations. The counterpart of conditions (12.2) and (12.4) is that

$$\lambda' u \geqslant \text{ for all } P_k \text{ in } A ,$$

and the efficiency of P_k is defined in terms of $\lambda'u$ precisely as before.

In fact, this criterion is simply a generalisation of the previous ones. It can easily be shown that in the case where $m = 1$ (so that X_i is a scalar) the two procedures are equivalent. Let $\lambda = (\lambda_1, \lambda_2, \ldots \lambda_{n+1})$ be the solution of Equation (12.5) and define $\mu = (\mu_1, \mu_2, \ldots \mu_n)$ by

$$x_{i+j-1}\lambda_j = X_k\mu_j \text{ , where } j = 1, 2, \ldots, n . \quad (12.6)$$

The Equation (12.5) may be written

$$\lambda'u = \mu'u$$

$$\left(\left[\frac{1}{X_i} x_i, \frac{1}{X_{i+1}}(x_{i+1}), \ldots, \frac{1}{X_{i+n-1}} x_{i+n-1} \right] \mu = \frac{1}{X_k} x_k \right) \quad (12.7)$$

It will be seen that Equation (12.7) consists of Equation (12.3) rewritten in the present notation, plus the statement that $\lambda'u = \mu'u$, i.e., that the two criteria are equivalent.

The interpretation of the technical efficiency of P_k defined in this way is precisely the same as before. If an efficient firm were to produce outputs X_k, it could do so from inputs $1/(\lambda'u)x_k$; or, using inputs x_k, it could produce outputs $\lambda'uX_k$. Thus, except for the need to change the geometrical picture, this generalisation, too, is straightforward.

12.3.3 Shortcoming of the method

The method described for the estimation of the efficient isoquant is based on the assumption of constant returns to scale. Unfortunately, it is not possible to relax this constraint to allow for economies of scale (increasing returns to scale); however, it is quite simple to allow for diseconomies of scale (decreasing returns to scale). The difference between the three cases is illustrated in Figure 12.4 for a simple case of one

input and output. In the case of constant returns to scale (the straight line), the percentage change in output is the same as the percentage change in each input. In the case of increasing returns to scale, the percentage increase in the output is greater than the percentage change in each of inputs, and vice versa in the case of decreasing returns to scale. The parameter, R, represents the three states of operation scales.

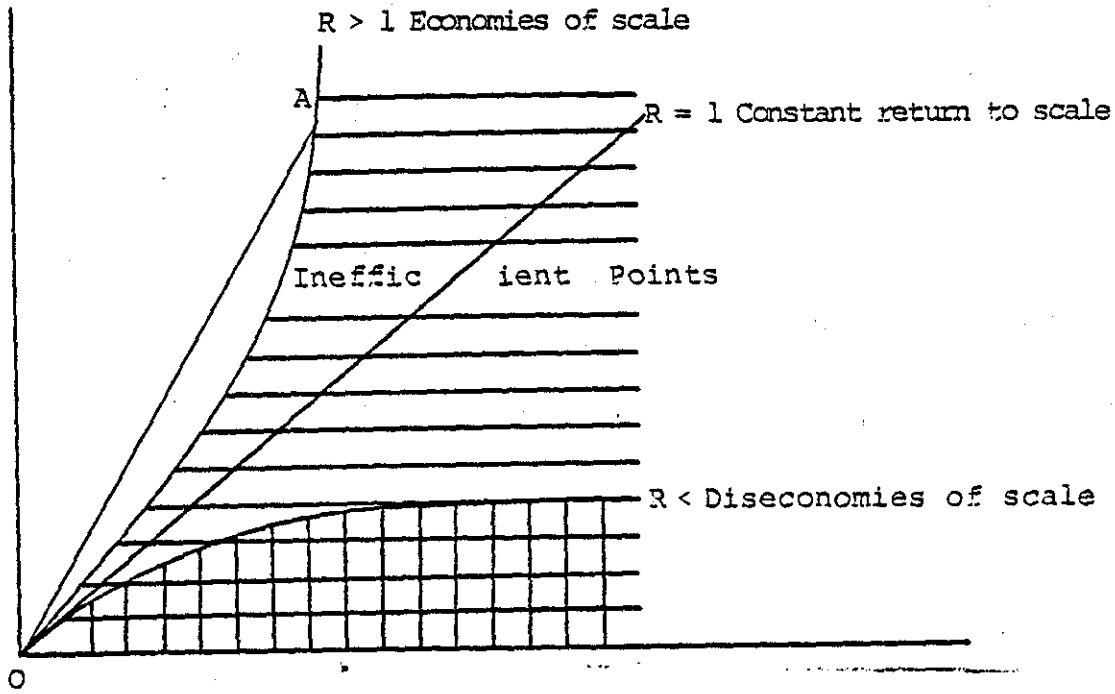


Figure 12.4 Returns to Scale

All that is necessary to account for diseconomies of scale, is to alter the definition of a facet offered in the last section so as not to permit a negative weight to the origin, in cases of multi-input and -outputs Equations (12.3), so as to permit any set of n + m points from A (not necessarily including the origin) to determine a facet.

The method described in previous sections breaks down completely in the case of economies of scale, because it is based on the assumption of convexity, and the efficient production is concave. This simply means that the average

of two points on isoquant is unattainable in the case of economies of scale. As a consequence, the method will give an optimistic instead of a conservative estimate of the isoquant, some straight line like OA -- and, of course, a pessimistic estimate of the efficiency of any point (Fig. 12.4). Indeed, none of the justifications of the method advanced in previous sections will hold, and furthermore, the estimated isoquant will always show apparently constant returns.

The only practical method of dealing with this problem seems to be that of dividing the observations into groups of roughly equal output (Ref. 6), and applying the method to each of these groups separately, the assumption being that returns are constant within a group to a sufficient degree of approximation. This will yield a different efficient isoquant for each level of output, and comparison of these isoquants will show the extent and the nature of the economies of scale. The disadvantage of this device is the need for much larger numbers of observations in comparison with the original method.

12.3.4 Interpretation of technical and price efficiency

One of the most important features of the method outlined above is the distinction between price and technical efficiency. The former measures a firm's success in choosing an optimal set of inputs, the latter its success in producing maximum output from a given set of inputs. This distinction is quite a natural one, but it also has the merit that most of the difficulties are associated with price efficiency, leaving technical efficiency as a relatively uncomplicated measure (Ref.).

In interpreting technical efficiency one must be aware that factors of production are heterogeneous. Thus, the technical efficiency of a firm must always, to some extent, reflect the quality of its inputs; it is impossible to measure the efficiency of its management entirely separately from this factor. Technical efficiency, then,

is defined in relation to a given set of firms, in respect of a given set of factors measured in a specific way, and any change in the specifications will affect the measure. The price efficiency of a firm depends on the set of firms (i.e., cross sectional analysis; this point will be discussed later) in the analysis, and is indeed much more sensitive to the introduction of new firms than is technical efficiency. It can be seen from Figure 12.2 that OR/OQ, the price efficiency of P, depends on the slope of AA', the slope of SS' at Q, and its curvature between Q and Q'. The introduction of fresh observations is likely, if it affects this part of SS' at all, to affect both the slope and the curvature, in either direction and perhaps quite substantially.

This would have a large effect on the price efficiency of P, as indeed would a change in the slope of AA'. Thus price efficiency is very sensitive to the introduction of new observations and to errors in estimating factor prices, so that it is likely to be unstable.

The use of the straight line AA', Figure 12.2, in defining price efficiency, implicitly assumes a perfectly-elastic supply of each factor. In fact, the elasticities of supply will usually be positive, so that changing the proportions of the inputs will change their price ratios, those of which relatively more is used becoming relatively dearer. This means that OR/OQ will tend to underestimate the true price efficiency of the firm.

However, over and above these problems there remains the question of whether a high price efficiency is necessarily desirable. It may be that a firm's best policy is to operate for a time well above optimum output (in a period of expansion, say, or one of temporarily high demand) even though this gives it a low price efficiency. Similarly, a firm whose inputs are adjusted to past or expected future prices may not be inefficient. In short, its price efficiency measures the extent of a firm's adaptation to a particular set of prices, and will

therefore provide a good measure of its efficiency in adapting to factor prices only in a completely static situation.

Thus, price efficiency is a measure that is both unstable and of dubious interpretation; its virtue lies in leaving technical efficiency free of these faults, rather than in any intrinsic usefulness. From the point of view of the planner, the technical efficiency of a firm or plant indicates the undisputed gain that can be achieved by simply "gingering up" the management, while its price efficiency indicates the gain that, on certain assumptions about the future price structure, can be obtained by varying "the input ratios".

12.4 The Cobb-Douglas Production Function

The method described in Section 12.3 attempts to estimate the efficient production function, by fitting a convex frontier isoquant to the observed points on the scatter diagram and comparing the observed, with the best-achieved, performance. Although the method is theoretically sound, there are practical difficulties in application. These are discussed in the following chapter.

If one was to modify the efficiency definition presented in Section 12.2, to comparing the average achieved performance with the observed performance, then it is possible to use the Cobb-Douglas production function. The value of this ratio would not obviously vary between zero and one as before, depending on the position of observed performance; it could have values larger than one. Apart from Cobb-Douglas, there are other production functions. However, these are more appropriate to long-run macro-situations and also estimation problems are much more complex. For these reasons in the present study we have attempted only to estimate Cobb-Douglas types of production function.

12.4.1 The function

A mathematical relationship between output and inputs, i.e., capital and labour factors of production, was first introduced in 1928 by Cobb and Douglas (Ref. 7). This relationship, which has come to be known as the Cobb-Douglas function (C-D function) has the form:

$$P = AL^{\alpha}K^{1-\alpha} \qquad (12.8)$$

where

P is net output;
L is a measure of labour factor input;
K is a measure of the capital factor input; and
A and α are scale and elasticity constants.

In derivation of this function, they made the following explicit and mutually-exclusive assumptions:

(a) That the law of diminishing returns operates (this is equivalent to assuming an isoquant convex to the origin); and

(b) Constant returns to scale.

This function was based on observations of the share of wages in the total output at macro-level. The relationship they found was that the total wage bill was a constant proportion of the output, i.e.:

$$WL = \alpha P \qquad (12.9)$$

where

W is the wage rate.

It can be shown (Ref. 12) that in perfectly-competitive markets with profit-maximising entrepreneurs, wages equal the marginal product of labout ($W = \frac{dP}{dL}$). Therefore, Equation (12.9) may be rewritten as:

$$W.\frac{dP}{dL} = \alpha.\frac{P}{L} . \qquad (12.10)$$

From this empirical result they worked back to obtain Equation (12.8). Durand (Ref. 11) states that the following function also satisfies the condition stipulated by Equation (12.10):

$$P = AL^{\alpha}K^{\beta} \qquad (12.11)$$

and there is no need for imposing constraint on the exponent of capital, thus removing the assumption of constant returns to scale. The exponents α and β in Equation (12.11) can take any positive values; if $\alpha + \beta = 1$, then we have economies of scale; if $\alpha + \beta > 1$, then we have increasing returns to scale; and if $\alpha + \beta < 1$, we have dis-economies of scale.

In fact, the sum of exponents α and β have been approximately equal to unity, with values of 0.35 and 0.65, respectively, in the case of C-D production functions estimated for various industrial sectors and national economies (Ref. 13, 14).

Assumption (a), which implies a convex isoquant, is, in fact, implicit in C-D functions. Hicks (Ref. 15) devised a parameter called the elasticity of substitution for describing the shape of the isoquant. It is defined as the ratio of the percentage change in factor proportions to the percentage change in the factor's relative prices. He proved that a C-D function has a constant elasticity of substitution of unity (Ref. 12, 15). This means that a 1 per cent change in the factor's relative price will bring about a 1 per cent change in factor proportions. This holds independently of the values given to the constants α and β. Hence, a particular C-D function is one of a class of unit elasticity functions. This means that the isoquant implied by a C-D function is convex to origin independent of assumption (a).

This function can be expanded to accommodate other factors which may influence the production. As well, it could be modified to relate gross output to labour, capital and material inputs. A more general model is

of the form:

$$\text{Output } P = A\left((x_i^{\alpha i}) \ldots (xm^{\alpha m})\right) \quad i = 1, \ldots m \qquad (12.12)$$

where

x_i = level of the ith factor; and

A and α_i are parameters to be estimated.

12.4.2 Estimation of parameters A, α, β

The procedure most commonly used to estimate the parameters of the production function involves dealing with the linear logarithmic transformation of the general function (Equation 12.12). Thus, the transformation of the production function is:

$$\text{Log } P = \text{Log } A + \sum_{i=1}^{m} \alpha_i \text{Log} X_i \qquad (12.13)$$

or

$$p = a + \sum_{i=1}^{m} \alpha_i x_i \qquad (12.14)$$

Equation (12.4) is linear in a and α_i,s so that linear regression procedure minimises the sum of sequences of deviations of the transformed values of P and X_i.

12.4.3 Economic interpretations

In this section we discuss the economic interpretation of constant and exponent terms in the C-D function. The production function (in its original form) was defined as:

$$P = AL^{\alpha}K^{\beta}$$

where

$$\alpha + \beta = 1.$$

In the above equation the rate by which the marginal

productivity of a given factor

$$\frac{\Delta P}{\Delta L} \text{ and } \frac{\Delta P}{\Delta C}$$

(represented by the symbols $M.P_L$ for labour and $M.P_c$ for capital) changes with each proportionate variation in the quantity of that factor is (assuming that the quantity of other factors remains constant) the sum of the exponents of the other factors of production (Ref. 16). This may be termed the coefficient of flexibility of the marginal productivity function of a factor: $\Phi M.P_L$ and $\Phi M.P_c$. It is obtained by dividing the relative change in the marginal productivity of a factor by the relative change in its quantity, and may be expressed as follows:

$$\frac{\Delta \text{ Log } M.P_L}{\Delta \text{ Log } L}$$

and similarly for $M.P_c$. This means that an increase of 1 per cent in quantity of labour, with capital constant, would cause the marginal productivity of labour to decrease by β, while an increase of 1 per cent in quantity of capital (labour constant) would cause the marginal productivity of capital to decrease by α.

Assuming that the demand curve for each factor is identical with its marginal productivity curve, this would mean that the elasticity of demand for these factors (η_L and η_C) would be the reciprocal of their respective flexibilities, i.e.

$$\frac{\Delta \text{ Log } L}{\Delta \text{ Log } M.P_L} \text{ and } \frac{\Delta \text{ Log } C}{\Delta \text{ Log } M.P_C}$$

It also follows mathematically (Ref. 17) that, to the degree that marginal productivity in a competitive society (i.e., perfect market situation) determines the share of the total product received by labour and capital, we should expect each to receive a fraction equal to its own exponent. This, in fact, has been the case for studies conducted at the macro-level.

The sum of the exponents of the above equation also has an economic interpretation in terms of constant, increasing and decreasing scales or returns. This point has been discussed in previous sections and is not repeated here.

The constant term A maintains dimensional consistency between the left-hand side and the right-hand side of the production function equation. The units and size of "A" depends upon the units used for measuring P, L and K. "A" is also in a sense an efficiency parameter, as it fixes the position of the isoquant (Ref. 12). Thus, as "A" grows, less capital and labour is required to produce the given output P. For example, consider the production function for two economies. If the elasticities (α, β, etc.) for each economy are identical and the factor terms are consistently measured, the economy with a greater scale factor is more efficient (it can convert the same factor input into greater output) than the other economy.

12.5 Technical Change and the Aggregate Production Function

Solow (Ref. 18) recognised that the set of all known production techniques (of which the isoquant is the southwest boundary) may expand over time. This expansion is known as "technical progress".

There are two kinds of technical progress, "embodied" and "disembodied". Embodied technical progress proceeds at a rate dependent upon both the learning rate and the rate at which capital is changed (i.e., the rate at which investment takes place). In order to deal with embodied technical progress, it is necessary to distinguish various vintages of capital which comprise the current stock (and this is beyond the scope of the present work, and is very close to the theory of economic growth). Disembodied technical progress, on the other hand, requires no change in the type of capital stock (it may, for example, be an organisational change) and it depends solely upon the learning rate.

The learning rate may, in turn, be explained by research and development effort (Ref. 19) or by the cumulative experience (Ref. 20) or simply by the passage of time. It is this last type of explanation with which we shall be concerned. It will be remembered that the production function describes the shape and the positions of the isoquants; therefore, any technical progress will influence some or all of the parameters of the production function. However, in this case attention has been focused principally on the efficiency parameter "A" -- the other parameters α, β, etc., are assumed to remain constant over time.

Parameter "A" fixes the position of the isoquant. Technical progress which influences only "A" may, therefore, be described in terms of movement of the isoquant rather than by a change in its shape. The two extreme kinds of movement would be purely horizontal or purely vertical shifts in the isoquants in the direction of the origin (i.e., less of one or the other of the factors is required to produce the same output). A combination of these two cases would mean that less of all factors of production is required for a given output and would show itself as a diagonal shift of the isoquant towards the origin. Technical progress of this kind is therefore called factor-augmenting technical progress.

The three particular forms of factor-augmenting technical progress which were sketched out above (i.e., horizontal, vertical or diagonal movements of the isoquants) correspond to what are called Harrod-neutral, Solow-neutral and Hicks-neutral, respectively (Ref. 21). Each was born out of its author's own idea of what constitutes neutrality, but, for C-D function, all three are algebraically equivalent and empirically indistinguishable. Consider first the Hicks neutral case. This most obviously corresponds to horizontal changes in "A". If we assume that learning progresses at a constant proportional rate, we can write the production function as:

$$P = Ae^{x_1 t} L^{\alpha} K^{\beta} \qquad (12.15)$$

The parameters A, x, α and β, may again be estimated by multiple regression techniques if the function is linearised by taking natural logarithms:

$$\text{Ln } P = \text{Ln}A + x_1 t + \alpha \text{Ln}L + \beta \text{Ln}K \ . \qquad (12.16)$$

Harrod-type neutrality may be expressed as an increase in the efficiency of labour. Thus, if the labour input is measured in terms of "efficiency" units $\bar{L}$, we can rewrite the function as

$$P = A(\bar{L})^{\alpha} K^{\beta} \qquad (12.17)$$

and if the efficiency of labour is again improving at a constant proportionate rate we have

$$\bar{L} = e^{x_2 t} L. \qquad (12.18)$$

Combining 12.17, 12.18 and 12.16 yields:

$$P = Ae^{x_2 t} L^{\alpha} K^{\beta} \ , \qquad (12.19)$$

which is equivlent to the Hicks case of Equation (12.15), where $x_1 = x_2 \alpha$. Similarly for Solow neutrality we have:

$$P = AL^{\alpha} (\bar{K})^{\beta} \ , \quad \text{and} \qquad (12.20)$$

$$\bar{K} = e^{x_3 t} K \quad ; \qquad (12.21)$$

therefore,

$$P = A_e^{x_3 t} L^{\alpha} K^{\beta} \ , \qquad (12.22)$$

which, again, is equivalent to the Hicks case, Equation (12.15), where:

$$x_1 = x_3 \beta \ .$$

This equivalence stems from the case that with this particular function there will be no change in factor proportions unless α and β are changed by technical progress or unless the relative price of labour to capital is changed.

However, we have assumed that both are fixed.

12.6 Some Points on Methodology

There are two ways which the necessary information for derivation of a production function (regardless of the method) may be gathered. The first is to observe the outputs and inputs of a particular process, a company, or an industry over a period of time. If the factor proportions change over that period, then the isoquant can be estimated. This is called the time-series analysis approach. The second approach is to observe the outputs and inputs of each of a number of processes at one time. If each process has the same production function but has different factor proportions, then each will be producing at a different point on the isoquant. From these separate observations the shape of the isoquant can be estimated. This is known as the cross-section analysis approach. Clearly this empirical work would be incapable of yielding any information about the shape of the isoquant if the quantity of labour remained in fixed proportion to the quantity of capital. We would simply observe one point on the isoquant. Consequently, it is necessary to observe a series of different labour/capital combinations, the larger the difference in the ratios, the more of the isoquant being made "visible" to the observer.

12.7 Further Applications

So far, we have discussed the use of the production function in measurement of productivity. However, production functions have the potential of providing manufacturing management with a very powerful tool in forecasting and in long-range planning. In this section we discuss this latter use of the production function. In the case of time-series analysis, a production function can be defined as:

$$P(t) = AX \prod_{i=1}^{m} \{Xi(t)\}^{\alpha i} , \qquad (12.23)$$

$$t = 1, \ldots n .$$

This is, in fact, consistent with the Equation (12.12) as presented in Section 12.4.1. This equation can be used in estimating and predicting costs, the planning of capacity and in sourcing problems.

12.7.1 Cost estimation and prediction

A common requirement of production engineers is to make estimates of future costs of existing and of new products. These estimates are often used in important decisions such as system configuration and sales forecasting.

The total cost of producing the product in time t at a plant is determined by the levels of the factors required to meet the desired output $P_i(t)$.

The total cost can be defined as:

$$C_{i(t)} = W_{i(t)}L_{i(t)} + \Gamma_{1(t)}K_{i(t)} + \Gamma_{2(t)}E_{i(t)} + M \quad ,$$

where

$W_{i(t)}$ is the wage and overhead rate applied to direct labour hours;

$\Gamma_{1(t)}$, $\Gamma_{2(t)}$ are costs of investment in capital and other production factors such as engineering time, E_i ; and finally,

M is the material cost.

However, if the output is measured in value added, then there is no need for inclusion of M.

The above production and cost functions can be used to find the unit cost at time t as $C_{i(t)}/P_{i(t)}$ determines the unit cost. This involves an analysis of historical records to determine the parameters of the production function. Based on demand, forecast and budget constraints, the production function can be used to estimate future factor levels and the resulting costs.

12.7.2 Capacity planning

Long-term demand growth is usually met by either expansion of existing plants or by construction of a new plant. Both of these alternatives incur capital expenses as well as requiring management talent and labour. However, the most operations research models for long-term capacity planning consider only capital expenses incurred in installing physical capacity. Some of the most important considerations such as the rise in productivity of both capital and labour due to technological progress and interaction between labour, capital and management are overlooked. For example, instead of adding physically to the current plant, some investment in process research and development may increase the output of existing equipment and labour, thus alleviating the need for physical expansion of the plant. The production function is one model which specifies the output of a plant in terms of interactions between capital, labour, engineering, management and any other appropriate factors. The rate of output is the capacity of the plant. Lele *et al.* (Ref. 22) have suggested a mathematical model for long-term planning of capacity based on production functions. The model is as follows:

Let

d_{jt} = Demand at supply centres J at time t ;

P_{it} = Output rate at plant i at time t ;

l_{it} = Labour at plant i at time t ;

k_{it} = Capital at plant i at time t ; and

e_{it} = Engineering at plant i up to time t .

The quantities l_{it}, k_{it} and e_{it} correspond with L, I and E, respectively, which were defined earlier.

Let the production function be:

$$P_{it} = A_i^{\alpha 1i} . L_{it}^{\alpha 2i} . K_{it}^{\alpha 3i} . e_{it} .$$

Other factors can be incorporated in the production function if appropriate.

The constraints can be of the form

$$(P_t, l_t, k_t, e_t) E \Omega_t$$

where P_t, l_t, k_t and e_t are corresponding vectors and Ω is a convex set.

The objective function is

$$f_t(p_t, d_t) + g_t(l_t, k_t, e_t)$$

where f is the cost of meeting demand d_t given the output rate p_t and g is the cost of providing for output rate p_t by properly allocating l_t, k_t and e_t. The cost component f will include production costs other than capital, direct labour and indirect labour. It will include costs incurred due to inventory, distribution, over-supply and shortage.

The particular technique to find an optimal policy

$$(\dot{l}_t, \dot{k}_t, \dot{e}_t)$$

will depend upon the type of the objective function, the type of constraints which form the convex set Ω_t, and size of the problem. The model is a sequential model so that the techniques such as dynamic programming, or Pontryagin's maximum principal can be used for temporal decomposition of the problem. An additional level of decomposition is also available because of the structure of the decisions at any given time. The decisions can be grouped into two levels: (1) decisions made at corporate levels; and (2) decisions made at manufacturing management level. Figure 12.5 shows schematically such a decision structure.

This decomposition, parallel to the hierarchical structure of the management organisation, can be efficiently used to solve the problem. A model given (Ref. 23) shows

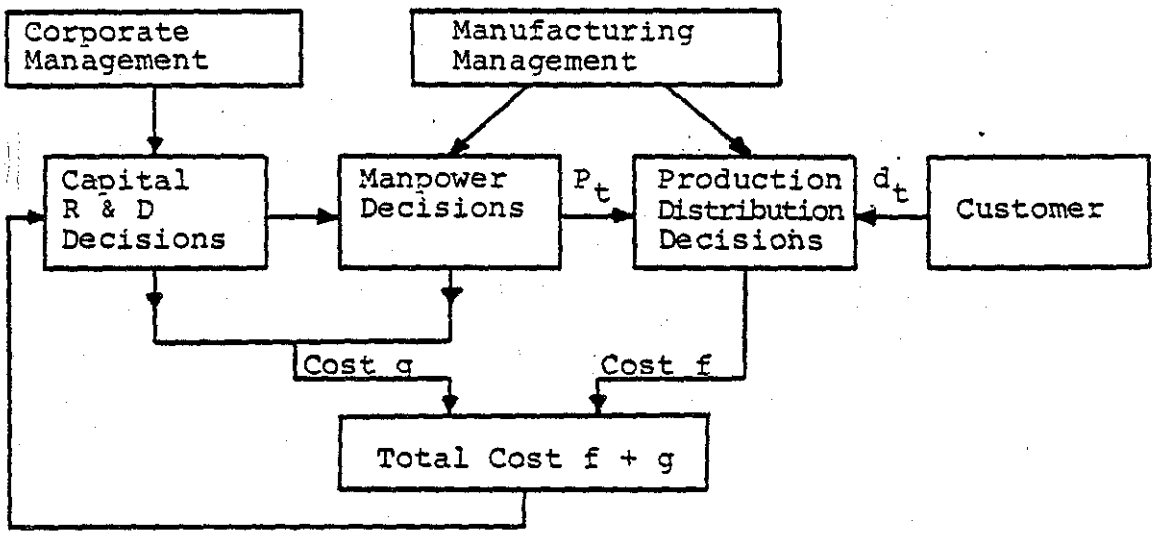


Figure 12.5 Schematic Diagram of Decision Structure

such an application. Notice that the solution to this problem will produce a time schedule of resource allocation. Production function analysis allows for an evaluation of many different time patterns of resource expenditure to achieve stated goals.

12.7.3 Sourcing problems

It is a common practice to have the same product produced at various plants. Many feel that larger production volume leads to lower unit costs, the principle which is termed "economics of scale". The sourcing problem is to determine the optimal configuration of plants by allocating various products among many plants so as to minimise total system costs given a certain demand function for each of the products. The total system costs include several cost components such as production, inventory, transportation, supply reliability and many others. Some of them favour the manufacture of a product in only one plant, namely single sourcing, whereas other favour the manufacture of a product in several plants, namely, multi-

sourcing. Production functions can be used in determining economies of scale and consequently to evaluate quantitatively the effect of sourcing on production costs. Therefore production functions can be incorporated in sourcing models. To see how production functions can enter into sourcing problems consider the following simple model (Ref. 22). Suppose that a product can be produced in only one plant F_o (single sourcing) or in two plants F_1, and F_2 (dual sourcing). Let P_i be the output of plant F_i and L_i and K_i be labour and capital, respectively, in plant F_i. Suppose the production function for plant F_i is of the form:

$$P_i = L_i^{\alpha} \times K_i^{\beta} \qquad i = o, 1, 2 .$$

Since total output must be the same in both cases:

$$P_o = P_1 + P_2 .$$

The respective production cost at plant F_i is

$$C_i = WL_i + \Gamma K_i ,$$

where W is the wage rate and Γ is the rate of payment for capital services.

The question is under what conditions the cost for single sourcing is less than the total cost for dual sourcing, i.e.:

$$WL_o + \Gamma K_o < (WL_1 + \Gamma K_1) + (WL_2 + \Gamma K_2) \qquad (12.25)$$

The relationship between elasticities and relative factor shares of total output, based on the assumption of perfect competition and cost minimization (Ref. 12) is given as:

$$\alpha/\beta = \frac{WL}{\Gamma K} . \qquad (12.26)$$

If the elasticities at each of the three plants and W and Γ are assumed to be the same, then it follows that:

$$\frac{\alpha}{\alpha + \beta} = \frac{WL_i}{WL_i + \Gamma K_i}$$

$$\frac{\beta}{\alpha + \beta} = \frac{\Gamma K_i}{WL_i + \Gamma K_i} \qquad i = o, 1, 2 \qquad (12.27)$$

From equations (12.26) and (12.27), it can be shown that:

$$\gamma^{(\alpha+\beta+1)} = \left(\frac{K_o}{K_2}\right)^{\beta} \left(\frac{L_o}{L_2}\right)^{\alpha} \qquad (12.28)$$

and

$$= \left(\frac{WL_o + \Gamma K_o}{WL_2 + \Gamma K_2}\right)^{\alpha+\beta}$$

where

$$= L_1/L_2 = K_1/K_2$$

The total cost of production at two plants F_1 and F_2 is:

$$W(L_1 + L_2) + \Gamma(K_1 + K_2)$$

which equals

$$(\gamma + 1)(WL_2 + \Gamma K_2) .$$

Therefore, the ratio of the total cost for the single source case and the dual source case is:

$$\frac{TC_o}{TC_1 + TC_2} = \left[1 + \gamma^{(\alpha+\beta)}\right]^{\alpha+\beta} \left(\frac{1}{1 + \gamma}\right) . \qquad (12.29)$$

Specifically, if $\alpha+\beta = 1$, i.e., in the case of constant returns to scale, the two costs are equal. If $\alpha+\beta < 1$ (i.e., increasing return to scale), the cost for single sourcing is higher than the cost for dual sourcing, and if $\alpha+\beta > 1$ (i.e., increasing return to scale), the cost for dual sourcing is higher. In simple terms, economies of

scale exist if the returns to scale are increasing and single sourcing will be advisable only if economies of scale are obvious ($\alpha+\beta < 1$).

A general model for the sourcing problem should consider incurred costs other than production costs and the constraints on various decision variables. The production costs can be represented with the aid of production function.

REFERENCES

1. Katz, J.M. "Production Functions, Foreign Investment and Growth". North Holland Publishing Company, Amsterdam, 1969.

2. Helps, I.G. "Forecasting Manpower: A Review of some Models used for Forcasting Changes in Total Employment at National and Sectoral Level". Working Paper National Economic Development Office, 1974.

3. Ferguson, C.E. "Time Series Production Functions and Technological Progress in American Manufacturing Industry". Journal of Political Economy, 1965.

4. Bosworth, D.L. "Production Functions". Saxon House, D.C. Heath Ltd., England, 1976.

5. Robinson, J. "Exercises in Economic Analysis". Macmillan, London, 1960.

6. Farrell, M.J. "Measurement of Productive Efficiency". Journal of the Royal Statistical Society, Series A, Part III, 1957.

7. Cobb, C.W. and Douglas, P.H., "A Theory of Production", American Economic Review, Vol. XVIII, 1928.

8. Arrow, K.J., Chenery, H.B., Minhas, B.S. and Solow, R.N. "Capital and Labour Substitution and Economic Efficiency". Review of Economics and Statistics, 1961.

9. Johansen, L. "Production Functions". North Holland, Amsterdam, 1972.

10. Chenery, H.B. "Engineering Production Function". Quarterly Journal of Economics, Vol. LXIII, 1949.

11. Durand, D. "Some Thoughts of Marginal Productivity with Special Reference to Professor Douglas' Analysis", Journal of Political Economy, 1937.

12. Heathfield, D.F. "Production Functions". Macmillan Press Ltd., London, 1971.

13. Gunn, G. and Douglas, P.H. "Production Function for Australian Manufacturing". Quarterly Journal of Economics, 1941.

14. Gunn, G. and Douglas, P.H. "Production Function for American Manufacturing in 1914". Journal of Political Economy, 1942.

15. Hicks, J.R. "Theory of Wages". Macmillan, London, 1963.

16. Douglas, P.H. and Handsaker, M.L. "Theory of Marginal Productivity Tested by Data for Manufacturing in Victoria". Quarterly Journal of Economics, Nov. 1937.

17. Gunn, G. and Douglas, P.H. "Further Measures of Marginal Productivity". Quarterly Journal of Economics, 1940.

18. Solow, R. "The Technical Change and the Aggregate Production Function". Review of Economics and Statistics, 1957.

19. Brown, M. and Conrad, A.M. "The Influence of Research Education in C.E.S. Production Relations". Studies in Income and Wealth, Vol. 31, National Bureau of Economic Research, New York, 1967.

20. Arrow, K.J. "The Economic Implications of Learning by Doing". Review of Economic Studies, 1962.

21. Allen, R.G.D. "Macro-Economic Theory". Macmillan, London, 1967.

22. Lele, P.T. and O'Leary, J.W. "Applications of Production Functions in Management Decisions". A.I.I.E. Transactions, Vol. 4, No. 1, 1972.

23. Cobian, M.J. and Lele, P.T. "Long Range Multi-Plant Capacity Expansion". Technical Papers, 21st A.I.I.E. American Convention, Cleveland, May 1970.

CHAPTER THIRTEEN

AN ECONOMETRIC APPROACH TO MEASUREMENT OF PRODUCTIVITY: APPLICATION

13.1 Introduction

In the previous chapter we discussed two econometric approaches to the measurement of productivity at the enterprise level. The application of these techniques are demonstrated in this chapter, using exclusively the data collected from company A (background described previously).

The advantages and disadvantages of each method are discussed, and also comparisons are made between productivity values calculated using various definitions of labour and capital inputs.

We have assumed throughout these case studies that factors of production consist only of labour and capital (treating material and bought-out services as throughput inputs). As well, the net outputs of the firm (value added) were aggregated to represent a single output. However, as has been mentioned previously, both techniques are capable of dealing with any other relevant factor of production. In the case of the technique put forward by Farrell it is possible to have multi-output cases, also.

However, before we demonstrate the application of these techniques, it is necessary to discuss briefly the problems associated with the measurement of inputs and outputs, and quasi-factors of production. These are discussed in the following section.

13.2 Measurement of Outputs and Inputs

The practical difficulties of measuring particular inputs or outputs are similar to those described previously (Chapter 5). However, the application of these techniques as opposed to those described in previous chapters create a new set of difficulties as well as removing some of the old problems.

As one may recall in the case of total factor productivity, value added productivity and productivity costing, it was necessary to represent the vector of inputs by a scalar -- to add up labour, materials, capital, etc., into a single quantity. This obviously required dimensional consistency, so that all inputs and outputs were measured in the same unit. Such a restriction does not apply in the case of Farrell's technique or Cobb-Douglas production function. The output and inputs could be measured in physical units or in any other units as well as in mixed units. The dimensional consistency between the left- and right-hand sides of the production function equation (previous chapter, Equation [12.8]), is achieved through the constant A, the unit and the size of which will depend upon the units used for measuring P, L and K. This holds true in the case of the Farrell technique, as the only difference between the two, is that one is fitting a frontier curve (Farrell) and the other an average curve (Cobb-Douglas production function).

In using either technique, it is important at the outset to recognise that the length of the working week affects the position of the isoquant (Ref. 1). For example, if a factory works on one shift basis plus overtime and it changes to two shifts, plus no overtime, this would change the capital and labour utilisation and consequently the position of the isoquant. The problem of shift working is a complex problem and dealing with it is outside the scope of the present study.

The other question which arises in the application of these techniques is whether in a particular application the inputs of a given firm or different time periods are really "the same" as those represented by the corresponding point on the efficient isoquant. Of course, if (as has been implicitly assumed) there is a small number of homogeneous factors of production, each of which can be measured in physical or monetary units, there is no problem. However, factors of production are notoriously heterogeneous.

The mere heterogeneity of factors does not matter, so long as it is spread evenly over firms or time periods. It is when there are differences between firms (or time periods) in the average quality (or, more strictly, in the distribution of qualities) of a factor, that a firm's technical efficiency will reflect the quality of its inputs as well as efficiency of its management. If these differences in quality are physically measurable, it may be possible to reduce their effect by defining a larger number of relatively homogeneous factors of production, but in practice it is never likely to be possible to completely eliminate it. Capital, in this respect, presents a particularly difficult problem. The relative productiveness of two different sets of equipment may vary considerably according to the amounts of other inputs. This is to say that each must be represented by a production function of different shape. In this case, it would be impossible to measure capital by any scalar quantity, such as a money value. It is only when the functions are of roughly the same shape, so that the relative productiveness does not vary much with changes in other inputs, that measurement in money terms will be satisfactory. Ideally, the treatment of capital must, then, be to define a number of different sorts of capital, each homogeneous ~~in this~~ sense, and to measure each in either physical units or money terms. This is obviously extremely difficult, or in some cases, it is impossible in practice.

13.2.1 Measurement of output

The net value of output (value added) has been used in the majority of studies conducted at macro-level (Refs. 1, 3, 4, 7, 12, 13, etc., of previous chapter). The reason for this is to avoid double accounting as explained in Chapter 7. In present case studies, we have used value added by the firm (net output) as the measure of the enterprise's output. As before, value added was computed by subtracting from sale values the cost of purchased raw materials, parts and services. These values were deflated to a base period value to obtain a physical

measure of net output using a double deflation technique described in Chapter 7.

13.2.2 Capital input

Capital input at macro-level studies is measured using various estimating methods, such as fuel proxy (Ref. 4, previous chapter), gross stock of capital, net stock of capital, rate of flow of investment per annum, etc.

In present case studies, we used the techniques described in Chapter 5 for determining the capital input. In addition, we used depreciation values per period as these represent, in a sense, the physical use of capital stock.

As mentioned, the measurement of capital input presents considerable difficulties, especially in relation to relative productiveness of different sets of equipments and relating the annual measure of capital input to its utilisation output. We did not attempt to divide the capital assets to groups of similar productiveness as this was infeasible. However, it is important to account for under-utilisation of capital input. This was ~~done~~ by multiplying the capital input by a utilisation factor. The utilisation factor was simply defined as the ratio of output to the maximum capacity. Capacity, as before, was defined as the maximum feasible physical output.

13.2.3 Labour input

We used both physical (number of hours) and financially-weighted measures of labour input. Various categories of physical measure of labour input used were (1) number of hours attended by direct production workers: (2) number of hours actually produced by direct employees; and (3) the total number of hours attended by all wage earners.

The method of determing the financially-weighted measure of labour input was discussed in Chapters 5 and 6

and is not repeated here. The categories of labour input (financially weighted) used were: (1) direct production employees input; (2) total direct and indirect blue collar workers contribution; (3) indirect labour input (salaried staff); and (4) finally, the total work force contribution.

In these studies we did not attempt to include the effect of shift working. However, as in the period under consideration, the pattern of working practices did not change markedly, this was justified. The labour input (blue collar) was adjusted by a labour utilisation factor. Labour utilisation factor was defined as the quotient of standard hours of production and the total number of hours attended. This information was readily available from companies accounting records.

13.2.4 Other factors of productions

As has been mentioned in the present study, we have only considered two factors of production, labour and capital. However, it is well-known that production depends on certain other factors besides those considered in this study -- location, the nature of the market in which a particular enterprise operates (demand ~~may be~~ seasonally dependent), energy requirements, climate, etc.

Econometric approaches have a very important advantage in that they can accommodate such quasi-factors of production, as long as the analyst can identify them and if they can be represented by a continuous or dummy variable as the case may be.

The inclusion of quasi-factors of production assumes greater importance in the case of cross-sectional analysis -- as in this instance, for example, location may affect production considerably.

The reason for not including quasi-factors of production in the present studies was the short span of the data, the analysis methodology (time series analysis), and finally,

the difficulties involved in identifying such factors in a relatively short period of time spent by the author in the collaborating company.

13.3 Method of Computation: Farrell's Technique

In this section, we will discuss the computing problems which arise in cases where there are n inputs, one output and constant returns to scale. The problem is essentially very simple; as a glance at Section 12.3.2 of the previous chapter shows, Equation (12.4) is a necessary and a sufficient condition for n vectors on the left-hand side of Equation (12.3) to define an efficient facet. An obvious solution is thus to solve Equation (12.3) for all possible combinations of n points in a set A, and to determine in each case whether Equation (12.4) is satisfied. If there are m observed points, this involves $N = {}^{n+m}C_n$ matrix inversions and an equal number of matrix multiplications. A numerical example would make the magnitude of the problem clearer, in the case of three variables and nine observations; N is equal to 220, and four variables and eleven observations, N = 1,365. Clearly, in the case of even modest numbers of variables and observations the number of matrix inversions and multiplications would be prohibitively large for manual computation. Furthermore, the nature of the problem is such that it would be too large for most mini-computers as well. This, indeed, is one disadvantage of the method. In order to be able to employ this technique for a modest number of observations and variables one has to have access to a main frame computer.

There are also difficulties associated with points at infinity in set A. The method adopted to deal with the problem was simply to treat them on a par with the other vector inputs, substituting a suitably large number for the infinite element. Inclusion of points at infinity obviously increases the size of N considerably.

13.3.1 Results

The technical efficiency of the firm was calculated based on Farrell's technique for the past four-and-a-half and two-and-a-half years using a six-montly interval between each measurements, i.e., a total of nine and of five observations, respectively. The reason for the choice of time spans and intervals were discussed in Chapter 6 and are not repeated here.

In the case of two-and-a-half years time span, we used two measures of labour input, namely, total employee input (weighted financially, and actual hours spent on production by direct labour, and four measures of capital input, i.e., service value, investor contribution, depreciation, and net stock of capital.

Figures 13.1 to 13.8 shows the scatter diagrams used for this purpose and Table 13.1 shows the technical efficiencies for periods 1 to 5, i.e., the first half of financial year 1977/78 to the first half of financial year 1979/80.

As it is evident from this table, the absolute values of technical efficiency are dependent upon the method used for measurement of inputs. In all cases bar one, period 2 had a 100 per cent efficiency, i.e. it lied on the efficient isoquant and period 5 had 100 per cent efficiency in six cases. It is interesting as well to note that despite the differences in absolute values of technical efficiencies, the patterns of variation were similar regardless of the method used for measuring the inputs. This leads us to conclude that if this technique was adopted for the purpose of measuring the technical efficiency of a firm, it is imperative to use a consistent definition and method of measurement for all outputs and inputs.

Figures 13.9 to 13.12 show the scatter diagrams used for calculating the technical efficiency for the past nine periods, i.e., the first half of 1975/76 to 1979/80,

and Table 13.2 shows the values of technical efficienies. A comparison between Table 13.1 and 13.2 shows a similar pattern of variation for period 1 to period 5 of Table 13.1, which coincides with periods 5 to 9 of Table 13.2. However, the absolute value of technical efficiencies varies between two cases. This leads us to conclude that the introduction of new points may lower the technical efficiency of existing observations, but it cannot increase their technical efficiencies.

The curve SS' on Figure 13.1 is the efficient isoquant. As it is evident from Section 12.3.2 of the previous chapter and present arguments this method of measuring the technical efficiency of a firm consist of comparing points in time with hypothetical points which use the factors in the same proportions. This hypothetical point is constructed as a weighted average of two observed points, in the sense that each of its inputs and outputs is the same weighted average of those of the observed points. The weights being chosen so as to give the desired factor proportions.

From the results of calculations presented in Tables 13.1 and 13.2, it is clear that technical efficiency is defined in relation to a given set of observations, in respect of a given set of factors measured in a specific way and any change in these specifications will affect the measure. This is inevitable in any such measure. But with assumptions stated previously in force, effects of qualities of input and these qualifications, it functions in a natural and satisfactory way as a measure of efficiency.

13.4 Cobb-Doublas Production Functions

The concept of Cobb-Douglas production function was discussed in Section 12.4 of the previous chapter. Here we are concerned with the derivation of such functions for company A.

The factors of production considered were labour and capital. As before, various measures of labour input

used were: (1) actual labour hours spent on production; (2) hours attended by production workers; (3) total hours attended by all blue collar employees; (4) financially weighted; direct labour input; indirect labour input, and total work input. Five measures of capital input were used. These were, service value of capital, investor contribution, net stock of fixed capital, total stock of capital (fixed plus working capital), and finally depreciation. The output was measured using the value added concept.

At this point, it is important to recognise one very important difference between the Farrell's technique and production functions. Farrell's technique could theoretically be amended to handle cases of n inputs and m outputs, while production functions are applicable in cases of one output and n inputs. It is possible to derive a production function for each item of output, but then the addition of these functions does not normally lead to the overall production function of the firm.

The Cobb-Douglas functions (Equation 12.12 of the previous chapter) was linearised by natural logarithmic transformation of the observations. The values of constants α were computed using the linear multiple regression sub-routine of the SPSS program. The SPSS package and multiple regression technique are briefly described in Chapter 14.

13.4.1 Results

In order to perform multiple regression at least ten observations are required. To comply with this requirement the net output, labour and capital inputs were estimated for the past two-and-a-half years, using a monthly interval between each measurement, i.e., a total of 30 observations. This was not satisfactory, as the interval between the measurements were too short. One cannot expect much capital movement in such a short interval. However, if we had used a longer interval between each estimation (e.g., six months or a year), the number

of observations would have been too small for a sensible analysis.

The number of observations required, coupled with a sensible estimation interval, could be a problem in derivation of production functions for an enterprise. The scale of problem would obviously depend on the efficiency of a particular company in preserving its historical records in a manner which is easily accessible. Unfortunately, record-keeping was not very efficient in the case of company A, and we were forced to use a very short interval between each estimation.

Tables 13.3 to 13.8 show Dobb-Douglas production functions derived for company A. The asterisks on top of values of α, β, $(\alpha+\beta)$, λ, A, α_s, β_s, λ_s and F show the statistical significance of the estimated parameters. The meaning of statistical significance is explained in the following chapter. The definition of parameters presented in Tables 13.3 to 13.8, and the significance of numbers of asterisks, is given at the end of this chapter (key to Tables 13.3 to 13.8).

The F values presented in these tables are the overall F statistics for the equations, and it is evident that the overall regression is significant at 99 per cent confidence limit, except for the first equation, presented in Table 13.5, which is significant at the 95 per cent confidence limit. This indicates that the sample of observations being analysed has been drawn from a population which bears a multiple correlation not equal to zero; and that multiple correlation is not due to sampling fluctuations or measurement error.

Unlike the overall values of F statistics, there is a wide variation in the confidence limit of statistical significance of values of A, α, β and λ, and in some instances their values were even statistically insignificant. Apart from the short interval used for estimating the required observations, there are various other reasons

which cause the values of A, α, β, and λ to be statistically insignificant and these are discussed in the following section.

Symbols α_s, β_s, γ_s, and λ_s represent the standardised regression coefficients. These are calculated by standardising both dependent and independent variables to have unit variances (i.e., the standard deviation of both dependent and independent variables is equal to one). These coefficients obviously cannot be used to estimate the values of dependent variables in the original raw value unit. However, when variables are measured in different units, as is the case here, standardised coefficients provide a better mean to compare the relative effect on dependent variables of each independent variable. Furthermore, constant A is equal to zero and can be omitted. From Tables 13.3 to 13.8, we can see the relative influence of capital, labour and time on the output. Take as an example the first equation presented in Table 13.3, the value of λ measuring the percentage increase in P which would be caused by an increase of 1 per cent in capital with labour being constant; i.e., 0.912, while α_s indicates the number of standard deviation units change in output that would be predicted when capital changes by one standard deviation. $\alpha_s = 0.521$ indicates that the predicted output increases by 0.521 standard deviation units for each standard deviation unit increase in capital.

An interesting point to notice is that the values of α, β, λ and γ and their standardised counterparts are dependent on the method used for estimating the labour and capital input, as is evident from Tables 13.3 to 13.8. This indicates that if these functions are to be used as a management tool, it is imperative to measure the net output and various inputs in a consistent manner. The other interesting point is that in the majority of cases, the value of α is larger than β. This indicates that the company under consideration was highly labour-intensive as opposed to capital-intensive. In addition, the value

of $(\alpha + \beta)$ in majority of cases was greater than unity indicating increasing returns to scale.

The value of R^2 indicates the proportion of variation of dependent variables explained by independent variables, i.e., strength of linear relationship between output, labour, capital and time. The R^2 values, as is evident from Tables 13.3 to 13.8, had an average of 0.58, which is not very high. In fact, output variations were best explained when depreciation was used as the measure of capital input. The highest R^2 value was 0.738, Table 13.8.

The inclusion of time in all cases increased the value of R^2. As was mentioned in Section 12.5 of the previous chapter, inclusion of the time variable accounts for disembodied technical progress. In another word, the inclusion of a time factor permits the calculation of the rate of growth of total factor productivity (A); or, to put the matter more accurately, of that part of the rate of growth of output that cannot be explained by the weighted growth of capital and labour as conventionally measured. Such a measure of technical change constitutes a "catch all" residual which combines all factors influencing the rate of growth of output other than weighted rates of growth of capital and labour. Within this framework, there is no way of isolating technical change from the impact of non-constant returns to scale. Neither is there any way of isolating changes in the quality of labour input from changes in the quality of the capital services used in production.

13.5 Data Problems

Regression analysis is best applied under experimental conditions where the selection of values for independent variables is under the control of analyst. However, econometric variables cannot be varied for investigation purpose. Parameters of production functions are estimated from historical records in the form of the time series or cross-sectional data, which may have sample points lying in

a limited range. If one of the independent variables has a small variance compared to the variance of error terms, it will be difficult to estimate that factors elasticity with a suitable accuracy. Unfortunately, this condition existed in our data. The most likely explanation for this is the short time interval used for estimating the independent variables.

Other serious problems that typically arise in developing production functions are multicollinearity and autocorrelation. The term "multicollinearity" denotes the presence of linear relationship (or near-linear relationships) among explanatory variables. Time series values for the factors of production often are highly correlated with each other. In the case of our data, the level of correlation between independent variables varied according to the method of measurement used. The highest correlation coefficients were of the magnitude of 0.8, between total actual hours attended and capital input measured using the service value, investor contribution, net fixed stock of capital, and the net stock of capital concepts. As well, high correlation coefficients (of the order of 0.78) were observed between the financially-weighted direct labour input and the above-mentioned measures of capital input. The lowest correlation coefficient (of the order of 0.58) observed was between various labour input measures and depreciation and between actual hours of production and various capital input measurements.

The effect of multicollinearity is uncertain. The evidence from the theoretical econometric studies (with controlled data) as well as from applied research is controversial and by no means conclusive. In addition, there is argument as to the level of zero order correlation coefficients which could possibly cause problems. Generally, from the literature one can tentatively conclude that the presence of strong multicollinearity cast doubt on the relative regression estimates of the elasticities. When this happens, the analyst may choose to eliminate one of the correlated factors (which then might limit the

usefulness of his model) or to manipulate his variables to find an uncorrelated series (Ref. 2).

Autocorrelation refers to the correlation between values of regression residual in any particular period with its own preceding values. The problem of autocorrelation only arises in the case of time series data. The presence of autocorrelation affects the values and the standard errors of the parameter estimates. We tested for first-order autocorrelation (i.e., a relationship between successive values of residuals) using the Durbin-Watsond statistics. Based on this test, we did not detect any autocorrelation. However, this test is not a hundred per cent conclusive.

As before aggregation of data can be another serious problem in econometric models. Heterogenuity of labour and capital implies that they have divergent characteristics, i.e., they have different longevity, productivity and utilisations. This can cause difficulties in interpretation and correctness of coefficients.

13.6 The Use of Production Function for Productivity Measurement

The Cobb-Douglas production function can be used for the measurement of productive efficiency of an enterprise. The productive efficiency in this case is defined as the actual output per period divided by the output which could be achieved with the appropriate labour and capital input using the derived production function for the form. Obviously, the production function derived using regression analysis is an average function; consequently, the denominator of the above ratio does not represent the maximum possible output for the given level of inputs. As the result, this ratio could have values larger than one, and, in fact, is desirable to have values larger than one.

As previously mentioned, the production functions presented in Tables 13.3 to 13.8 were derived using monthly

observations for the past 30 months. However, the interval used for the measurement of productivity was six months. Obviously, as the production function is not linear, we could not have simply determined the output of the firm using the aggregated six-monthly measures of input.

To compute the six-monthly output for the past 2½ years, we had to calculate the output for each month, and to sum these up. For this purpose we used the following production functions:

$$P = 4.06\ K_{DE}^{0.296}\ L_{TL}^{0.682} \qquad (13.1)$$

$$P = 0.464\ K_{DE}^{0.462}\ L_{TL}^{0.722}\ e^{0.014t} \qquad (13.2)$$

where

K_{DE} = Capital input measured by depreciation; and

L_{TL} = Total financially-weighted labour input.

These two equations were chosen because the coefficient of correlation between the independent variables were low (in the order of 0.5) and R^2 values, i.e., the ~~percentage~~ of output variation explained by the equations were relatively high. From Table 13.7 it can be seen that the values of R^2 for Equations (13.1) and (13.2) were 0.622 and 0.719, respectively.

The productivity ratios computed for the company using this technique are presented in Table 13.9. As is evident, the pattern of variations is similar between the productivity ratios calculated using Equation (13.1) and and those of Equation (13.2). However, in absolute terms, the ratios calculated using Equation (13.2) are higher than those for Equation (13.1) in later periods. This is due to the parameter λ which measures the disembodied technical efficiency or the rate of growth.

The other applications of production functions were discussed in Section 12.7 of the previous chapter. However, the aim of this work is the measurement of productivity, and as a result the other applications were not examined.

13.7 Discussion and Conclusions

The Farrell's method is based on the assumption of constant returns to scale. The assumption could be relaxed to accommodate cases of reducing returns to scale. However, the method cannot accommodate cases of increasing returns to scale. This obviously is a very considerable shortcoming, particularly in its application to the measurement of technical efficiency at firm level, because in reality the assumption of constant return to scale does not hold at enterprise level. This in fact is evident from Tables 13.3 to 13.8, in the majority of cases $\alpha + \beta$ being larger than 1. Farrell suggests that this problem could be overcome by applying the technique to groups of roughly equal outputs. However, this is not entirely satisfactory for two reasons: (a) a relatively large number of observations are required which would make this solution not feasible, as is the case in the present study; and (b) in such an application, comparison of technical efficiencies computed would be invalid.

Application of this technique in most cases would require the use of a main frame computer which could be an unfeasible proposition in the cases of most smaller manufacturing enterprises. The reasons for the requirement of a main frame computer were discussed in previous sections and is not repeated here. In addition there are problems in the definition of outputs and inputs -- these were discussed in Section 13.2 and are not repeated.

On the credit side, the technique is applicable to n number of outputs and m inputs; also, there is no restriction on the units used for the measurement of outputs and inputs. The other important advantage of this

technique from the analyst's point of view is the ability to include discrete variables as well as the continuous variables.

The Cobb-Douglas production function provides an alternative method for the measurement of productivity of the firm. An obvious advantage of this technique is that there is no restriction on returns to scale, i.e., production functions are applicable to cases of reducing, constant, and increasing returns to scale. Another advantage of production function lies in the fact that the equation describes the actual isoquant, while Farrell's technique only seeks to estimate the relative position of various firms or points in time with those lying on the frontier isoquant. At best the use of Farrell's technique yields a series of equations for the lines or facets which make up the frontier isoquant. This simply means that Farrell's technique is only useful in estimating the technical efficiency, while the production functions have other management applications, as discussed in Section 12.7 of the previous chapter.

There are two disadvantages associated with the production function when used for the measurement of productivity. The first lies in the fact that these functions are only average functions and one compares the output achieved with only median potential output for a given level of inputs. The second disadvantage concerns the inability of these functions to handle cases of multi-outputs.

From the case studies, it is evident that the technical efficiency and estimates of elasticities are dependent on the method used for the measurement of factor inputs. However, because of the definition chosen for the efficient production function, the introduction of new firms or points in time into the analysis may reduce, but cannot increase, the technical efficiency of a given firm. This is not, of course, the case as far as the production functions are concerned.

At the expense of repetition, the most important consideration in the application of these techniques to the measurement of productivity is the need for consistency in definition and assessment methods used for aggregating the outputs and inputs. The definition and estimation techniques are dependent on the purpose of measurement and the availability of the data. It is impossible to generalise as to what constitutes the best estimation technique.

One very important advantage of econometric techniques as opposed to other methods described in previous chapters for the estimation of productivity at enterprise level is their use in the measurement of efficiency for comparison purposes. The data required for econometric techniques are easier to obtain (a very good source would be published accounts), because there is no restriction on measurement units. While in the case of other techniques one needs a great deal of detailed financial data which is difficult to obtain; and in any case, collection of data is time-consuming and labourious.

The use of Farrell's technique or the Cobb-Douglas production function for comparison purposes is most appropriate in cases where the sample firms are drawn from the same industry with similar characteristics.

Figure 13.13 shows the variation of productivity of company A for the past 2½ years, computed using Farrell's technique and the two Cobb-Douglas functions. The interesting point to notice is the similar pattern of variations. This pattern reinforces our earlier arguments.

Key to Tables 13.1 and 13.2:

C.S.V.	=	Capital Input Service Value Concept
C.I.C.	=	Capital Input Investor Contribution Concept
D.E.P.	=	Capital Input Depreciation Concept
C.N.S.	=	Capital Input Net Stock of Capital Concept
A.H.P.	=	Actual Hours Spent on Production by Direct Labour

Table 13.1 Measurement of Technical Efficiency Using Farrell's Technique for Past Two and Half Years

Period	Total Labour Capital C.S.V.	A.H. Production Capital C.S.V.	Total Labour Capital C.I.C.	A.H. Production Capital C.I.C.	Total Labour Capital D.E.P.	T.H. Production Capital D.E.P.
1	0.9015	0.871	0.8592	0.8959	0.8882	0.8836
2	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00	0.9445	1.00	0.9132	1.00	0.8937
4	0.9363	0.8465	0.9370	0.8467	0.9370	0.8465
5	1.00	1.00	0.9847	0.9802	1.00	1.00
	Total Labour Capital C.N.S.	A.H. Production Capital C.N.S.				
1	0.8744	0.8097				
2	0.9935	1.00				
3	1.00	0.9452				
4	0.9361	0.8821				
5	1.00	1.00				

Table13.2 Measurement of Technical Efficiency Using Farrell's Technique for Past Four and Half Years

Point	Total Labour Capitals S.V.	Direct Labour Capitals S.V.	Total Labour Total Capital C.I.C.	Efficiency Total Labour C.N.S.
1	1.00	1.00	1.00	1.00
2	0.901	0.9479	0.8866	0.9179
3	0.8876	0.8526	0.8326	0.9429
4	0.5984	0.7056	0.6294	0.6683
5	0.5889	0.6428	0.6014	0.7176
6	0.6583	0.8056	0.6935	0.8048
7	0.5974	0.7874	0.6910	0.8329
8	0.5517	0.8413	0.6737	0.8022
9	0.6869	0.7017	0.6844	1.00

Key to Tables 13.3 to 13.8:

K_{SV} = Capital Input Using Service Value Concept

K_{IC} = Capital Input Using Investor Contribution Concept

K_{FSC} = Capital Input Using Fixed Stock of Capital Concept

K_{TSC} = Capital Input Using Total Stock of Capital Concept

K_{DE} = Capital Input Using Depreciation Concept

L_{AH} = Labour Input Using Actual Hours Spent on Productions by Direct Workers

L_{TAH} = Labour Input Using Total Hours Attended by All Blue Collar Employees

L_{DL} = Labour Input Using Financially-Weighted Blue Collar Employees Input

L_{TL} = Labour Input Using Financially-Weighted Total Labour Input (Blue and White Collar Employees)

L_{IN} = Labour Input Using Financially-~~Weighted~~ White Collar Employees Input

Level of significance in the tables denoted by:

* Significant at 10% level

** Significant at 5% level

*** Significant at 1% level

Table 13.3 Cobb-Douglas Production Function : Capital Input Annualized Using Service Value Concept.

	α	β	$(\alpha+\beta)$	λ	A	α_s	β_s	λ_s	Standard Error	R^2	F
$P = AK_{SV}^{\alpha} L_{AH}^{\beta}$	0.912***	0.188**	1.10***	-	2.068*	0.521***	0.109**	-	0.301	0.533	13.36***
$P = AK_{SV}^{\alpha} L_{AH}^{\beta} e^{\lambda t}$	1.248***	0.230**	1.478***	0.0155***	0.096*	0.713***	0.134**	0.383***	0.281	0.638	6.75***
$P = AK_{SV}^{\alpha} L_{DL}^{\beta}$	0.521**	0.496**	1.017*	-	3.03*	0.298**	0.352**	-	0.291	0.374	8.054***
$P = AK_{SV}^{\alpha} L_{DL}^{\beta} e^{\lambda t}$	0.903***	0.439**	1.342**	0.0143***	0.100*	0.516***	0.311**	0.353***	0.275	6.63	7.469***
$P = AK_{SV}^{\alpha} L_{TAH}^{\beta} e^{\lambda t}$	0.900***	0.441**	1.341*	0.0143***	0.122*	0.514***	0.313**	0.354***	0.275	6.63	7.476***
$P = AK_{SV}^{\alpha} L_{DPH}^{\beta} e^{\lambda t}$	1.141***	0.260*	1.401**	0.0152***	0.082*	0.652***	0.195*	0.377***	0.279	0.648	7.039***
$P = AK_{SV}^{\alpha} L_{TL}^{\beta} e^{\lambda t}$	0.608*	0.762***	1.37**	0.0136***	0.041*	0.348*	0.458***	0.338***	0.272	0.673	7.788***

Table 13.4 Cobb-Douglas Production Function : Capital Input Annualized Using Investor Contribution Concept.

	α	β	$(\alpha+\beta)$	λ	A	α_s	β_s	λ_s	Standard Error	R^2	F
$P = AK_{IC}^{\alpha} L_{AH}^{\beta}$	1.027***	0.081	1.108	-	2.51	0.547***	0.047	-	0.302	0.528	6.60***
$P = AK_{IC}^{\alpha} L_{AH}^{\beta} e^{\lambda t}$	1.158***	0.125	1.283	0.0089*	0.391	0.617***	0.0727	0.221*	0.298	0.570	5.09***
$P = AK_{IC}^{\alpha} L_{DL}^{\beta} e^{\lambda t}$	0.670	0.538**	1.208*	0.0097**	0.449*	0.357*	0.382**	0.240*	0.286	0.618	6.232***
$P = AK_{IC}^{\alpha} L_{TAH}^{\beta} e^{\lambda t}$	0.667*	0.541**	1.208	0.0097**	0.580*	0.474*	0.353**	0.0066**	0.286	0.618	6.240***
$P = AK_{IC}^{\alpha} L_{DPH}^{\beta} e^{\lambda t}$	0.994***	0.316**	1.310*	0.0099**	0.333*	0.529***	0.237**	0.245***	0.290	0.604	5.362***
$P = AK_{IC}^{\alpha} L_{TL}^{\beta} e^{\lambda t}$	0.198	1.060***	1.258	0.0108**	0.093	0.106	0.639***	0.267**	0.278	0.651	7.12***

Table 13.5 Cobb-Douglas Production Function : Capital Input Net Fixed Capital Stock

	α	β	$(\alpha+\beta)$	λ	A	α_s	β_s	λ_s	Standard Error	R^2	F
$P = AK^{\alpha}_{FSC} \; L^{\beta}_{AH}$	0.658**	0.177	0.835	-	3.935	0.415**	0.103	-	0.323	0.431	4.044**
$P = AK^{\alpha}_{FSC} \; L^{\beta}_{DL} \; e^{\lambda t}$	0.720*	0.524**	1.244*	0.0166***	0.0247	0.454*	0.372**	0.407**	0.286	0.618	6.218***
$P = AK^{\alpha}_{FSC} \; L^{\beta}_{TAH} e^{\lambda t}$	0.716*	0.526**	1.242	0.0164***	0.033*	0.452*	0.374**	0.407**	0.286	0.618	6.229***
$P = AK^{\alpha}_{FSC} \; L^{\beta}_{DPH} e^{\lambda t}$	1.065***	0.279*	1.344*	0.0197***	0.034	0.672***	0.209*	0.487**	0.291	0.598	5.735***
$P = KK^{\alpha}_{FSC} \; L^{\beta}_{TL} \; e^{\lambda t}$	0.228	1.047**	1.275	0.0129	0.036*	0.144	0.630*	0.320*	0.278	0.651	7.132***

Table 13.6: Cobb-Douglas Production Function: Capital Input Total Net Stock of Capital

	α	β	$(\alpha+\beta)$	λ	A	α_s	β_s	λ_s	Standard Error	R^2	F
$P = AK_{TSC}^{\alpha} L_{AH}^{\beta}$	1.027***	0.0813	1.108	-	0.0273	0.547***	0.0474	-	0.302	0.529	6.604***
$P = AK_{TSC}^{\alpha} L_{AH}^{\beta} e^{\lambda t}$	1.159***	0.125	1.284	0.0089*	0.021	0.617***	0.0727	0.222	0.298	0.570	5.093***
$P = AK_{TSC}^{\alpha} L_{DL}^{\beta} e^{\lambda t}$	0.670**	0.538**	1.208*	0.0097**	0.029*	0.357**	0.382**	0.240**	0.286	0.618	6.233***
$P = AK_{TSC}^{\alpha} L_{TAH}^{\beta} e^{\lambda t}$	0.667*	0.541**	1.208*	0.0098**	0.034**	0.355*	0.384**	0.242**	0.286	0.619	6.241***
$P = AK_{TSC}^{\alpha} L_{DPH}^{\beta} e^{\lambda t}$	0.994***	0.316*	1.310*	0.0099**	0.017	0.529***	0.237*	0.245**	0.290	0.603	5.86***
$P = AK_{TSC}^{\alpha} L_{TL}^{\beta} e^{\lambda t}$	0.198	1.061**	1.259	0.0108*	0.0408	0.106	0.639**	0.267*	0.2779	0.651	7.121***

Table 13.7: Cobb-Douglas Production Function : Capital Input Depreciation

	α	β	$(\alpha+\beta)$	λ	A	α_s	β_s	λ_s	Standard Error	R^2	F
$P = AK_{DE}^{\alpha} L_{AH}^{\beta}$	0.594***	0.133	0.727	-	33.11**	0.559***	0.0776	-	0.295	0.558	7.525***
$P = AK_{DE}^{\alpha} L_{AH}^{\beta} e^{\lambda t}$	0.763***	0.175*	0.938	0.014***	21.33**	0.718***	0.102*	0.348**	0.278	0.650	7.084***
$P = AK_{DE}^{\alpha} L_{TAH}^{\beta}$	0.391**	0.455**	0.845*	-	35.16*	0.368**	0.324**	-	0.284	0.656	9.252***
$P = AK_{DE}^{\alpha} L_{TAH}^{\beta} e^{\lambda t}$	0.563***	0.475***	1.038***	0.014***	4.953**	0.529***	0.337***	0.350***	0.265	0.700	8.653***
$P = AK_{DE}^{\alpha} L_{DPH}^{\beta}$	0.519***	0.274*	0.793*	-	29.96	0.488***	0.205*	-	0.289	0.584	8.414***
$P = AK_{DE}^{\alpha} L_{DPH}^{\beta} e^{\lambda t}$	0.688***	0.321**	1.009**	0.015***	9.974**	0.647***	0.241**	0.364***	0.269	0.684	8.119***
$P = AK_{DE}^{\alpha} L_{DL}^{\beta}$	0.392**	0.457**	0.849**	-	27.11*	0.368**	0.324**	-	0.284	0.607	9.265***
$P = AK_{DE}^{\alpha} L_{DL}^{\beta} e^{\lambda t}$	0.564***	0.474***	1.038**	0.014***	3.974**	0.530***	0.336***	0.349***	0.265	0.700	8.648***
$P = AK_{DE}^{\alpha} L_{TL}^{\beta}$	0.296**	0.682**	0.978**	-	4.055*	0.410**	0.279**	-	0.280	0.622	9.849***
$P = AK_{DE}^{\alpha} L_{TL}^{\beta} e^{\lambda t}$	0.462***	0.722***	1.184***	0.014***	0.464**	0.434***	0.435***	0.357***	0.260	0.719	9.330***

Table 13.8: Cobb-Douglas Production Function : Capital Input Depreciation

	α	β	γ	λ	A	α_s	β_s	γ_s	λ_s	R^2	F
$P = AK_{DE}^{\alpha} \; L_{DL}^{\gamma} \; L_{IN}^{\beta} \; e^{\lambda t}$	0.380**	0.262*	0.690**	0.015***	0.465*	0.357**	0.189*	0.351**	0.370***	0.738	6.983***

Table 13.9: Productive Efficiency of Company A Computed Using Cobb-Douglas Production Function

Formula Used \ Productivity \ Period	P_1/P_1^*	P_2/P_2^*	P_3/P_3^*	P_4/P_4^*	P_5/P_5^*
	1st Half 77/78	2nd Half 77/78	1st Half 78/79	2nd Half 78/79	1st Half 79/80
$\overset{*}{P} = 4.07\ K_{DE}^{0.296}\ L_{TL}^{0.682}$	0.8321	0.9115	0.8890	0.7425	0.9135
$\overset{*}{P} = 0.464\ K_{DE}^{0.462}\ L_{TL}^{0.722}\ e^{0.014t}$	0.9229	0.9302	0.8050	0.6340	0.7379

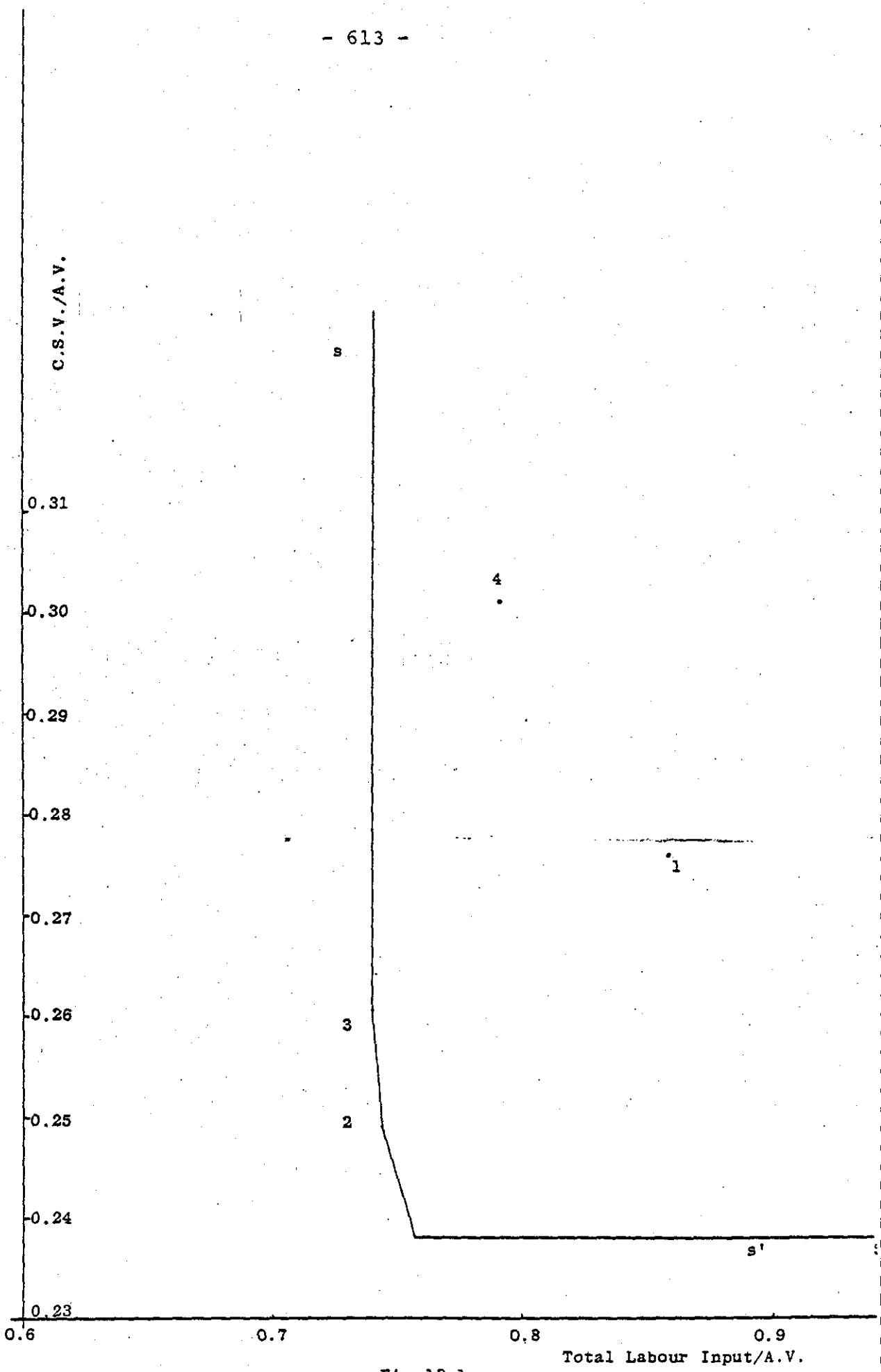

C.S.V./A.V.
s
0.31
4
0.30
0.29
0.28
1
0.27
0.26
3
0.25
2
0.24
s'
0.23
0.6
0.7
0.8
0.9
Total Labour Input/A.V.

Fig.13.1

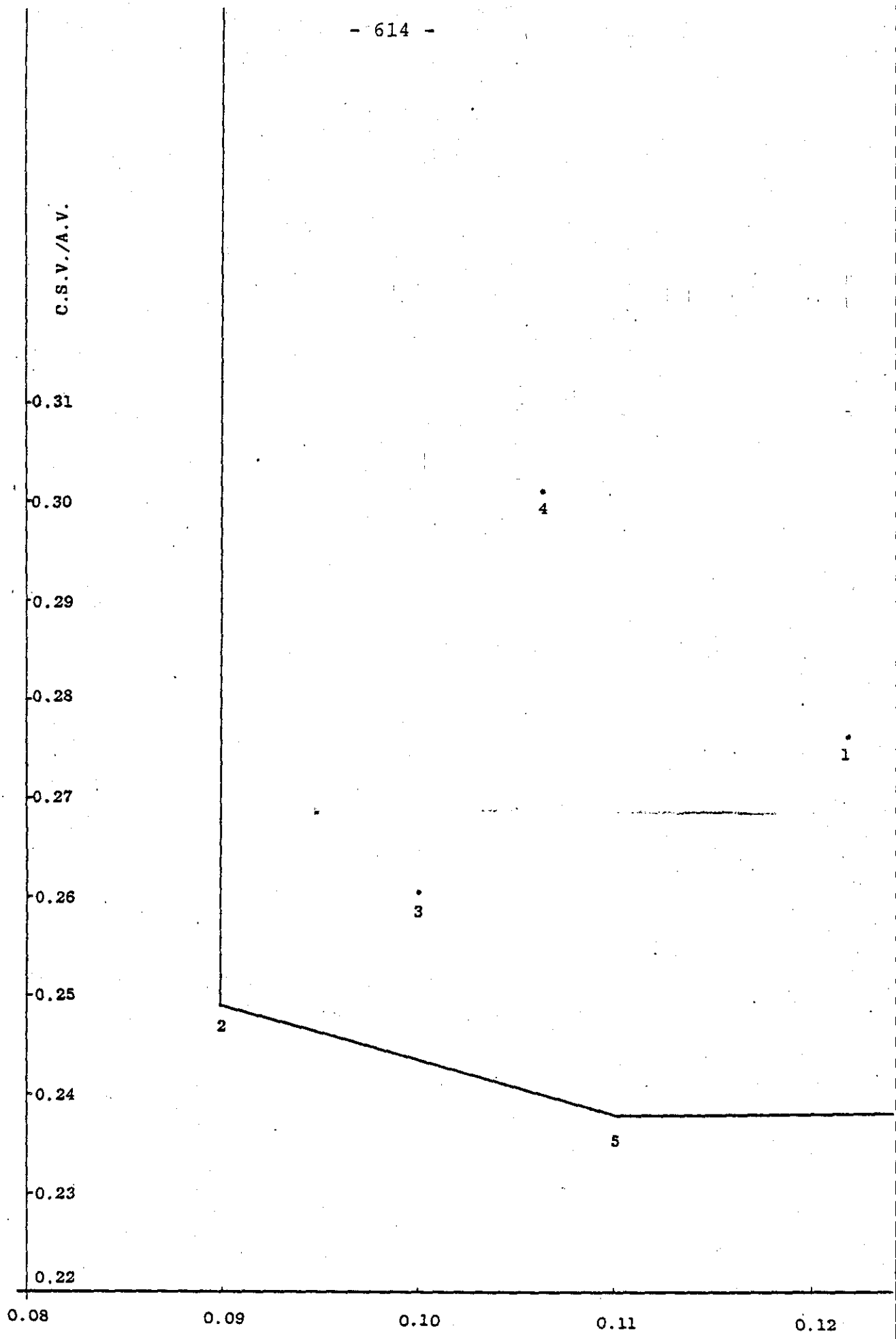


Fig. 13.2 A.H. Production/A.V.

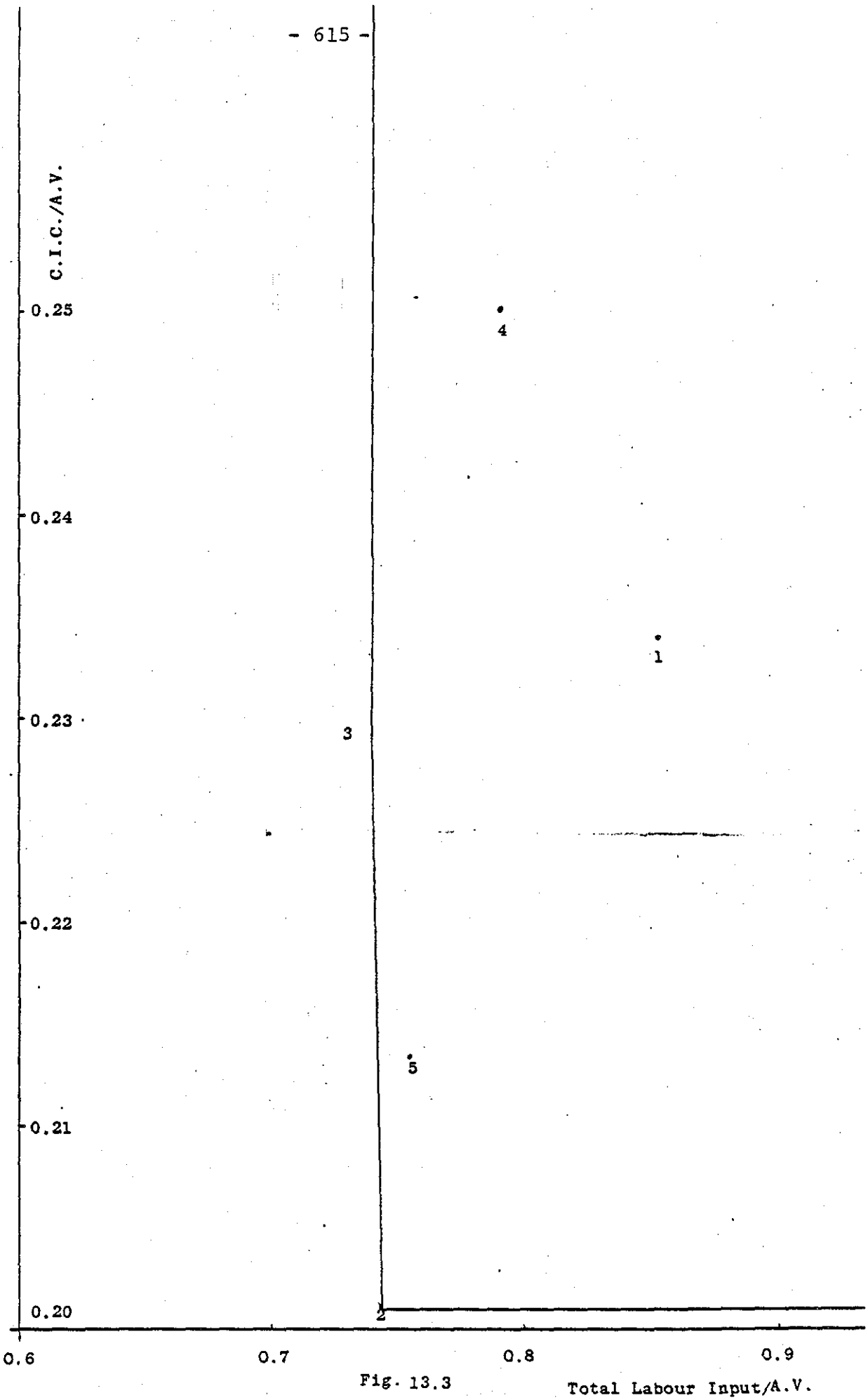

C.I.C./A.V.
0.25
0.24
0.23
0.22
0.21
0.20
4
1
3
5
2
0.6
0.7
0.8
0.9
Total Labour Input/A.V.

Fig. 13.3

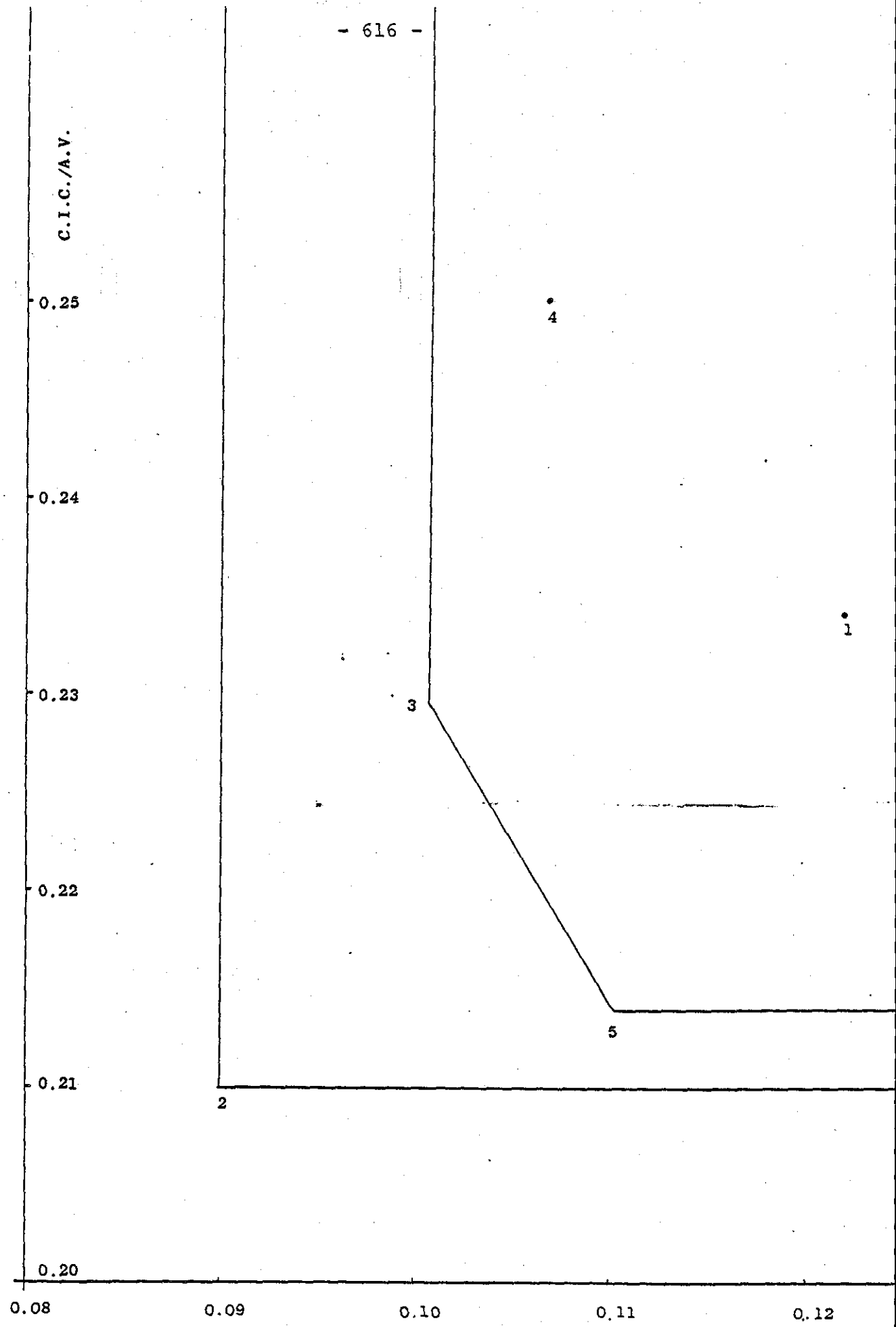


Fig. 13.4 A.H. Production/A.V.

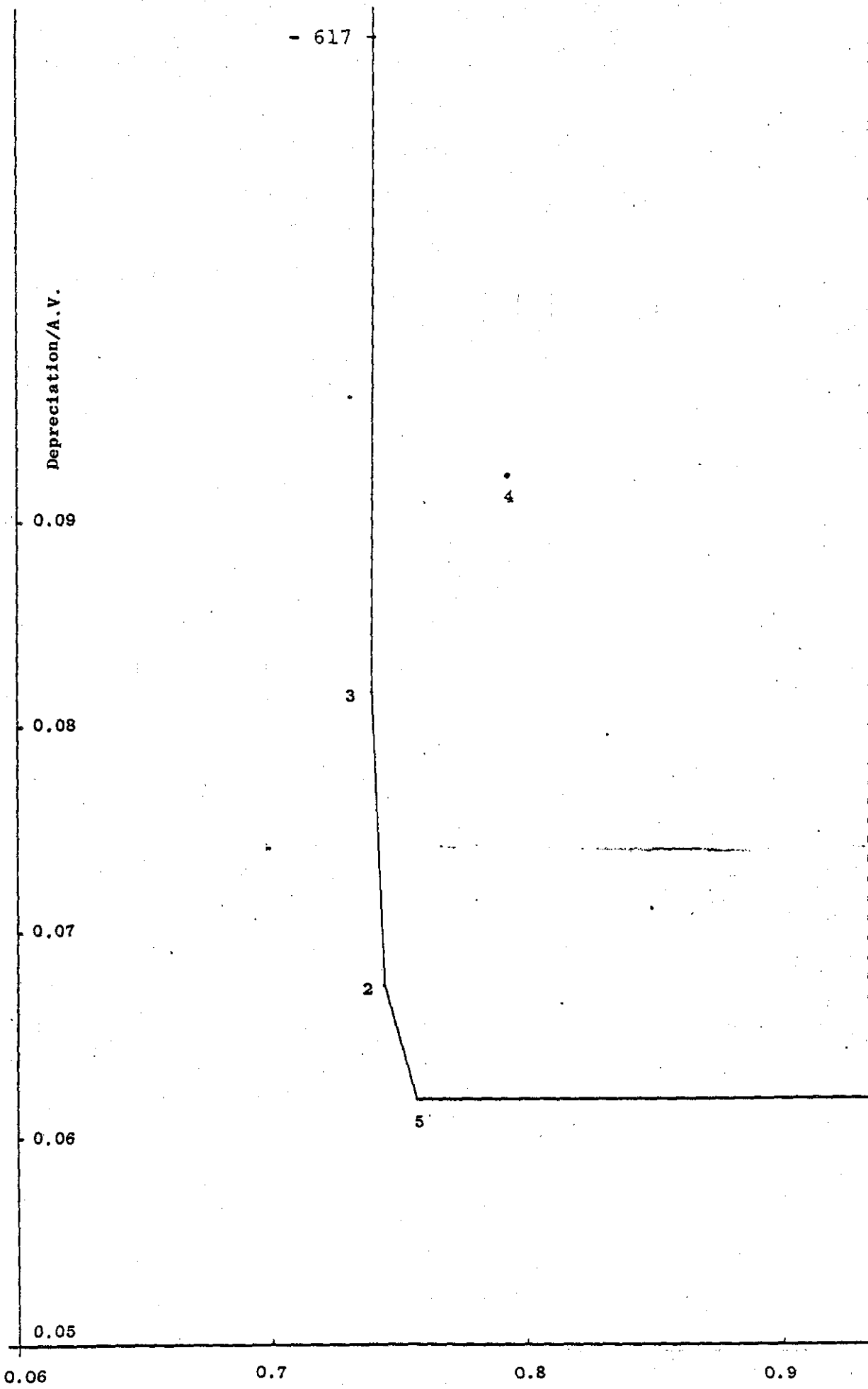


Fig. 13.5 Total Labour Input/A.V.

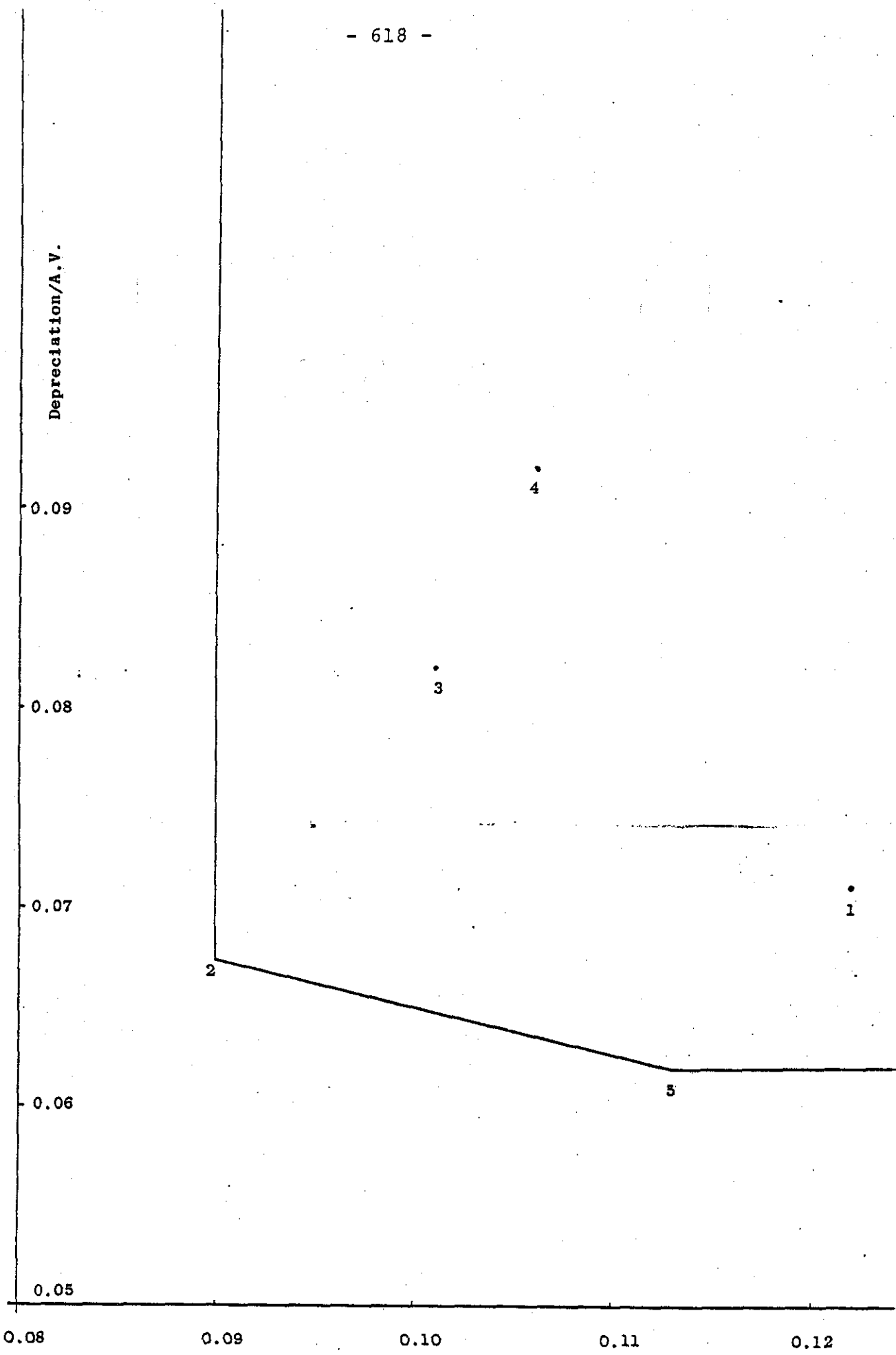

Depreciation/A.V.
0.09
0.08
0.07
0.06
0.05
4
3
1
2
5
0.08
0.09
0.10
0.11
0.12
A.H. Production/A.V.

Fig. 13.6

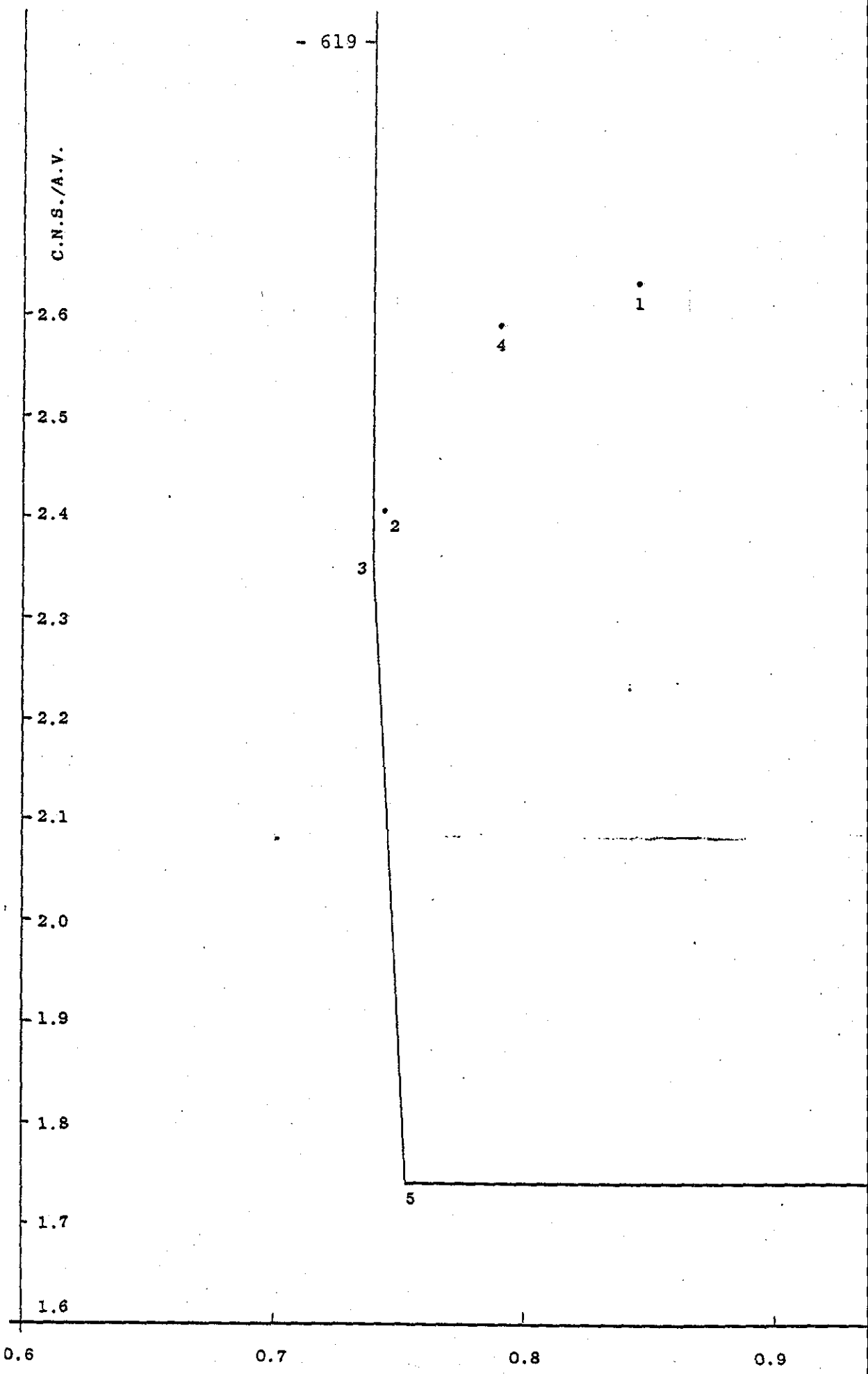


Fig. 13.7 Total Labour/A.V.

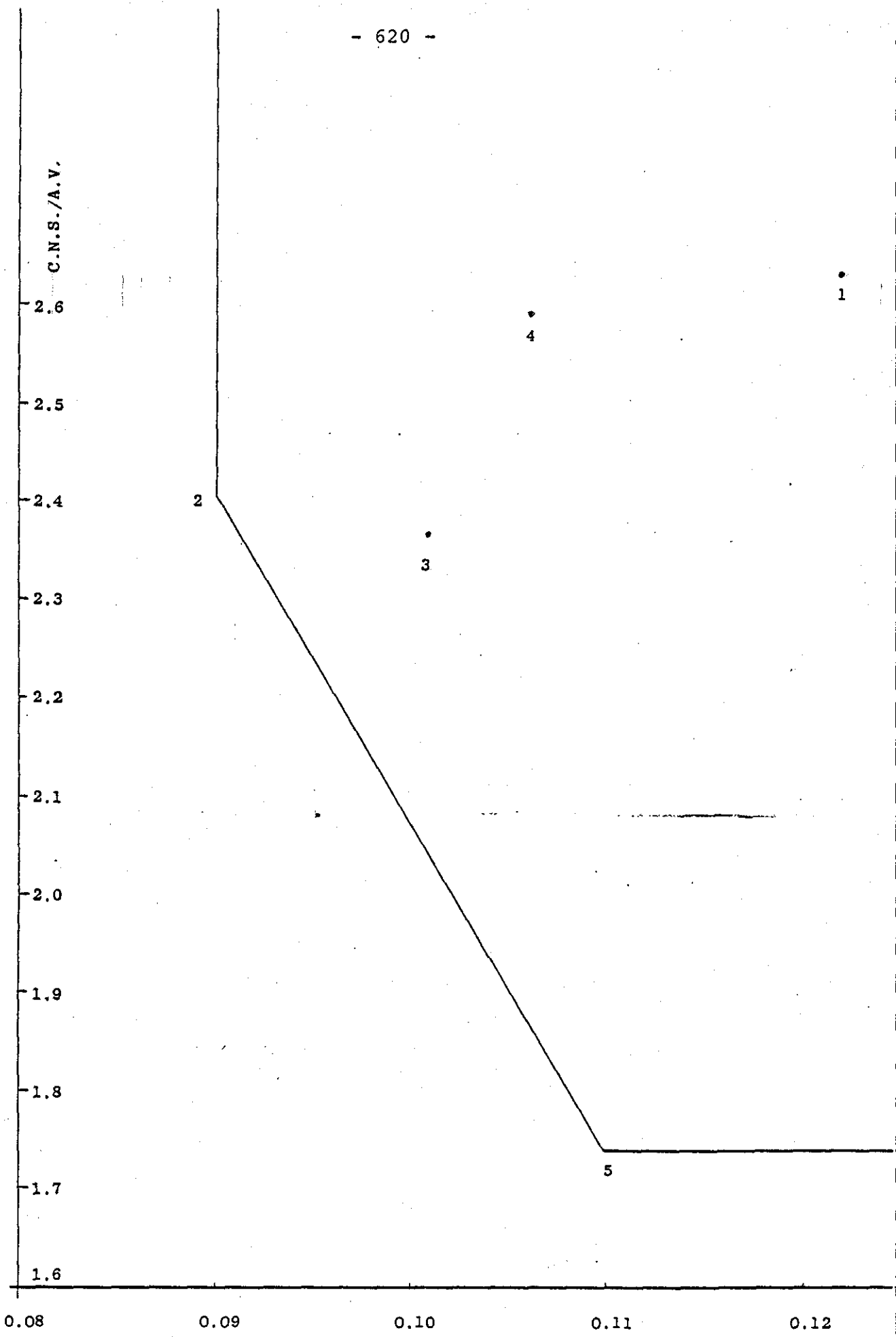


Fig. 13.8 A.H. Production/A.V.

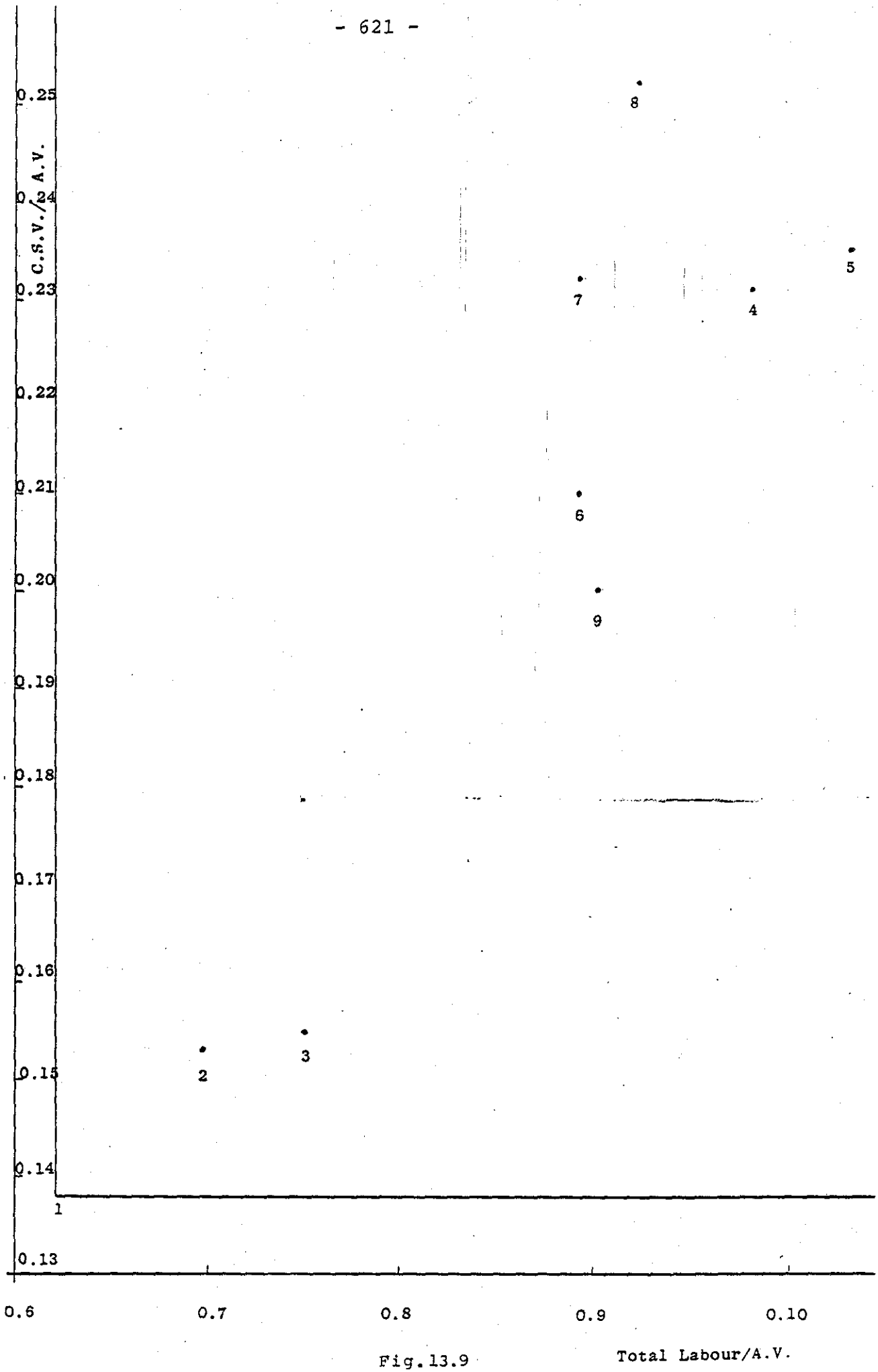

C.S.V./A.V.
0.25
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
1
2
3
4
5
6
7
8
9
0.6
0.7
0.8
0.9
0.10
Total Labour/A.V.

Fig.13.9

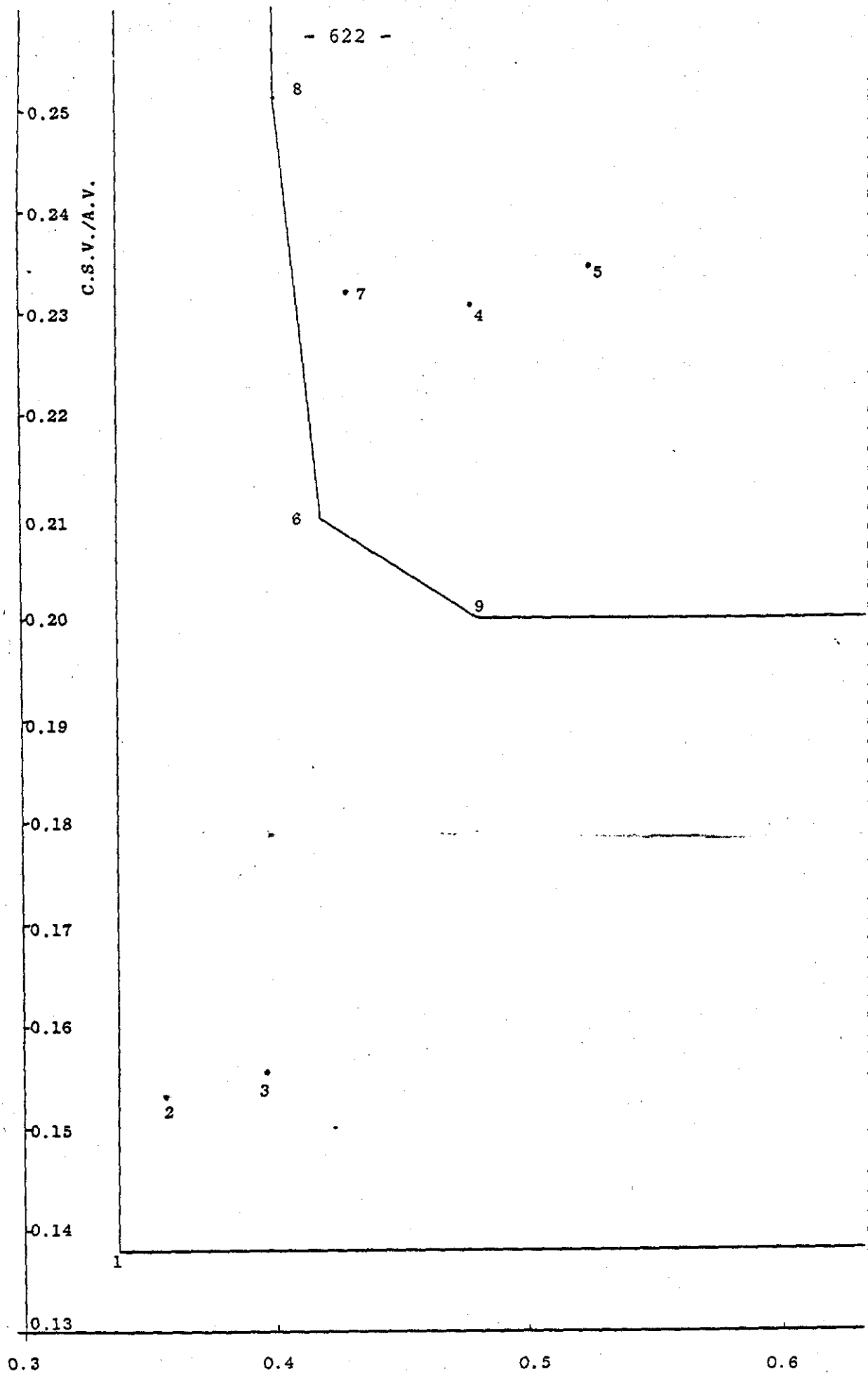


Fig. 13.10 Direct Labour/A.V.

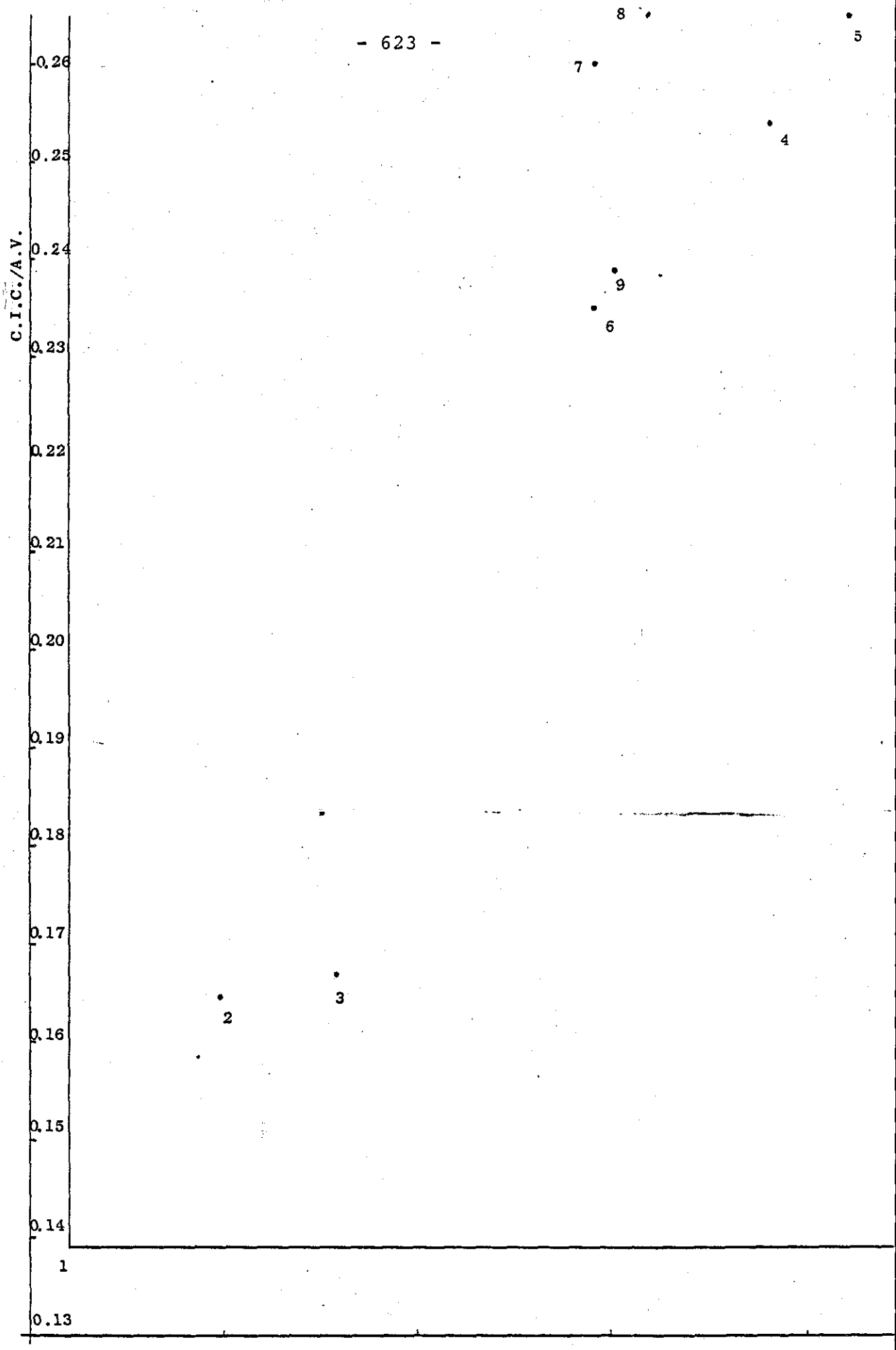

C.I.C./A.V.
0.26
0.25
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
1
2
3
4
5
6
7
8
9
0.6
0.7
0.8
0.9
1.0
Total Labour/A.V.

Fig .13.11

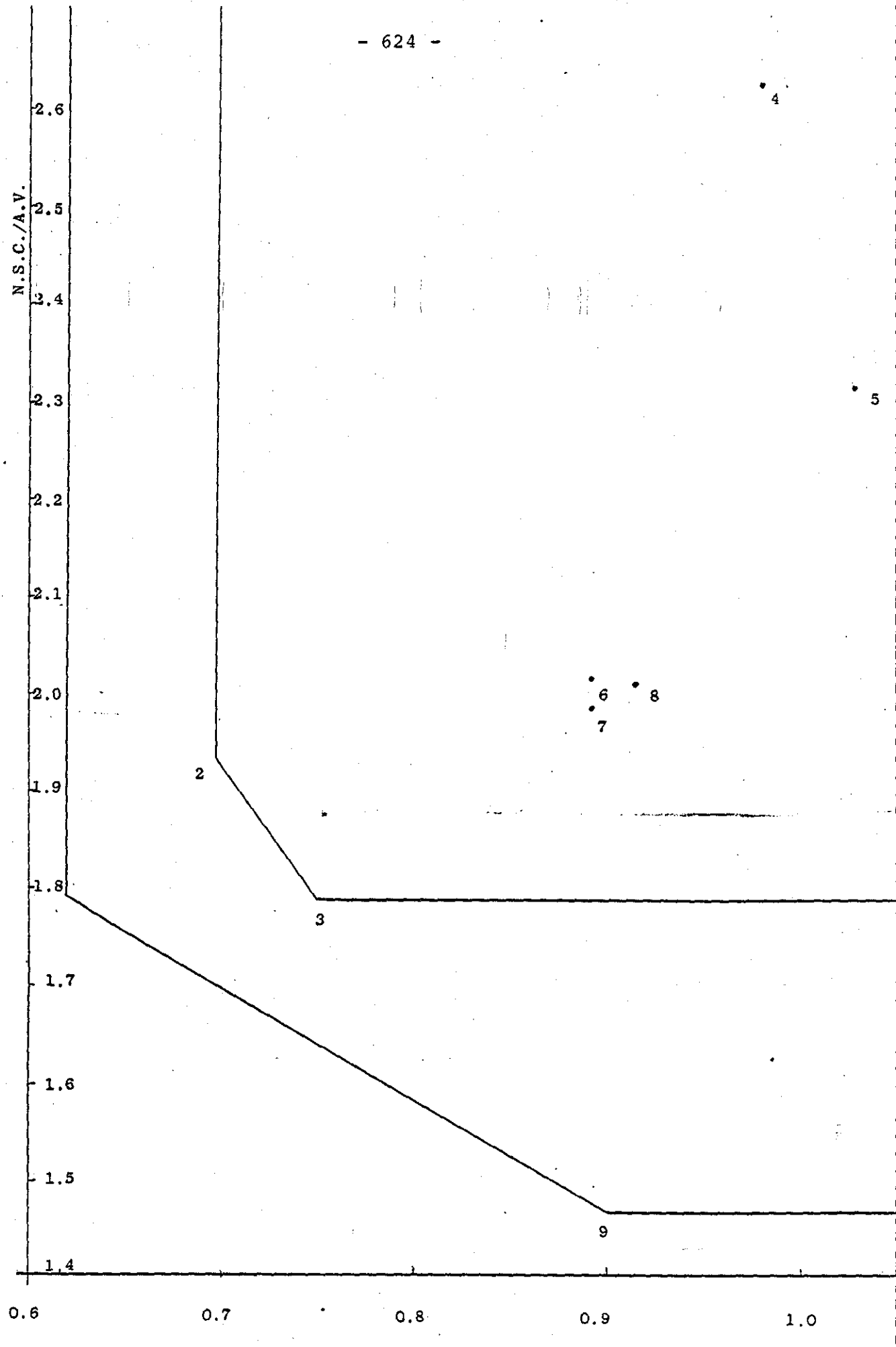
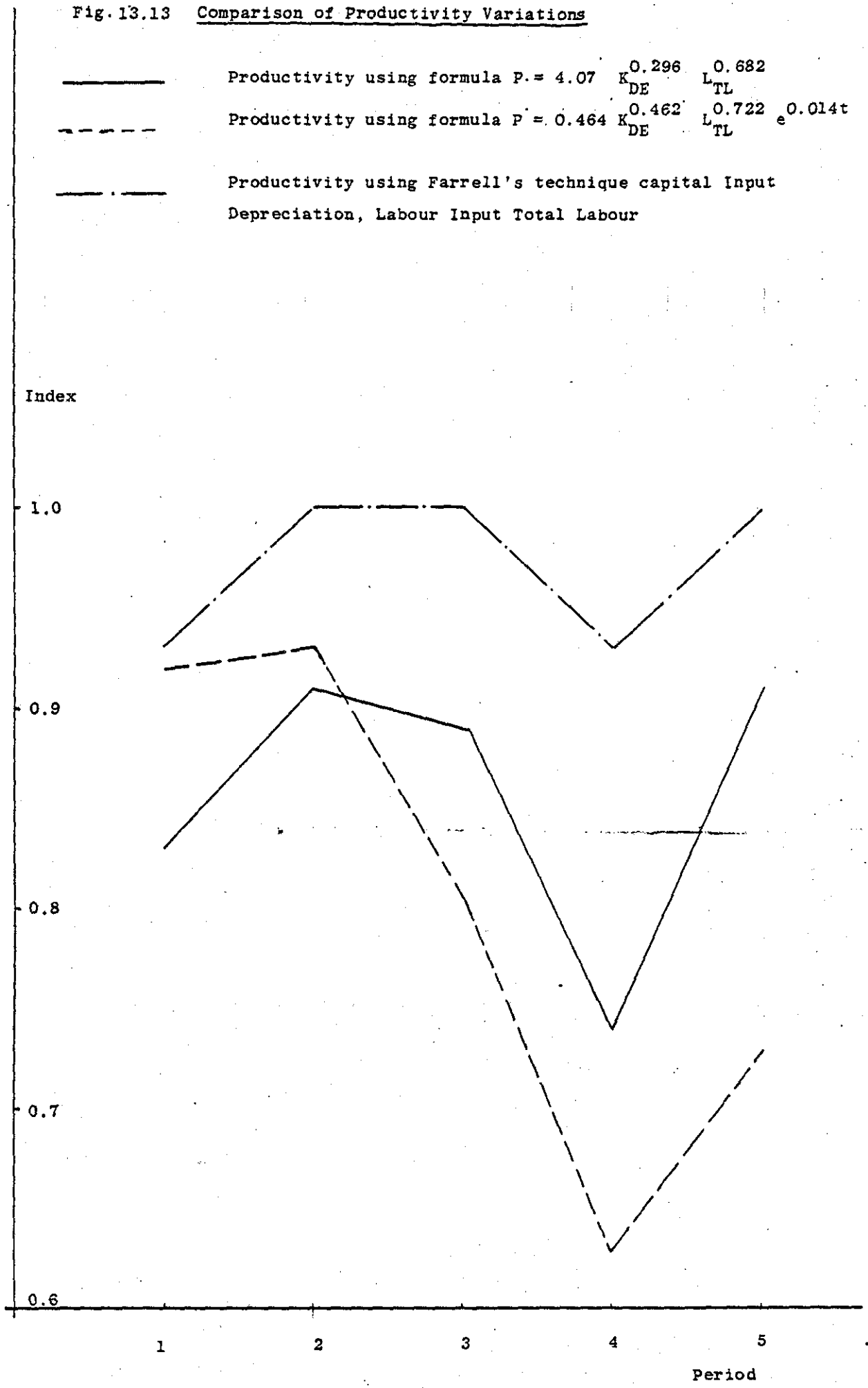

N.S.C./A.V.
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
0.6
0.7
0.8
0.9
1.0
Total Labour/A.V.
2
3
4
5
6
7
8
9

Fig. 13.12

Fig. 13.13 Comparison of Productivity Variations



References

1) Fisher, F.M.

"Aggregate Production Functions and the Explanation of Wages: A Simulation Experiment".

Review of Economics and Statistics 1971.

2) Farrar, D.E., and Glauber, R.R.

"Multicollinearity Regression Analysis: The Problem Revisited".

The Review of Economics and Statistics, Vol. 49, 1969.

CHAPTER FOURTEEN

STATISTICAL ANALYSIS

14.1 Introduction

The data in previous chapters were analysed using the time-based methodology. This chapter is concerned with the statistical analysis of the data collected from collaborating companies. Two techniques were employed for this purpose. They were (a) correlation; and (b) regression analysis. These were carried out with the aid of a digital computer, utilising the "Statistical Package for the Social Sciences", "SPSS" for short.

Before we present the result of the analysis, it is important to describe briefly the SPSS package, correlation and regression techniques.

14.2 Brief Description of SPSS Package

The Statistical Package for the Social Sciences (SPSS) is an integrated system of computer programs designed for the analysis of social science data. SPSS enables the social scientist to perform an analysis through the use of natural language control statements. The text is a complete instructional guide to SPSS and is designed to make the system easily accessible to users with no prior computer experience.

The system offers the researcher a large number of statistical routines commonly used in social sciences. In addition to the usual descriptive statistics, simple frequency distribution and cross tabulation, SPSS contains procedures for simple correlation, partial correlation, means and variance for stratified subpopulations, one-way and n-way analysis of variance, multiple regression, discriminant analysis, scatter diagrams, factor analysis, canonical correlations and Guttman Scaling. There are various versions of SPSS available. This is because their implementation is machine-dependent. In addition, the package is undergoing continuous change to improve its performance. For a full description of procedures

and characteristics of the SPSS package, see reference (1).

SPSS allows a great deal of flexibility in the manipulation and formating of the data. The data-management facilities can be used to modify a file of data permanently and can also be used in conjunction with any of the statistical procedures. These facilities enable the user to generate new variables which are mathematical and/or logical combinations of existing variables, to recode variables, and to sample, select, or weight specified cases. Furthermore, the user can add to or alter the data cases or the data-descriptional information in the file, such as labels, missing-value codes, etc.

14.3 Correlation Analysis

Correlation is defined as the degree of relationship existing between two or more variables. This may be linear, when all points (X, Y) on a scatter diagram seem to cluster near a straight line, or non-linear, when all points seem to lie near a curve.

The degree of linear covariability between two variables X and Y is measured by a parameter called the correlation coefficient r. The values that r ~~may assume~~ vary from -1 to +1. The absolute value of r represents the strength of relationship between variables X and Y, while the sign preceding r explains the direction of movement of the two variables. When r is positive, the variables X and Y increase or decrease together. Negative r means that the two variables move in opposite directions.

Of course, r is a sample estimate of the true correlation coefficient ρ which measures the degree of the interrelationship of the populations of X and Y values. The computed r value consequently has to be tested for statistical reliability. This is referred to as the "test of significance".

Briefly, the test of significance seeks to reject one of the following hypotheses:

Null hypothesis $H_o : \rho = 0$; and

Alternate hypothesis: $H_1 : \rho \neq 0$.

The rejection of the null hypothesis at a given level of significance means that the corresponding population's ρ differs from zero.

For a more detailed study of correlation analysis, see references 2 and 3.

14.4 Regression Analysis

Multiple regression is a general statistical technique through which one can analyse the relationship between a dependent or criterion variable and a set of independent or predictor variables. Multiple regression may be viewed either as a descriptive tool by which the linear dependence of one variable on others is summarised and decomposed, or as an inferential tool by which the relationships in the population are evaluated from the examination of sample data. In practice, however, these two aspects of the technique are closely related.

The most important uses of techniques as a tool are: (1) to find the best linear prediction equation and to evaluate its prediction accuracy; (2) to control other confounding factors in order to evaluate the contribution of a specific variable or set of variables; and (3) to find structural relations and provide explanations for seemingly complex multivariate relationships, such as is done in path analysis.

The general form of the regression equation is:

$$Y' = A + B_1X_1 + B_2X_2 + \dots B_KX_K , \qquad (14.1)$$

where Y' represents the estimated value for Y, A is the Y intercept, and B_i are regression coefficients. The As and Bs are selected in such a way that the sum of squared residuals $\Sigma(Y - Y')^2$ is minimised (Ref. 4).

A partial regression coefficient, say B_1, in Equation (14.1), stands for the expected change in Y with a change of one unit X_1 when all other explanatory variables (X_2, ... X_K) are held constant. An equally important and obvious interpretation is that the combined "effects" of changes are additive. For example, if we were to increase or decrease a variable by one unit then the expected change in Y would be $\pm(B_1 + B_2 + \ldots B_k)$.

The degree of linear dependence of dependent variable on the independent variables is measured using the "coefficient of multiple determination" R^2. This shows the percentage of the total variation of Y explained by the regression plane, that is, by changes in X, s. The value of R^2 lies between 0 and 1. The higher R^2, the greater the percentage of the variation of Y explained by the regression plane, that is, the better the "goodness of fit" of the regression plane to the sample observations. Prediction accuracy in absolute units is reflected by the standard error of estimate for the regression equation.

In cases where independent variables are measured in different units, it is difficult to determine the relative importance of each explanatory variable on the basis of the B values alone. If the relative contribution of each variable is of interest, one should examine the standardised regression coefficients B_s. These are computed using standardised data, in which case standard deviation of both Y and X, s are equal to one.

14.4.1 Statistical inference: regression problems

Regression analysis is commonly performed on sample data which one is interested in generalising to a population. The phrase "generalising to a population" refers either to estimating population parameters from sample regression statistics or to testing statistical hypotheses about the population parameters. In addition, one requires to know the statistical reliability of the estimates of the regression coefficients.

In this section, we deal with the two most commonly-used tests of statistical significance, namely, (1) the "overall" test for goodness of fit of the regression equation; and (2) the test for a specific regression coefficient.

(I) Testing the overall significance of a regression

This test aims at finding out whether the explanatory variables (X_1, X_2, ... X_K) do actually have any significant influence on the dependent variable. Formerly, the test of the overall significance of the regression implies testing the null hypothesis:

$$H_o : B_1 = B_2 = \ldots = B_K = 0$$

against the alternative hypothesis:

$$H_1 : \text{not all } (B_i)\text{s are zero.}$$

Expressed in another way, the test indicates whether the (assumed random) sample of observations being analysed has been drawn from a population in which the multiple regression is equal to zero, and that the observed multiple correlation is due to samplifying fluctuation or measurement error.

Rejection of the null hypothesis means that one or more of the population regression coefficients have an absolute value greater than zero. For a more detailed description, see references 3, 4 and 5.

(II) Testing significance of the parameter estimates

The overall test of significance does not indicate which specific B_i values are non-zero. Therefore, additional tests for specific regression coefficients are required. Such tests may be used in deciding how much confidence can be placed in the sign of the sample regression coefficients.

Formally, this means testing the null hypothesis:

$$H_o : B_i = 0$$

against the alternative hypothesis:

$$H_1 : B_i \neq 0 .$$

The acceptance of the null hypothesis leads to two different kinds of conclusions, depending on the purpose of the regression analysis. If one is interested in making inferences about the population parameters, acceptance of the null hypothesis simply means that the true population parameter $B_i = 0$. This implies that the explanatory variable to which this estimate relates does not, in fact, influence the dependent variable Y and should not be included in the function. On the other hand, if the regression equation is to be used for forecasting, acceptance of the null hypothesis simply means that there is a 15% chance that the sign of the sample regression coefficient is wrong.

Tests mentioned in Sections (I) and (II) are carried out at a given level of significance. For example, rejecting a null hypothesis at the 5% level of significance simply means that in repeated sampling the coefficients computed from the sample, would include the true population parameter in 95% of the cases.

For a more detailed discussion of the procedures available for testing the parameter estimates, see references 3, 4 and 5.

14.5 Correlation Analysis of the Data

In this section we present the result of the correlation analysis carried out on the result of computations presented in Chapters 6 and 8 and other data collected from companies A and B.

The aim of the analysis was (a) to examine the applicability of correlation analysis: (b) to determine

the extent which prior expectations were met; and (c) to establish whether any significant relationship exists between the total, added value productivities, value added and partial productivity measures and accounting variables.

14.5.1 Prior expectations

Based on the literature and on intuition, we expected that the total and added value productivities would correlate with all of their respective partial productivity measures and the strength of the relationship to be dependent on the intensity which a given resource is used in a particular enterprise.

Total and added value productivities and value added, in normal circumstances, should also correlate with sales revenue, profit, rate of return, and other accounting ratios used for measuring the profitability and the level of output of a firm (Ref. 6). There are, however, exceptions depending on the conventions used for measurement of profit and market situations. It is well-known that the declared profit of an enterprise could be affected markedly by items such as transfers to or from reserves and stock-taking gains/losses or inflation. In addition, the profit position can be affected (Ref. 6) by favourable shifts in demand, special purchasing economies or financial arrangement. The influence of such factors on profit is to obscure the productivity position of the company. In such circumstances, there is a strong possibility that productivity measures would not correlate with declared current cost profits of the company.

14.5.2 Results of correlation analysis

To carry out either correlation or regression analysis, one requires at least ten observations and ideally many more. The fewer the number of observations available, the less the confidence one can place in the accuracy of the coefficients being estimated. This presented difficulties, in both case studies, owing to a lack of easily-assessible long-term historical data,

changes in accounting practices, and the time available for data collection.

In the case of both companies, these difficulties were partially overcome by computing the total and the added value factor productivities on a monthly basis, using the appropriate formulas presented in Chapters 5 and 7. This process is not entirely satisfactory because the analysis is based on only a short span of time. However, this did not limit the scope sufficiently, so as not to be able to achieve the objectives stated in Section 14.4.

14.5.2a Company A

We correlated total factor productivity, added value productivity and added value with the following factors: direct labour productivity, DLP; indirect labour productivity, ILP; total labour productivity, TLP; capital productivity, CP; material productivity, MP; other inputs productivity, OIP; depreciation, DEP; total fixed capital, TFC; total working capital, TWC; total capital, TC; profit, PRO; rate of return, RR; output in constance, OC; final product cost, FPC; input cost, IC; cost performance, CP; selling price index, SPI; actual hours of production, AHP; labour utilisation factor, LU; labour efficiency factor, LEF; activity factor, AF; revenue, REV; added value direct labour productivity, ADLP; added value indirect labour productivity, AILP; added value total labour productivity, ATLP; and finally, added value capital productivity, ACP. For glossary and definitions of the above variables, see key to Tables 14.1 to 14.3 and Tables 14.7 to 14.9.

Some of the variables listed above were computed by the author. These included various total, partial and added value productivities. The rest of the variables were measured by the host company and were available from accounting records.

The results of these analyses are presented in Tables 14.1, 14.2 and 14.3. Table 14.1 shows that the total factor

productivity correlated with DLP, TLP, CP, MP, OIP, OC, REV, AV, ADLP, AILP, ATLP, AKP and ATP. As expected, it correlated with partial productivities such as labour, capital, material and other inputs productivities. However, the numerical value of the correlation coefficient was not strictly dependent upon the intensity of usage. As for company A, salaries constituted on average 13.3% of costs; wages, 19.8%; total employee compensation, 33%; materials, 43%; capital, 9.7%; and other inputs, 14.3%.

The total productivity, TP, did not correlate with indirect labour productivity, ILP. The reason for this was the employment structure of the firm; in this conformation, all production and allied workers (including supervisors) were on wages, while all office (white collar) employees were on salaries.

More interestingly, the total productivity did not correlate with the rate of return on assets, profits and other accounting variables presented in the company's accounting package. The only exceptions were revenue and output, measured in constat. Possible reasons for lack of correlation between total productivity, TP, and profit or rate of return on assets was discussed earlier in this section and is not repeated here. But lack of any correlation between total productivity or at least direct labour productivities and labour utilisation, and efficiency, is more difficult to explain. However, in the author's view, the only possible reason was inaccuracy or lax standard times.

Tables 14.2 and 14.3 show that value added productivity and value added correlated with DLP, TLP, CP, MP, OIP, OC, REV, ADLP, AILP, ATLP, AKP and TP. As is evident, these factors are similar to the factors which correlated with total productivity, TP. This is not surprising since total productivity, added value productivity and added value are highly correlated with each other.

14.5.2b Company B

We correlated total factor productivity, TP; added value productivity, AVP; and added value, AV, with the following factors: direct labour productivity, DLP; indirect labour productivity, ILP; total labour productivity, TLP; capital productivity, CP; other inputs productivity, OIP; material productivity, MP; added value direct labour productivity, ADLP; added value indirect labour productivity, AILP; added value total labour productivity, ATLP; added value capital productivity, ACP; added value working capital productivity, AWCP; added value fixed capital productivity, AVFCP; stock-held performance, SHP; added value sales ratio, AVSR; material usage performance, MUP; level of activity, LOAC; rate of return, RR; profit, PRO; scrap rate, SCR; buying efficiency, BUEF; assets managed, ASMA; deliveries, DEL; total employment cost, TEC; direct employment cost, DEC; indirect employment cost, IEC; interest charges, IC; rectangular departmental performance, RDP; circular departmental performance, CDP; switches departmental performance, SDP; machine shop departmental performance, MDP; mould shop departmental performance, MDDP; total departmental performance, TDP; operator performance rectangular, OPR; operator performance circular, OPC; operator performance switches, OPS; operator performance machine shop, OPM; operator performance mould shop, OPMD; total operator performance, TPM; operator utilisation, OU; services purchased, SP; and depreciation, DEP. See key to Tables 14.4 to 14.6 and 14.10 to 14.12 for glossary and a definition of the above variables.

The number of variables used for correlation analysis were 40, as compared to 26 for the previous case. The only reason for this difference was the amount of additional information available from company B's accounting records.

The result of correlation analysis is presented in Tables 14.4, 14.5 and 14.6. Table 14.5 shows that the

total productivity correlated with AVP, AV, TLP, DLP, ILP, MP, AVSR, MUP, LOAC, RR, PRO, SCR, ASMA, DEL, ACP, AILP, ATLP, AWCP, and also, correlation coefficients and the level of significance are presented. As is evident, the total productivity did not correlate with capital or other inputs productivity. While it correlated highly with material productivity and negatively with various labour productivities. These results are very interesting in so far as they reinforce the points raised in Chapter 3. To reiterate, it was argued that the total productivity of a firm is a function of various partial productivities, and that there is a clear interaction between components of total productivity. A change in any component, such as labour, may be merely the passive resultant of changes initiated elsewhere in the network, because all components must be brought back into balance. For example, the replacement of raw materials with bought-out components would lead to an increase in the labour productivity and a decrease in material productivity without any increased effort by the labour force, if output level remained constant.

In the present case, total productivity inversely correlated with indirect labour productivity, ~~ILP, while~~ there was no correlation between these two factors in the previous case. The reason for this was due to styles of management. The management of company B was moving away from compensating their employees, including production and allied workers on hourly bases. The aim was to create a framework in which a majority of employees were paid salaries. In the belief that changing the status of blue collar workers to those of white collar employees would reduce tension and increase the cooperation of the production work force. As a result of the consequence of this deliberate policy, quite a large number of production employees were compensated on a monthly basis. The percentage of salaries as a proportion of the total cost on an average was 26.3%, compared to 11% for wages. Thus, the inverse correlation of total productivity with

direct labour productivity in the case of company B and the lack of any correlation in the case of company A.

As expected, total factor productivity, TP, correlated highly with profit, rate of return, deliveries and assets managed. In addition, other factors which total productivity correlated with appear to be intuitively correct.

Tables 14.5 and 14.6 show the result of correlation analysis for added value productivity, AVP, and added value, AV, respectively. As is evident from these tables and Table 14.4 correlated variables were, by and large, similar in all three cases. This is not surprising as total productivity, TP, added value productivity, AVP, and added value, AV, were highly correlated with each other.

14.6 Regression Analysis of the Data

We carried out regression analysis to obtain formulas relating dependent variables: total productivity, TP; added value productivity, AVP; and total unit costs, TUC, to an appropriate set of independent variables. This type of analysis is useful for pursing questions of causality, and for prediction and planning purposes.

In regression analysis, the fewer the number of observations available the less the confidence one can place in the accuracy of regression coefficients. Consequently, the problems encountered in these analyses were similar to those described in Section 14.5.2. The method used to overcome these difficulties were as before, i.e., shortening the time span between relevant computations. The results of these analyses are presented in the following sections.

14.6.1 Result of regression analysis: company A

The analysis was divided into three distinct components. There were (1) development of an equation, using multiple linear regression techniques, for total productivity, TP,

in terms of various partial productivities; (2) derivation of an equation relating added value productivity, AVP, to its partial productivities; and (3) finally imputation of an equation relating the total unit cost to partial unit costs.

Table 14.7 shows a series of equations relating the total productivity, TP, of the company A to various partial productivities. It is evident from Table 14.7a that total labour productivity, TLP, accounts for 71.3% of variations in total productivity, TP, and material productivity for 65.8% (Table 14.7b). Combined total labour and material productivities explain 95.5% of total productivity variations of TP. These results lead us to conclude that in order to control, and to improve, the total productivity, management must concentrate on labour and material productivities.

The difference between Tables 14.7a and 14.7b is simply that in Table 14.7b we have used direct and indirect labour productivities as two separate independent variables, while in Table 14.7a total labour productivity is used.

Apart from explaining the causes of variation in total productivity, these formulas are useful for planning and predictive purposes. For example, one can easily assess the implication of a decision to change the balance between in-house produced components and purchases of more fabricated parts, on total productivity of the company. In addition the effects of forward planning decisions on total productivity can readily be estimated.

Table 14.8 simply shows a series of equations relating the added value productivity, AVP, to added value total, direct, indirect labour and capital productivities. Direct labour productivity accounts for 90.5% of variations in added value productivity, AVP. Combined direct and indirect labour productivities explain 99.3% of added value productivity changes.

The standardised coefficients show the relative importance of independent variables in influencing the dependent variables. As is clear from Table 14.7a (last equation), the influence of total labour productivity is greatest (0.473) upon the total productivity followed by material (0.446), other inputs (0.193) and capital productivity (0.153). At each stage the introduction of a new explanatory variable reduces the influence, of variables already in the equation.

It is readily apparent that inverting Equation (5.1) presented in Chapter 5 will yield the total unit cost of production. Thus, total unit cost, TUC, is

$$TUC = \frac{L + C + R + Q}{O_t} \qquad (1)$$

or

$$TUC = \frac{L}{O_t} + \frac{C}{O_t} + \frac{R}{O_t} + \frac{Q}{O_t}$$

$$TUC = TLUC + CUC + MUC + OUC$$

where

$TLUC = \frac{L}{O_t}$ total labour unit cost;

$CUC = \frac{C}{O_t}$ capital unit cost;

$MUC = \frac{R}{O_t}$ material unit cost; and

$OUC = \frac{Q}{O_t}$ other inputs unit cost.

An increase in total productivity obviously results in a decrease in total unit cost.

Table 14.9 shows a series of equations for the dependent variable TUC in terms of independent variables TLUC, MUC, OUC, DLUC, ILUC. Labour and material unit costs account for 97.6% of variations in total unit cost. This shows that, in order to control the total unit cost

effectively, management should concentrate on labour and material costs. This conclusion may appear to be obvious as labour and material account for 76% of the total company's cost. However, as is shown in the following section, variation in unit costs is not necessarily dependent on the proportions of unit costs.

These equations are useful in management decision-making. For instance, it is easy to assess the effect of wage settlements on the total unit cost using these. Also, they provide the basis for assessing the implication of forward plans on total unit costs.

It is obviously possible to divide the costs to finer components. As an example, Table 14.9a shows a series of equations in which the total labour cost was divided to direct and indirect costs. This process can be extended to other unit costs.

14.6.2 Result of regression analysis: company B.

The result of multiple regression analysis carried out on the total and partial productivities of company B are presented in Table 14.10. As is evident, material productivity explains 90% of variations in total productivity. Interestingly, the addition of total labour productivity as an explanatory variable increased the goodness of the fit only by 1.9%. This suggests that improvement in total productivity in this particular company can be achieved mainly by improving the material productivity. This is not to say that labour productivity is of no consequence as it has a very large standardised coefficient of 0.831. In fact, this is the second largest standardised coefficient, after the material's productivity (1.799).

In the previous section, we discussed the areas of possible applications of regression equations. These are not repeated here.

Table 14.11 shows a series of equations relating

the dependent, AVP, to independent variables AILP, ACP, ADLP, and ATLP. As can be seen, added value indirect labour productivity and capital productivity explain 97.7% of variations in added value productivity. Furthermore, they have standardised regression coefficient of 0.886 and 0.288 compared to 0.186 for added value direct labour productivity. This suggests that substantial improvement in added value productivity can be achieved through improving indirect labour and capital usage.

Table 14.12 shows a series of equations relating total unit cost, TUC, to material unit cost, MUC; capital unit cost, CUC; other unit costs, OUC; total labour unit cost, TLUC; indirect labour unit cost, ILUC; and direct labour unit cost, DLUC.

Total labour cost on average accounted for 37.4% of total cost incurred by the company. Combination of material and labour costs accounted on average for 77.4% of the company's costs. As is evident from Table 14.2, material unit cost explained 71.2% of total unit cost variations. Addition of the total labour unit cost improved the goodness of fit by only 8%. This shows that the percentage of variation in total unit cost is not necessarily dependent upon cost proportions. However, this is not to say that total labour unit cost does not influence the total unit cost. The last equation of Table 14.12a shows clearly that the standardised coefficient of the total labour cost is the third largest coefficient (0.671), and thus, has a considerable influence on total unit cost.

14.7 Conclusions

Any conclusions based on the analysis presented in the previous section have to be treated with caution. The reason for this is the short span of historical data used for these analyses. These were thirty months (2½ years) in the case of company A, and twelve months (one year) in the case of company B.

The result of correlation analysis confirms the view held by the majority of authors' references (Refs. 6, 10, 11)

that total productivity is a function of partial productivities. Clearly, relying on labour productivity as a measure of effectiveness (or efficiency) of an enterprise could be misleading. As an increase in labour productivity could be associated with a decrease in total productivity. This fact is demonstrated amply by negative correlation between these two factors in the case of company B.

As mentioned, one of the questions in the assessment of labour input (Chapter 5, Section 5.6.1) is whether or not this measure should be inclusive of indirect employees' contributions. This question is often a source of controversy, as some authors (Refs. 7, 8), argue that indirect workers do not contribute to output and should not be included as an input, others argue that the function of productivity measurement is to determine the effectiveness of the use of scarce resources and hence the need to include the indirect employees (Refs. 9, 10, 11). To a large extent, the root of this argument is a different conception held, as with regards, to what constitutes the effectiveness of an organisation. The result of correlation analysis, however, shows regardless of ones conception, the decision to include ~~or exclude~~ the indirect workers (i.e., salaried staff) in productivity assessments depends on the employment structure of the organisation under consideration.

Another important aspect of correlation analysis was the absence of any covariability between profit and rate of returns on assets and total productivity in the case of company A. This confirms Kendrick's arguments (6) that relying solely on profit and rate of returns on assets could mislead the management and hide from them below average productivity gains.

The use of labour productivity is often justified on the grounds, that at the firm level labour represents a large part of the total cost of production (Refs. 12, 13). This argument presumably could be extended to any of the

scarce resources However, as is evident from various regression equations and correlation coefficients, the variations in total productivity or total unit costs are not necessarily dependent on cost intensity. On the other hand, to a large extent, the absolute values of standardised and non-standardised coefficients in the regression equations are dependent on cost proportions.

The regression equations are, in the author's opinion, very useful management tools. Two very important uses of these equations are in: (1) determination of causes of variations of total productivity and unit costs; and (2) determination of impacts of various forced or enforced changes, on total productivity and unit costs.

An interesting observation was the fact that in both cases total added value productivity and added value correlated highly with each other.

Key to Tables 14.1 to 14.3 and 14.7 to 14.9

Glossary of Symbols

TP	Total Productivity
DLP	Direct Labour Productivity
ILP	Indirect Labour Productivity
TLP	Total Labour Productivity
CP	Capital Productivity
MP	Material Productivity
OIP	Other Inputs Productivity
DEP	Depreciation
TFC	Total Fixed Capital
TWC	Total Working Capital
TC	Total Capital
PRO	Profit
RR	Rate of Return
OC	Output in Constat
FPC	Final Product Cost
IC	Input Cost
CP	Cost Performance
SPI	Selling Price Index
AHP	Actual Hours of Production
LU	Labour Utilization
LEF	Labour Efficiency Factor
AF	Activity Factor
REV	Revenue

contd ...

contd...

Meaning of Symbols Used

AV	Added Value
ADLP	Added Value Direct Labour Productivity
AILP	Added Value Indirect Labour Productivity
ATLP	Added Value Total Labour Productivity
ACP	Added Value Capital Productivity
ATP	Added Value Total Productivity

Definition of Variables

In this section, we have only defined variables which have not been explained previously or where their meaning is not immediately apparent to the reader.

Output In Constat OC

A Constat is a unit of production or sales measured in terms of 1975/76 standard cost.

Output in constat is defined as the product of physical output and direct cost of producing that output in constant term.

Final Product Cost FPC

FPC is defined as the quotient of total cost incurred in producing the output and cost of own production in constant terms, divided by number of working days in a given period i.e. month, year, etc.

Imput Cost IC

Input cost is defined as follows:

$$IC = \frac{c \times a}{b}$$

where IC = Input cost at the end of the current period.

a = Input cost at the beginning of the year.

b = Input price index at the beginning of the year.

c = Input price index at the end of the current period.

Cost Performance Index CP

CP is defined as follows:

$$CP = B/_A$$

where A = Final Product Cost.

B = Input Cost.

Selling Price Index SPI

SPI is the quotient of total sales and number of working days, and total sales and transfers in constant.

Labour Utilization Factor LU

Labour utilization factor is defined as follows:

$$LU = \frac{\text{Direct Workers Time Spent on Production}}{\text{Direct Workers Total Attendance Time}}$$

Labour Efficiency Factor LEF

Labour efficiency factor is defined as follows:

$$LEF = \frac{\text{Standard Hours Produced}}{\text{Direct Workers Time Spent on Production}}$$

Activity Factor AF

$$AF = \frac{\text{Standard Hours Produced}}{\text{Normal Standard Hours for Number of Working Days in Month}}$$

Table 14.1: Result of Total Productivity Correlation Analysis For Company A

Total Productivity, TP, Correlates with:	Variables												
	DLP	TLP	CP	MP	OIP	OC	REV	AV	ADLP	AILP	ATLP	AKP	ATP
Correlation Co-efficient r	0.7916	0.8444	0.7553	0.8113	0.5926	0.6268	0.7390	0.9943	0.9407	0.9121	0.9808	0.9444	0.9872
Signficant Level	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table 14.2: Result of Added Value Productivity Correlation Analysis For Company A

Value Added Productivity, VAT, Correlates with:	Variables												
	DLP	TLP	CP	MP	OIP	OC	REV	AV	ADLP	AILP	ATLP	AKP	TP
Correlation Co-efficient r	0.814	0.879	0.771	0.786	0.544	0.589	0.748	0.930	0.951	0.933	0.996	0.947	0.987
Significant Level	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table 14.3: Result of Added Value Correlation Analysis For Company A

Added Value, AV, Correlates with:	Variables													
	DLP	TLP	CP	MP	OIP	OC	REV	AV	ADLP	AILP	ATLP	AKP	ATP	TP
Correlation Co-efficient r	0.638	0.747	0.815	0.754	0.630	0.684	0.804	1.00	0.811	0.912	0.900	0.969	0.930	0.944
Significant Level	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Key to Tables 14.4 to 14.6 and 14.10 to 14.12

Glossory of Symbols

TP	Total Productivity
TLP	Total Labour Productivity
DLP	Direct Labour Productivity
ILP	Indirect Labour Productivity
CP	Capital Productivity
OIP	Other Inputs Productivity
MP	Material Productivity
ATLP	Added Value Total Labour Productivity
ADLP	Added Value Direct Labour Productivity
AILP	Added Value Indirect Labour Productivity
ACP	Added Value Capital Productivity
AWCP	Added Value Working Capital Productivity
AFCP	Added Value Fixed Capital Productivity
SHPI	Stock Held Performance
AVSR	Added Value Sales Ratio
MUP	Material Usage Performance
LOAC	Level of Activity "Added Value Per Day"
RR	Rate of Return
PRO	Profit
SCR	Scrap
BUEF	Buying Efficiency
ASMA	Assets Managed
DEL	Deliveries

contd ...

contd ...

Glossary of Symbols

TEC	Total Employment Cost
DEC	Direct Employment Cost
IEC	Indirect Employment Cost
IC	Interest Charges
AV	Added Value
RDP	Rectangular Department Performance
CDP	Circular Department Performance
SDP	Switches Department Performance
MDP	Machine Shop Department Performance
MDDP	Mould Shop Department Performance
TDP	Total Department Performance
OPR	Operator Performance Rectangular
OPC	Operator Performance Circular
OPS	Operator Performance Switches
OPM	Operator Performance Machine Shop
OPMD	Operator Performance Mould Shop
TPM	Total Operator Performance
OU	Operator Utilization
MP	Material Purchased
SP	Services Purchased
DEP	Depreciation

Definition of Variables

In this section, we only have defined variables which have not been explained previously or where their meaning is not immediately apparent to the reader.

Stock Held Performance SHP

Stock held performance was defined as follows:

$$SHP = \frac{\text{Added Value}}{\text{Average Stock Held During a Given Period}}$$

Material Usage Performance MUP

Material usage performance was defined as follows:

$$MUP = \frac{\text{Added Value}}{\text{f of Material Used}}$$

Level of Activity LOAC

Level of activity was defined as follows:

$$LOAC = \frac{\text{Added Value}}{\text{Number of Working Days in a Given Period}}$$

Buying Efficiency BUEF

Buying efficiency is defined as follows:

$$BUEF = \frac{\text{St cost of Purchases}}{\text{Actual value of Purchases}}$$

Departmental Performance

Total and various departmental performances were defined as follows:

$$\text{Total and Departmental Performance} = \frac{\text{Standard Hours of Measured Work in a Given Department}}{\text{Attendance Hour in a Given Department}}$$

Operator Performance

Operator performance was defined as follows:

$$\text{Operator performance} = \frac{\text{Standard Hours of Measured Work in a Given Departmen}}{\text{Hours of Measured Work in a Given Department}}$$

Operator Utilization

Operator utilization was defined as follows:

$$OU = \frac{\text{Total Time Spent on Production}}{\text{Total Attendance Time}}$$

Interest Charges IC

This is the charge levied by the parent's company on firm B. The amount was calculated by multiplying the total assets managed (fixed plus working capital) by the cost of captial and dividing it by number of working days in a given period. The cost of capital figure was supplied by the parent's company.

Table 14.4: Result of Total Productivity Correlation Analysis for Company B

Total Productivity, TP, Correlates with	AVP	AV	TLP	DLP	ILP	MP	AVSR	MUP	LOAC	RR	PRO	SCR	ASMA	DEL	ACP	AILP
Correlation Coefficient r	0.969	0.811	-0.933	-0.794	-0.901	0.949	0.972	0.967	0.892	0.933	0.914	-0.876	0.872	0.884	0.537	0.879
Significance Level	0.001	0.025	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.036	0.001
Total Productivity, TP, Correlates with:	ATLP	AWCP														
Correlation Coefficient r	0.904	0.545														
Signficance Level	0.001	0.033														

Table 14.5: Result of Added Value Productivity Correlation Analysis for Company B

Added Value Productivity, AVP, Correlates with:	TP	AV	TLP	DLP	ILP	MP	AVSR	MUP	LOAC	RR	PRO	SCR	ASMA	DEL	ACP	AILP
Correlation Coefficient r	0.969	0.972	-.875	-.697	-.800	0.889	0.934	0.918	0.905	0.937	0.927	-0.900	0.824	0.906	0.475	0.905
Significance Level	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.05	0.001
Added Value Productivity, AVP, Correlates with:	ATLP															
Correlation Coefficient r	0.962															
Signficance Level	0.001															

Table 14.6: Result of Added Value Correlation Analysis for Company B

Added Value, AV, Correlates with:	TP	AVP	TEC	IEC	DEC	MP	AVSR	MUP	LOAC	RR	PRO	SCR	ASMA	DEL	AILP	ATLP
Correlation Co-efficient r	0.811	0.972	0.967	0.960	0.86	0.764	0.775	0.768	0.651	0.900	0.93	-0.791	0.885	0.921	0.61	0.75
Significant Level	0.025	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.033	0.001	0.001	0.001	0.001	0.001	0.025	0.001
Added Value, AV, Correlation with:	IC	SP	FD													
Correlation Co-efficient r	0.501	0.562	0.564													
Significant Level	0.048	0.030	0.030													

Table 14.7: Regression Equations For Total Productivity, TP, Company A

Table 14.7a

	C	α	α_s	β	β_s	γ	γ_s	λ	λ_s	θ	θ_s	ST Error	R^2	F
TP = C+αTLP	0.420***	0.191***	0.844***									0.0737	0.713	69.55***
TP = C+αTLP+βMP	0.0891***	0.137***	0.606***	0.209***	0.547***							0.0300	0.955	284.38***
TP = C+αTLP+βMP+γOIP	0.0350***	0.133***	0.588***	0.175***	0.458***	0.0211***	0.193***					0.0190	0.982	478.73***
TP = C+αTLP+βMP+γCIP+ +λCP	0.0112***	0.107***	0.473***	0.171***	0.446***	0.021***	0.193***	0.0104***	0.153***			0.0137	0.991	699.10***

Table 14.7b

TP = C+αMP	0.244***	0.311***	0.811***									0.0805	0.658	53.91***
TP = C+αMP+βDLP	0.172***	0.220***	0.575***	0.0580***	0.540***									
TP = C+αMP+βDLP+γCP	0.0814***	0.198***	0.516***	0.0402***	0.374***	0.0220***	0.325***					0.0286	0.960	206.84***
TP = C+αMP+βDLP+γCP+ +λOIP	0.0258***	0.163***	0.426***	0.0389***	0.362***	0.0215***	0.318***	0.0214***	0.196***			0.0157	0.988	529.98***
TP = C+αMP+βDLP+γCP+ +λOIP+GILP	0.0051***	0.169***	0.442***	0.0374***	0.348***	0.0187***	0.276***	0.0226***	0.0206***	0.0052**	3.606**	0.0150	0.989	467.72***

*** Significant at 1%
** Significant at 5%

Table 14.8: Regression Equations For Added Value Productivity, AVP, Company A

	C	α	α_s	β	β_s	γ	γ_s	λ	λ_s	θ	θ_s	ST Error	R^2	F
AVP = C+αATLP	0.0292***	0.759***	0.996***									0.0285	0.992	3606.81***
AVP = C+αATLP+βACP	0.001***	0.610***	0.800***	0.0472***	0.214***							0.0051	0.999	56970.58***
AVP = C+αADLP	0.161***	0.378***	0.951***									0.1002	0.905	265.55***
AVP = C+αADLP+ +βAILP	0.0085***	0.226***	0.569***	0.157***	0.484***							0.0273	0.993	1970.69***
AVP = C+αADLP+ +βAILP+ +γACP	0.0007*	0.211***	0.530***	0.0875***	0.269***	0.0563***	0.256***					0.0163	0.998	3701.93***

*** Significant at 1%
** Significant at 5%
* Significant at 10%

Table 14.9: Regression Equation for Unit Costs of Company A

Table 14.9a

	C	α	α_s	β	β_s	γ	γ_s	λ	λ_s	ST Error	R^2	F
TUC = C+αTLUC	0.404***	1.784***	0.879***							0.0738	0.773	95.385***
TUC = C+αTLUC+βMUC	0.0758***	1.309***	0.645***	1.137***	0.507***					0.0246	0.976	541.35***
TUC = C+αTLUC+βMUC+γOUC	0.0183**	1.216***	0.599***	1.0271***	0.458***	0.933***	0.156**			0.0129	0.994	1328.6***

Table 14.9b

TUC = C+αMUC	0.261***	1.804***	0.805***							0.0919	0.648	51.510***
TUC = C+αMUC+βDLUC	0.163***	1.278***	0.570***	1.507***	0.563***					0.0476	0.909	134.929***
TUC = C+αMUC+βDLUC+γILUC	0.0654*	1.133***	0.505***	1.226***	0.458***	1.517***	0.298***			0.0242	0.977	372.08***
TUC = C+αMUC+βDLUC+γILUC+λOUC	0.0053	1.010***	0.451***	1.062***	0.397***	1.565***	0.308***	1.021***	0.171***	0.0076	0.999	2900.26***

*** Significant at 1%
** Significant at 5%

Table 14.10: Regression Equations For Total Productivity, TP, Company B

	C	α	α_s	β	β_s	γ	γ_s	λ	λ_s	θ	θ_s	ST Error	R^2	F
TP = C+αMP	80.22***	0.201***	0.949***									0.416	0.900	90.25***
TP = C+αMP+βCP	70.67***	0.235***	1.111***	0.0643***	0.295***							0.274	0.961	110.55***
TP = C+αMP+βCP+ +γOIP	67.20***	0.222***	1.052***	0.0449***	0.207***	0.0628***	0.148***					0.222	0.977	114.03***
TP = C+αMP+βCP+γOIP+ +λTLP	12.84***	0.380***	1.799***	0.0319***	0.147***	0.155***	0.366***	0.304***	0.831			0.102	0.996	412.41***
TP = C+αMP+βCP+γDLP	55.71***	0.308***	1.456***	0.0413***	0.190***	0.0965***	0.433***					0.218	0.978	118.43***
TP = C+αMP+βCP+γDLP+ +λOIP	55.98***	0.283***	1.340***	0.308***	0.141***	0.0772***	0.346***	0.0494***	0.116***			0.177	0.987	136.40***
TP = C+αMP+βCP+γDLP+ +λOIP+θILP	26.18***	0.332***	1.573***	0.0788***	0.362***	0.007***	0.0314***	0.103***	0.242***	0.217***	0.477	0.113	0.996	271.36***

*** Significant at 1%
** Significant at 5%
* Significant at 10%

Table 14.11: Regression Equations For Added Value Productivity, AVP, Company B

	C	α	α_s	β	β_s	γ	γ_s	λ	λ_s	θ	θ_s	ST Error	R^2	F
AVP = C+αAILP	0.360***	0.498***	0.906***									0.0127	0.820	45.64***
AVP = ±C+αAILP+ +βACP	0.192***	0.479***	0.871***	0.0174***	0.398***							0.0048	0.977	192.31***
AVP = C+αAILP+ βACP+γADLP	0.0083***	0.487***	0.886***	0.0126***	0.288***	0.0345***	0.186***					0.0004	0.999	203.51***
AVP = C+αATLP	0.0542***	0.852***	0.962***									0.0082	0.925	122.93***
AVP = C+αATLP+ βACP	0.00115	0.799	0.901	0.0122	0.280							0.006	0.999	13285.9***

*** Significant at 1%
** Significant at 5%
* Significant at 10%

Table 14.12: Regression Equations for Unit Costs of Company B

Table 14.12a

	C	α	α_s	β	β_s	γ	γ_s	λ	λ_s			ST Error	R^2	F
TUC = C+αMUC	0.701***	0.539***										0.020	0.712	24.67***
TUC = C+αMUC+ +βCUC	0.614***	0.561***	0.878***	2.025***	0.366***							0.0160	0.844	24.34***
TUC = C+αMUC+βCUC+ +γOUC	0.527***	0.624***	0.976***	2.001***	0.362***	0.352***	0.283***					0.0124	0.914	28.46***
TUC = C+αMUC+βCUC+ γOUC+λTLUC	0.0412**	0.966***	1.513***	1.116***	0.201***	0.940***	0.756***	0.924***	0.671***			0.0033	0.994	312.09***

Table 14.12b

	C	α	α_s	β	β_s	γ	γ_s	λ	λ_s	θ	θ_s	ST Error	R^2	F
TUC = C+αMUC+βCUC+ +γOUC+λILUC	0.134***	0.878***	1.375***	1.794***	0.324***	0.820***	0.659***	0.924***	0.507***			0.0076	0.972	60.288***
TUC = C+αMUC+βCUC+ +γOUC+λILUC	0.131**	0.883***	1.382***	1.828***	0.330***	0.813***	0.654***	0.935***	0.513***	-0.0025	-0.014	0.008	0.972	41.42***

*** Significant at 1% ** Signficant at 5% * Signficant at 10%

REFERENCES

1. Nie, N.H, Hull, C.H., Jenkins, J.G., Steinbrenner, K. and Bent, D.H. "Statistical Package for the Social Sciences". McGraw-Hill, 2nd Edn., 1974.

2. Koutsoyiannis, A. "Theory of Econometrics". Macmillan, 2nd Edn., 1977.

3. Anderson, R.L. and Bancroft, T.A. "Statistical Theory in Research". McGraw-Hill, 1952.

4. Wonnacott, R.J. and Wonnacott, T.H. "Econometrics". Wiley, 1970.

5. Johnston, J. "Econometric Methods". McGraw-Hill, 2nd Edn., 1972.

6. Kendrick, J.W. and Creamer, D. "Measuring Company Productivity". The Conference Board, Studies in Business Economics, No. 89, 1965.

7. Greenberg, L. "A Practical Guide to Productivity Measurement". Bureau of National Affairs, Washington, D.C., 1973.

8. Erickson, P.O.M. "Do You Know How Your Factory is Performing" Manufacturing and Industrial Engineering, July 1952.

9. Hawre, L.A. and Juntti, K.J. "Productivity Measurement". Assembly Engineering, April 1974.

10. Taylor, B.W. and Davis, K.R. "Corporate Productivity Getting It All Together". Industrial Engineering, March 1977.

11. Craig, C.E. and Harris, R.C. "Total Productivity Measurement at Firm Level". Sloan Management Review, Spring 1973.

12. Smith, I.G. "The Measurement of Productivity". Gower Press, 1973.

13. Bureau of Labour Statistics. "Summary of Proceedings of Conference on Productivity". BLS, Bulletin No. 913, 1947.

CHAPTER 15

CONCLUSIONS AND RECOMMENDATIONS

15.1 Introduction

At the end of Chapters 2,3,4,6,8,10,11,13 and 14 conclusions relevant to the specific topic under consideration were provided. In this chapter we present a summary conclusion dealing with the more universal aspects of the research. Also, we put forward some suggestions for possible future research.

15.2 The Need for Measurement of Productivity at Company Level

The finite nature of resources and the unprecedented experience of persistent and vigorous inflation has convinced the economists, politicians and perhaps the population at large that the only way forward is through productivity improvements. The measurement of productivity has now become an essential element in the ongoing and difficult debate on how to improve productivity.

At the organizational level the adverse economic circumstances - a persisting high rate of inflation, recession and international competition for markets - will commend such monitoring in the interest of company survival and profitability.

15.3 Definition and Concept

Measuring, analysing and improving productivity in a given organization is a complex process that involves the contributions of economists, industrial engineers, operations researchers and management scientists. Consequently, productivity literature abounds with rival definitions and explanations. The most pervasive definition of productivity, however, associates it closely with the technological concept of efficiency as revealed by changes in the level of output derived from a given volume of inputs (i.e. a ratio of a measure of output to a measure of some or all of the resources used in its production). The other widely accepted definition of productivity is related to the engineers' concept of efficiency - the ratio of actual output to potential output. Also, in planning and designing a

manufacturing system, industrial engineers tend to assess the productive efficiency in terms of the cost of production per unit of output.

15.4 Partial and Total Productivity Measures

The technological concept of productivity yields two broad classes of measurement systems - partial and total measures. The former relates the total or partial output of the organization to one type of input, while the latter relates the total output of the enterprise to all the inputs expended in its production.

The partial productivity measures express the joint effect of a number of inter-related influences on the use of the input factor under consideration in the production process such as changes in technology; substitution of one factor for another; utilization of capacity; layout and flow of material; the skill levels and the efforts of the workforce; managerial and organizational skills.

Partial productivity measures are useful in showing the economics that have been achieved over time in consumption of individual inputs per unit of output, and in controlling (particularly at shop floor level) the use of resources.

The total productivity measure eradicates to a large extent the weaknesses inherent in partial productivity measures as discussed above. Also, the total factor productivity reflects the interactions of various subsystems of an organization upon one another. This eliminates the dangers of subsystems optimizations to the possible detriment of the system as a whole.

15.5 Requirements of Productivity Analysis

In designing a productivity measurement system, it is important for the analyst to ensure that:

(1) the variables used in productivity measurement are derived from an analytical framework which encompasses all of the inputs and outputs of the system;

(2) a theory of determinants of effectiveness for the function under consideration is identified;

(3) the qualitative stability of each input and output category through time is identified and in interpreting the changes in quantitative input-output relationships to compensate for qualitative changes in the factors of production;

(4) the core aspects of input and output flows are quantified and be aware of the dangers of quantifying the peripheral;

(5) the numerator and denominator of productivity ratios:
   (a) relate to congruent sectors of activity;
   (b) relate to properly linked time periods;

and

(6) the input's contribution is absorbed into, and affect the characteristics of the output.

15.6 Levels of Measurement

Within the manufacturing system three levels of activity system - a manufacturing system, production system and board of companies - are identified. At each of these levels objectives have to be set and progress monitored.

The measurement criteria to be employed are functions of the level of activity system for which assessments are required. At "manufacturing system" level partial physical input-physical-output relationships tend to dominate the performance evaluation criterion. At "production system" level financial-input-physical-output relationships are the dominant performance measures. Finally, managers at boardroom level are concerned with increasing profit relative to investment (hence their concentration on financial-input-financial-output relationships). However, operating management's primary responsibilities centre around the adjustment of the level and composition of the physical inputs and outputs through which financial inflows are converted into larger financial returns, hence the need for a performance criterion relating the total physical output quantities to the total physical input quantities.

Table 15.1 summarises the types of measurement suitable for various levels of activity system.

15.7 Choice of Measurement System

It is generally accepted that organizations have a variegated goal structure. The choice of productivity measure is a function of the specific purpose for which it is constructed. Furthermore, subsystems within an organization have different objectives. This means that productivity is not a monastic concept and each system is characterised by an array of productivity relationships correlating with the specific goal for which the measure is designed and hierarchy of objectives. Because the variety of relationships is so great, making an effective choice requires defining the particular activity sector to be probed and the criteria to be applied.

15.8 Uses of Productivity Measurement

The main purposes to which productivity measurement can be put are fourfold:

(a) Strategic purposes: to compare the performance of an organization with its competitors both nationally and internationally.

(b) Tactical purposes: to enable effective management through the identification and comparison of the performance of individual production units and products within the company.

(c) Planning purposes: to compare the relative benefits accruing from the use of different inputs or their proportions and hence understand the tradeoffs in productivity decisions and to evaluate the merits of future investment in the various production facilities within a company.

(d) Pay bargaining: to achieve effective productivity pay bargaining and evaluate the effect of government requirements.

15.9 Current Practices

How extensively and how comprehensively firms practice productivity measurement is not known, but recent circumstances must have encouraged an increase in formal monitoring activity.

In our experience most companies employ budgetary control and work measurement techniques for controlling their activities. Also, it is common for companies to monitor the productivity and utilization of the machinery employed in the production process.

Generally, however, there is a wide gap between the accepted need for a comprehensive system of productive efficiency indexes and what companies actually achieve in this direction.

15.10 Approaches to Evaluation of Organizational Effectiveness

Seven models for evaluation of organizational effectiveness were identified. These pertain to the performance of the organization's structure, the performance of individuals in certain administrative and organizational positions, and the impact of the organization on the surrounding environment.

To employ any of these models the analyst requires practical methods for measuring and analysing the appropriate data. Productivity measurement provides the necessary analytical tool with respect to the "rational goal model", "system resource model" and "managerial process model". To a lesser extent it also provides a means of assessment in the "organizational development model" and the "functional model".

15.11 Operational Aspects of Productivity Measurement

A fundamental issue in any productivity analysis is that of measurement: how to measure multi-inputs and multi-outputs, and how to determine plant capacity and utilization in multi-product systems which involves complex operations.

In this section we review the conclusions reached with respect to the operational aspects of the productivity measurement.

15.11.1 Units of measurement

The initial problem was specifying a technique which would facilitate the meaningful summation of diverse factors of production. There are essentially two different solutions to this problem: (1) weighting of each component by an appropriately devised weight (an index number approach), and (2) computing the contribution of each factor in the common unit.

In the first approach the weights should primarily reflect the relative contribution of each input factor to the production of goods.

The second approach requires the regular measurement of factors of production in common units. There are basically two types of measurement units, (1) Time Equivalent, and (2) Monetary. The "time equivalent" units were discarded because of the number of arbitrary assumptions that have to be made in converting the contribution of non-labour inputs to a manpower equivalent.

The main advantage associated with the "monetory" units is its extensive use by industry for expressing the inputs and outputs values.

15.11.2 Availability of data

The two case studies described in the previous chapters suggest that in general the data required for the productivity measurement is available as a byproduct of existing managerial planning and control functions. This is not to say that the data required is always available in the desired format and that no information gap exists. Admittedly, an analyst arriving fresh on an industrial scene will face difficulties in extracting the required information and interpreting the records; he may find various inconsistencies, changes in

accounting procedures, definitions which are incompatible with his needs, varying time lags associated with the information, even gaps in the records. But with the aid of people familiar with the system, and by restoring to reasonable assumptions regarding missing information, the task of constructing one of the models described and the data bank required for it can be completed.

An organization which intends to use one or more of the techniques described can, by suitably modifying its information system (at low cost), ensure that the relevant data are recorded in a way that is immediately amenable for analysis by the models.

15.11.3 Measurement of outputs and inputs

Measurements of heterogeneous outputs and inputs lies at the heart of empirical productivity studies. The measurement process gives the expression to a given set of definitions and assumptions about the various parameters that make up the production system. It is important to make these assumptions explicit throughout and to appreciate their consequences on the results of calculations and on the interpretation that can be put on these results.

(I) Outputs:

Outputs of an enterprise may be measured in the following formats:

(1) Gross or net value added using either single or double deflation techniques.

(2) Total earnings (excludes the materials cost but includes the external expenditure).

(3) Total production output either in terms of end products or components:

- (a) directly (weighting of physical quantities of individual products);
- (b) indirectly (deflation of value by price);
- (c) relating the output to physical quantities of components produced using multiple regression techniques.

(4) Total revenue generated including receipts from sources other than production, goods manufactured in plant and intangible capital outlays.

The central question in weighting the output is the choice of the measurement unit. Generally, the choice lies between a physical (e.g. standard hours of production) or financial (e.g. price or cost of production of a product) units. The output values, when using technique 3(a), were measured utilizing exclusively price weights because they represent an "economically oriented concept of physical output".

Deflation is a deceptively easy technique of indirect estimation used when output aggregates (or indexes) cannot be conveniently or at all computed directly from the physical quantities. It seems to yield adequate results at low cost in information and time; yet it could mislead if the value dividend and the price deflator do not match closely in content.

Measurement of output in terms of components (using multiple regression techniques) eliminates the problem of comparability of outputs of different time periods, inherent in the case of batch manufacturers. The technique also facilitates the computation of the output in constant term. However, this approach is not likely to produce results as precise as those of the other two methods.

II. Inputs:

The techniques described for the measurement of outputs are equally applicable in the assessments of the contribution of labour and material inputs. The contribution of miscellaneous goods and services generally can only be computed using the indirect (deflation) technique.

The assessments of the capital contribution is conceptually and computationally the most difficult. Three methods of measurement are utilized. Two of these, the "service value" and the "investor contribution" represent a flow concept, while the third approach (the "stock of capital") is

based on a stock concept. The flow concept represents a conception identical to those employed in the assessment of the contribution of labour, material and miscellaneous goods and services inputs and outputs.

The "service value" model is conceptually and intuitively more plausible, however, the "investor contribution" model is easier to apply. In practice the observed differences between the productivity assessments using these two models were small.

15.11.4 Capacity estimation

The measurement of capacity in a company organized along orthodox batch production lines is extremely difficult. Part of the difficulty arises from the fact that the capacity is a function of the batches of products being produced. Accepting the limitations inherent in the estimation of capacity, the following methods provide a reasonable approximation of the productive capacity:

(1) Estimating the total amount of any given product which can be produced, assuming some specified allocation of plant facilities to such an output.

(2) Estimating the composite productive capacity covering some specified mix of products.

(3) Estimating the standard hours of production for a standard mix of products.

The last method has been developed and tested by the author. This method overcomes the problem of dependability of capacity estimation on product mix. The technique suffers from two disadvantages, (i) it is laborious to carry out; and (ii) it depends on standard hours which are not always reliable.

15.12 Choice and the Effect of Base Period

The base period selected should have the following attributes:

(1) It should be comparatively recent.
(2) It should approximate closely the average output of past periods (i.e. it should be as "normal" or "representative" as possible).
(3) It should include no major aberrations.

The choice of the base period (when using weighted quantity index number formulations) affects the results of output and input index computations. However, in many cases the discrepancies emanating from the choice of base-period are very small.

The changes in base period (when using simple index formulation) merely affects the amplitudes of the factor but it does not alter the parameters trends.

15.13 The Effect of Formulation on Index Number

The output and input indexes are the function of the structure of the index number formulation utilized. Four variants of index number formulations were examined. Fisher's index is cumbersome and is only suitable when all the computations are relegated to a computer, Edgeworth's geometric approximation is a very good approximation of the Fisher's ideal index and not too cumbersome to use in practice, Edgeworth's arithmetic approximation is simpler to apply and usually accurate enough, while Lapeyers' is simplest to use but less accurate.

15.14 Methodological Tools of the Analysis

In analysing the data we utilized the following three methodological tools:

(a) Time based analysis - a record of a given parameter is plotted over a period of time, to reveal any exceptional modes of behaviour. This allows a stationary pattern or upward/downward trends to be detected, as well as peaks and troughs, so that the reasons for their occurrence may then be sought.

(b) A pattern analysis - the record of one parameter is plotted against another, to establish a time-path of the relationship between the two parameters and draw some inferences from the pattern that emerges.

(c) Correlation and regression analysis - in this case the major purpose is to discover whether the two variables X and Y are closely associated with each other. Once the hypothesis of a direct relationship between the two variables is held, it is possible to pursue questions of causability and prediction using multiple regressions.

15.15 Cost Behaviour

Analyses of costs at the two host companies do not appear to support some widely held beliefs concerning manufacturing costs. They indicate that a very thorough understanding of the nature of the cost structure of a plant is necessary to guide effective managerial decisions concerning cost reduction and performance improvements.

15.16 Inter-relationships between various Productivity Measures and Accounting Factors

The correlation analysis shows that total factor and value added productivity are functions of related partial productivities. Clearly, treating the labour productivity as a measure of effectiveness of an enterprise or labour is a misconception.

The anlaysis also shows that total factor and value added productivities do not always correlate with profit or rate of return, demonstrating the fact that, relying solely on profit and rate of return on assets could mislead the management and hide from them below average productivity gains.

Regression equations derived, relating the total unit cost to unit cost of factors of production; the total factor productivity to partial productivities; and value added productivity to relevant partial productivities, are very

useful management tools. Two very important uses of these equations are in; (1) determination of causes of observed variations of the total productivity, value added productivity, and total unit costs; and (2) determination of impacts of various forced or unforced changes on productivity or unit costs.

15.17 The Productivity Measurement Models

The methods available for assessments of productivity are numerous. Five measurement techniques, "Total Factor"; "Value Added"; "Productivity Analysis"; "Productivity Costing"; and "Production Functions", were selected for application. The reason for this selection was the compatability of these techniques with the technological and engineering concept of efficiency.

The values obtained, as the result of the application of these techniques, are dependent on the definition and the method of measurement used for quantifying the output and input components. Thus, it is feasible for example to have several "total factor" productivity values within an enterprise. The important point to remember is consistency in measurement of output and inputs from one period to the next. Table 15.1 shows the relevant organizational situations and the level of activity system for application of these techniques.

The applicability of these models is demonstrated in Chapters 6,8,10,11 and 13 using actual case studies.

15.17.1 Total factor productivity

The measure is useful at boardroom level. It demonstrates for management the result of trade-off decisions regarding the combination of input factors. It also provides the management with an overall efficiency measure which counsels against subsystems optimization.

The measure is helpful in the projection of labour materials, capital and miscellaneous inputs requirements. It is also useful in collective bargaining and the comparison

of efficiency of two or more plants within the same organization and to a lesser extent for comparison of a firm with its competitors.

15.17.2 Value added productivity

The value added productivity is also most useful at boardroom level. The measure is used frequently as the basis of a company wide incentive scheme. Value added is also used extensively in collective bargaining.

As a measure of productivity it shares the characteristics of the "total factor productivity". However, it suffers from one important disadvantage in that it fails to show the effects of the improvements in the use of material. Consequently, it has to be treated with caution when used to assess the productivity of a material intensive company.

Value added can be used as an analytical measure in the "rational goal model", the "systems resource model", the "managerial process model", the "organizational development model", and the "functional model".

15.17.3 Productivity analysis

As we have seen, the model can be used at different levels of activity system: for the analysis of productivity of a whole organization, for departments, or even with respect to individual processes. Comparative studies at different levels can also usefully employ the model: to compare costs and profitability of companies, or to compare the performance of divisions and departments within a given enterprise. In any comparative study, whether it is related to a particular operation over a period of time, or whether it attempts to show how a given plant performs in comparison with another, it is well to remember that the analysis would be valid only for a given set of assumptions regarding definitions and measurements of outputs and inputs and provided that consistency is maintained in the manner in which the monitoring process is carried out.

The use of r model provides the analyst with the decomposition of the relative change in the rate of return into its several constituent parts, so that their relative contributions can be better appreciated. The decomposition of total unit cash into its constituent elements and their comparison from one period to another reveals the partial unit costs contributing most or least to observed adjustments in the total unit cost. Moreover, if the analysis is applied to records covering a long period, the finding may be expected to reveal any persistent trends in the sources of upward and downward pressures on the total unit cost.

The computer program devised highlights the distinction between the descriptive and the predictive roles of the model, and emphasises that the latter cannot be undertaken without the former. Another distinction often of interest to management is that between the planning and the control functions. The latter is concerned with short term managerial reaction to current events, the former with long-term effects. Evaluation of past operations is essential for planning future activities of an enterprise, and in particular the effect on productivity on such factors as:

(a) scale of operations: the extent or the likely development of economies of scale, based on a comparative study of similar operations conducted at various scales;

(b) working methods: the extent to which changes in operating procedures, manning and organizational structure can influence the performance of a given plant;

(c) commissioning of new plants: the possible improvement to be gained by replacing plant and machinery, using existing or modified operating procedures;

(d) technological innovation: the expected contribution to be gained from new processes and the way they can be integrated in the plant.

(e) product mix: the likely advantages to be derived from changing the mix, from simplification of the product range, or from its diversification.

Each of these changes and others not listed here has technical, marketing, personnel, financial and organizational implications. Each may affect the arrays of inputs and outputs, the unit cost structure, and the profitability of the enterprise. These are central issues in the planning process, and an analysis of the productivity along the lines described in Chapters 9 and 10 can greatly assist the planners in their task.

But the very same ingredients of the "productivity analysis" model can be valuable for the control function as well. The program can be used to produce monthly reports on changes in the cost structure and to produce updated deterministic appraisals based on established trends or forecasts. With an interactive system, it is possible to re-run the program with fresh sets of assumptions so that on the basis of results appropriate adjustments can be carried out in the operating conditions of the plant.

The main disadvantage of the technique is the need for estimation of capacity. Even crude estimates of the capacity in the case of batch production manufacturers particularly those with "Jobbing Shop" characteristics are difficult to obtain.

15.17.4 Productivity costing

Productivity costing is an integrated productivity measurement and conversion capacity-absorption cost accounting model. The system's operating costs are allocated to each of the system's potentially productive facilities in proportion to their potential productiveness. Because these apportionments are converted into product processing cost rates based on the individually appraised maximum feasible utilization of each potentially productive facility the resultant product costs and their dependent product profits can be considered to have stable and near optimal values.

Productivity costing method emphasises the contribution to the productivity of a firm of individual products rather than the operating units or functional activities.

The development of productivity costing indexes brings various aspects of the operation of an enterprise under scrutiny. The processing facilities productivity, E_f, provides the basis for standardisation and rationalisation of facilities design, while the product productivity characteristics, E_d, bring into focus the importance of the product and process design function. This is an important attribute of the technique as the effect of design decisions on manufacturing costs and productivity is rarely appreciated. Design is the first step in the manufacturing process and decisions made here strongly influence all subsequent activities, particularly costs. Since the design stage is the occasion when most manufacturing costs are implicitly determined, it also provides the key opportunity for future cost reduction and productivity increases. The computer program developed can provide the designers with feedback on manufacturing and assembly cost consequences at the design stage together with the generation of data for the effective organization of production.

At the boardroom level the "productivity costing" technique coupled with the devised program provide the management with an analytical tool for optimization of the company's operations. It also provides useful management guidelines in determining the appropriate sales price for a product.

The "productivity costing" concept would be extremely difficult to apply in companies where effective work measurement techniques are not applied.

15.17.5 Production function

The use of the production function in the assessment of productivity represents an important departure from the other four techniques discussed in Sections 15.17.1 to 15.17.4. Using econometric techniques output is related to factors of production. The formula derived can be used to determine the level of output which should be achieved from the level of inputs consumed in its production. Comparison of the

potential output with the output achieved (engineers efficiency concept) reveals the degree of efficiency attained.

In deriving a "production function" the analysit is not limited to the use of continuous variables. This is an important advantage particularly in the case of cross-sectional studies as quasi-factors of production such as location or seasonality of demand may have an important bearing on production. Indeed, the use of the "productivity function" provides the best method of productivity comparison between companies. The reason for this is simply the availability of the required data from the published accounts of a company.

In the other four techniques it is necessary to represent the vector of inputs by a scalar, this obviously requires dimensional consistency. This restriction does not apply in the case of "production functions". The outputs and the inputs could be measured in physical or any other units, as well as in mixed units.

The "production function" method allows the analyst to include a variable, explaining the technical progress achieved. These include the effect of research and development, cumulative experience, or learning rates. The technique could also be used in cost estimation and prediction, capacity planning and in solving sourcing problems.

The use of production function is most useful in the "production system level", in particular, it provides the production manager with a simple tool of measuring the efficiency of the system under his control and the management services department with the means of planning capacity and solving sourcing problems.

The main disadvantage associated with the technique is the requirement of a digital computer for derivation of the function. Although with proliferation of computers, this is becoming less of a handicap.

15.18 Recommendations

As for the future course of research there are four recommendations:

(i) To assess the long-term influence of changes in manufacturing organization on total company performance.

(ii) To assess the influence of the strategic factors on the company's total performance.

(iii) To examine the usefulness of the "productivity costing" technique in classification and coding systems for use in computer aided design.

(iv) To examine the comparative productivity of the new technology with its predecessors, using the "production function" and "productivity analysis" techniques.

15.18.1 The effect of manufacturing organization on total company performance

The effect of manufacturing organization on total company performance is of the utmost importance. To my knowledge there has never been any attempt to determine the effects of such factors on total productivity of a company. The present work provides a basis for such a study.

I suggest using the "total productivity", "value-added" and "product productivity" models and the multiple regression techniques, that it is possible to determine the effect of the following factors:-

(a) throughput times;
(b) batch sizes;
(c) number of operations per batch of product;
(d) actual processing time of batches;
(e) percentage of orders delivered per period;
(f) orders delivered early/late per period;
(g) backlog of orders per period:
and (h) use of group technology
on the productivity of a company.

15.18.2 The effect of the strategic factors on the total company performance

An important reason for strategic business decisions is to improve "total factor productivity", so it is helpful for the decision maker to know what factors favourably affect TFP. By interviewing the top level managers and combining their recommendations with policy theory, it should be possible to create a comprehensive list of strategic factors important to the organization. This may embrace the following factors:-

(1) Product quality.
(2) Price relative to competition.
(3) Product price.
(4) Labour/machine productivity index.
(5) Gross profit per unit.
(6) Units produced per labour hour.
(7) Factory cost per unit.
(8) Total cost per unit.
(9) Units sold per salesman.
(10) Sales revenue per salesman.
(11) Marketing expenses as percent of sales revenue.
(12) Marketing expenses per unit.
(13) Output to capacity ratio.
(14) Collection period.
(15) Inventory to sales ratio.
(16) Market share.
(17) Labour absenteeism.
(18) Accident frequency.
(19) Labour turnover.

Using the multiple regression technique it is possible to determine the effect of strategic factors on the total factor productivity. The application of the procedure to inter- and intra-organizational studies would yield valuable information.

15.18.3 Productivity costing and computer aided design

As suggested, the "productivity costing" model can be used at the design stage to determine the effects of decisions

taken at this step, on cost and productivity. It would be of interest to exploit the possibility of using the technique in conjunction with classification and coding systems for specific processes as a basis for cost estimation and data generation for use in computer aided design.

15.18.4 Comparative productivity of the new technology with its predecessor

Like "productivity" application of new technology is a popular topic for discussion by politicians, economists, trade unionists, etc. There are real fears that Western Europe is already falling a long way behind the Japanese, and on the other hand, trade unions are fearful from the impact of new technology on the labour market.

The production functions can be used to compare the productivity of a new production system e.g. productivity of a cell of D.N.C. or C.N.C. Machines with its predecessor e.g. cell of traditional machines such as conventional lathes etc. This is particularly attractive as the interaction of various factors of production upon one another are taken into consideration.

The "productivity analysis" model can be used to assess the impact of new technology on physical inputs and outputs and the proportion in which they are combined, unit costs and rate of return on investment.

The application of these two techniques - on the lines suggested above would contribute considerably to the current debate with respect to:

(a) the impact of new technology on productivity;

and

(b) the impact of new technology on man-power requirements.

TABLE 15.1

PRODUCTIVITY MEASUREMENT MODELS

Type of Productivity Measure	Appropriate Level of Aggregation	Usefulness in the Organizational Effectiveness Models	Main Areas of Application	Advantages	Disadvantages
Partial Physical Measures	Manufacturing system e.g. various production shops etc.	The "System Resource Model" and to a lesser extent the "Rational Goal Model"	For controlling the resource utilization of the productive departments. These type of statistics should be issued daily or weekly to the Forman responsible and provide the basis for his accountability.	Computationally simple to construct, both in terms of availability of dates and concepts. Shows the economies that have been achieved over times.	Fails to distinguish between the joint effects of a number of inter-related influences.
Total Factor Productivity	Top management, boardroom level	The "Rational Goal Model", the "System Resource Model" the "Managerial Process Model", and in an indirect manner the "Managerial Process Model", the "Organizational Development Model", the "Bargaining Model" and the "Structural Functional Model".	For providing the top management with an overall measure of efficiency. The measure demonstrates the results of trade off decisions. It is also useful in pay bargaining.	Shows and counsels against subsystems optimization. Overcomes the substitution problems. Implicitly provides an efficiency measure of the productive unit.	The information required may prove difficult to obtain. Requires an analytical framework for measurement of inputs and outputs.
Value Added Productivity	Top management, boardroom level.	Same as the "Total Factor Productivity". The measure is also useful in the case of the "Functional Model".	As above. Also in company wide incentive schemes, pay bargaining and Employment Protection Act. Value added also determines the contribution of a company to nation's wealth creation efforts.	As above. Also the problem of double counting is avoided, and it is isolated from the effects of change in make or buy patterns. As a business indicator it has both extensive and intensive qualities.	As above. Also, fails to show the effects of the productivity gains resulting from improved utilization of materials input.
Productivity Analysis	"Manufacturing System", "Production System", and "Boardroom Level".	As in the "total factor productivity" model.	As in the "Total Factor Productivity" Model. Also, for planning and control of the organization's activity. The model can be used in a predictive manner, and for decomposition of the rate of return and unit costs into their component parts.	The model provides information on the changes in the level of each category of input requirement per unit of output; changes in the proportions in which inputs are combined; differences between productivity of inputs when they are fully utilized and when their contributions are reduced by idleness; initiating units responsible for changes in aggregate level of performance.	Difficulties inherent in estimating the productive capacity of an enterprise. The volume of the information required to perform a full analysis.

TABLE 15.1 (cont.)

Type of Productivity Measure	Appropriate Level of Aggregation	Usefulness in the Organizational Effectiveness Models	Main Areas of Application	Advantages	Disadvantages
Productivity Costs	"Production System" and "Boardroom Level".	As in the "Total factor productivity" model.	Determination of the contribution of individual products to the productivity of a firm; standardisation and anationalisation of facilities design; the impact of the product and process design; the impact of underutilization of the capacity; ranking of the products.	Demonstrate the impact of the idle time on production costs; highlights the underutilization of the capacity; and provides a sound criteria for optimization of the systems operations.	Difficult to apply in companies where effective work measurement techniques are not utilized. The apportionment of non-direct costs. Division of costs to fixed and variable.
Production functions	"Production System".	As in the "total factor productivity model.	Intera and inter comparison of productivity. The determination of the effect of the technical progress. Cost estimation and prediction. Capacity planning. Solving sourcing problems.	An analytical approach to measurement of productivity. No need for dimensional consistency. Quasi factors of production can be included in analysis.	The assumption that factors are substitutable and ignoring that factors may be complementary. The need for a digital computer for deriving the functions.

APPENDIX I

LISTING OF PROGRAM "PRODUCTIVITY ANALYSIS"

```
      PROGRAM ABBY(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      INTEGER B,TCYCL,BPER
      REAL MP,MQ,MH,NEMP,MPOU,NFI,INDW,INI,MATV,INLI,INDWI,INII
      REAL MATP,INLP,INP
      REAL MHI,NFINI,MATE,NFTI
      EQUIVALANCE (P(1,1),PM(1,1),RH(1,1),S(1,1))
      COMMON/A/ PP(20,50),PQ(20,50),MP(20,50),MQ(20,50),
     1 HR(20,50),MH(20,50),AVS(20,50),NEMP(20,50),MPOU(20),
     2 NFI(20),TMC(20),TFC(20),TR(20),PROF(20),TWC(20),DW(20),
     3INDW(20),FB(20),INI(20),DEP(20),TOC(20),NSIM,NPRO,NPER,NMT,NHET,
     4NSET,OTC(20)
C DIMENSION FOR VARIABLES CALCULATED
      DIMENSION SNO(20),SDO(20),OUTP(20),SNI(20),SDI(20),MATV(20),
     1SNM(20),SDM(20),MHI(20),SNS(20),SDS(20),INLI(20),SNFI(20),
     2SDFI(20),SNIF(20),SDIF(20),SNMF(20),SDMF(20),SNSF(20),
     3SDSF(20),SNE(20),SDE(20),P(20,50),SNIE(20),SDIE(20),
     4PM(20,50),SNME(20),SDME(20),RH(20,50),SNSE(20),SDSE(20),
     5S(20,50),SNOEG(20),SDOEG(20),SNIEG(20),SDIEG(20),SNMEG(20),
     6SDMEG(20),SNSEG(20),SDSEG(20),CAP(20),NFINI(20),TMCI(20),
     7TFCI(20),TRI(20),PROFI(20),TWCI(20),TI(20),TII(20),DWI(20),
     8INDWI(20),TW(20),TEWI(20),INII(20),TOC(20),TOCI(20),
     9MATP(20),DLP(20),FCP(20),INLP(20),WOC(20),INP(20),AUIF(20)
      DIMENSION OTCI(20)
      DIMENSION FPMM(20),FPMF(20),FPMHF(20),AVWR(20),AVMP(20),
     1AVSR(20),RCFI(20),UDWC(20),UIWC(20),UTWC(20),UMC(20),
     2UFC(20),OUC(20),TUC(20),WAGE(20),SALA(20),TEMC(20),
     3MATE(20),FIXC(20),OTCOS(20),DEPR(20),REOU(20),COOU(20),
     4OUCA(20),CANE(20),NFTI(20),PRTO(20),PROU(20),OUTO(20)
      DIMENSION UDEP(20),DEPI(20)
      READ (5,*) BPER
      READ (5,*) NSIM
      READ (5,*) MARK
      READ (5,*) NPER,NPRO,NMT,NHET,NSET
      READ (5,110) ((PP(I,J),J=1,NPRO),I=1,NPER)
  110 FORMAT (F11.3,6F10.3)
      READ (5,120) ((PQ(I,J),J=1,NPRO),I=1,NPER)
  120 FORMAT (F11.2,6F10.2)
      READ (5,*) ((MP(I,J),J=1,NMT),I=1,NPER)
      READ (5,*) ((MQ(I,J),J=1,NMT),I=1,NPER)
      READ (5,150) ((HR(I,J),J=1,NHET),I=1,NPER)
  150 FORMAT (F11.2,6F10.2)
      READ (5,160) ((MH(I,J),J=1,NHET),I=1,NPER)
  160 FORMAT (F11.2,6F10.2)
      READ (5,170) ((AVS(I,J),J=1,NSET),I=1,NPER)
  170 FORMAT (F11.2,6F10.2)
      READ (5,180) ((NEMP(I,J),J=1,NSET),I=1,NPER)
  180 FORMAT (F11.2,6F10.2)
      READ (5,190) (MPOU(I),I=1,NPER)
  190 FORMAT (F11.2,6F10.2)
      READ (5,200) (NFI(I),I=1,NPER)
```

```
  200 FORMAT (7F10.2)
      READ (5,210) (DEP(I),I=1,NPER)
  210 FORMAT (7F10.2)
      READ (5,220) (TMC(I),I=1,NPER)
  220 FORMAT (7F10.2)
      READ (5,230) (TFC(I),I=1,NPER)
  230 FORMAT (7F10.2)
      READ (5,240) (TR(I),I=1,NPER)
  240 FORMAT (7F10.2)
      READ (5,250) (PROF(I),I=1,NPER)
  250 FORMAT (7F10.2)
      READ (5,260) (TWC(I),I=1,NPER)
  260 FORMAT (7F10.2)
      READ (5,270) (DW(I),I=1,NPER)
  270 FORMAT (7F10.2)
      READ (5,280) (INDW(I),I=1,NPER)
  280 FORMAT (7F10.2)
      READ (5,290) (FB(I),I=1,NPER)
  290 FORMAT (7F10.2)
      READ (5,*) (INI(I),I=1,NPER)
      READ (5,294) (OTC(I),I=1,NPER)
  294 FORMAT (7F10.2)
      WRITE (6,310) NPER
  310 FORMAT (2X,*NUMBER OF PERIODS OF HISTORICAL DATA*,I3)
      WRITE (6,320) NSIM
  320 FORMAT (2X,*NUMBER OF SIMULATIONS REQUIRED*,I3)
      TCYCL=NPER+NSIM
      WRITE (6,330) TCYCL
  330 FORMAT (2X,*TOTAL PERIODS OF ANALYSIS*,I3)
       WRITE (6,335) NPER+1
  335 FORMAT (2X,*SIMULATION RUNS START FROM PERIOD*,I3)
      WRITE (6,340) BPER
  340 FORMAT (2X,*BASE PERIOD*,I3)
      B=BPER
      IF (NSIM.EQ.0) GO TO 305
      IF (NSIM.GT.0) CALL SIMUL
  305 CONTINUE
      IF (MARK.EQ.1) GO TO 1000
      IF (MARK.EQ.2) GO TO 2000
      IF (MARK.EQ.3) GOTO 3001
      IF (MARK.EQ.4) GO TO 1025
C CALCULATING THE OUTPUT INDEX OUTP(I) USING THE LASPEYERS APP
C DO LOOP FOR CALCULATIG THE NUMERATOR
 1025 PRINT,"CALCULATIONS ARE BASED ON LASPEYRS FORMULATON"
      PRINT,"-----------------------------------------------"
      DO 3100 I=1,NPER
      SNO(I)=0.0
      DO 3000 J=1,NPRO
      SNO(I)=SNO(I)+PP(B,J)*PQ(I,J)
 3000 CONTINUE
 3100 CONTINUE
```

```
C DO LOOP FOR CALCULATIG DENOMINATOR
      DO 3300 I=B,B
      SDO(I)=0.0
      DO 3200 J=1,NPRO
      SDO(I)=SDO(I)+PP(I,J)*PQ(I,J)
 3200 CONTINUE
 3300 CONTINUE
C DO LOOP CALCULATING OUTPUT INDEX OUTP(I)
      DO 3400 I=1,NPER
      OUTP(I)=SNO(I)/SDO(B)*100.
 3400 CONTINUE
C CALCULATING THE MATERIAL VOLUME INDEX MATV(I) USING LASPEYRS APP
C DO LOOP FOR CALCULATING NUMERATOR
      DO 3600 I=1,NPER
      SNI(I)=0.0
      DO 3500 J=1,NMT
      SNI(I)=SNI(I)+MP(B,J)*MQ(I,J)
 3500 CONTINUE
 3600 CONTINUE
C DO LOOP FOR CALCULATING THE DENOMINATOR
      DO 3800 I=B,B
      SDI(I)=0.0
      DO 3700 J=1,NMT
      SDI(I)=SDI(I)+MP(I,J)*MQ(I,J)
 3700 CONTINUE
 3800 CONTINUE
C DO LOOP CALCULATING MAT VOL INDEX MATV(I)
      DO 3900 I=1,NPER
      MATV(I)=SNI(I)/SDI(B)*100.
 3900 CONTINUE
C CALCULATING MAN HOUR INDEX USING THE LASPPEYERS APP
C DO LOOP FOR CALCULATING THE NUMERATOR
      DO 4100 I=1,NPER
      SNM(I)=0.0
      DO 4000 J=1,NHET
      SNM(I)=SNM(I)+HR(B,J)*MH(I,J)
 4000 CONTINUE
 4100 CONTINUE
C DO LOOP FOR CALCULATING DENOMINATOR
      DO 4300 I=B,B
      SDM(I)=0.0
      DO 4200 J=1,NHET
      SDM(I)=SDM(I)+HR(I,J)*MH(I,J)
 4200 CONTINUE
 4300 CONTINUE
C DO LOOP CALCULATING DIRECT LABOUR INDEX MH(I)
      DO 4400 I=1,NPER
      MHI(I)=SNM(I)/SDM(B)*100.
 4400 CONTINUE
C CALCULATING IDIRECT LABOUR INPUT INDEX INLI(I)
C DO LOOP FOR CALCULATING THE NUMERATOR
```

```
      DO 4600 I=1,NPER
      SNS(I)=0.0
      DO 4500 J=1,NSET
      SNS(I)=SNS(I)+AVS(B,J)*NEMP(I,J)
 4500 CONTINUE
 4600 CONTINUE
C DO LOOP FOR CALCULATING DENOMINATOR
      DO 4800 I=B,B
      SDS(I)=0.0
      DO 4700 J=1,NSET
      SDS(I)=SDS(I)+AVS(I,J)*NEMP(I,J)
 4700 CONTINUE
 4800 CONTINUE
C DO LOOP CALCULATING INDIRECT LABOUR INDEX INLI(I)
      DO 4900 I=1,NPER
      INLI(I)=SNS(I)/SDS(B)*100.
 4900 CONTINUE
      GO TO 8000
C OUT PUT INDEX USING FISHERS APP
C DO LOOP FOR CALCULATING THE NUMERATOR
 1000 PRINT,"CALCULATIONS ARE BASED ON FISHER FORMULATION"
      PRINT,"-----------------------------------------"
      DO 5010 I=1,NPER
      SNO(I)=0.0
      SNFI(I)=0.0
      DO 5000 J=1,NPRO
      SNO(I)=SNO(I)+PP(B,J)*PQ(I,J)
      SNFI(I)=SNFI(I)+PP(I,J)*PQ(I,J)
 5000 CONTINUE
 5010 CONTINUE
C TWO DO LOOPS REQUIRED FOR CALCULATING DENOMINATIR
      DO 5030 I=B,B
      SDO(I)=0.0
      DO 5020 J=1,NPRO
      SDO(I)=SDO(I)+PP(I,J)*PQ(I,J)
 5020 CONTINUE
 5030 CONTINUE
      DO 5050 I=1,NPER
      SDFI(I)=0.0
      DO 5040 J=1,NPRO
      SDFI(I)=SDFI(I)+PP(I,J)*PQ(B,J)
 5040 CONTINUE
 5050 CONTINUE
C DO LOOP CALCULATING OUT PUT INDEX FISHER APP OUTP(I)
      DO 5065 I=1,NPER
      OUTP(I)=SQRT((SNO(I)*SNFI(I))/(SDO(B)*SDFI(I)))*100.
 5065 CONTINUE
C CALCULATING MAT VOL INDEX MATV(I) FISHER APP
C DO LOOP CALCULATING THE NUMERATOR
      DO 5070 I=1,NPER
      SNI(I)=0.0
```

```
      SNIF(I)=0.0
      DO 5060 J=1,NMT
      SNI(I)=SNI(I)+MP(B,J)*MQ(I,J)
      SNIF(I)=SNIF(I)+MP(I,J)*MQ(I,J)
 5060 CONTINUE
 5070 CONTINUE
C TWO DO LOOPS REQUIRED FOR CALCULATING THE DENOMINATOR
      DO 5090 I=B,B
      SDI(I)=0.0
      DO 5080 J=1,NMT
      SDI(I)=SDI(I)+MP(I,J)*MQ(I,J)
 5080 CONTINUE
 5090 CONTINUE
      DO 5110 I=1,NPER
      SDIF(I)=0.0
      DO 5100 J=1,NMT
      SDIF(I)=SDIF(I)+MP(I,J)*MQ(B,J)
 5100 CONTINUE
 5110 CONTINUE
C DO LOOP FOR CALCULATING MATV(I) FISHER APP
      DO 5120 I=1,NPER
      MATV(I)=SQRT((SNI(I)*SNIF(I))/(SDI(B)*SDIF(I)))*100.
 5120 CONTINUE
C CALCULATING MAN HOUR ONDEX MH(I) USING FISHERS APP
C DO LOOP FOR CALCULATING THE NUMERAYOR
      DO 5140 I=1,NPER
      SNM(I)=0.0
      SNMF(I)=0.0
      DO 5130 J=1,NHET
      SNM(I)=SNM(I)+HR(B,J)*MH(I,J)
      SNMF(I)=SNMF(I)+HR(I,J)*MH(I,J)
 5130 CONTINUE
 5140 CONTINUE
C TWO DO LOOP REQUIRED FOR CALCULATING THE DENOMINATOR
      DO 5160 I=B,B
      SDM(I)=0.0
      DO 5150 J=1,NHET
      SDM(I)=SDM(I)+HR(I,J)*MH(I,J)
 5150 CONTINUE
 5160 CONTINUE
      DO 5180 I=1,NPER
      SDMF(I)=0.0
      DO 5170 J=1,NHET
      SDMF(I)=SDMF(I)+HR(I,J)*MH(B,J)
 5170 CONTINUE
 5180 CONTINUE
C DO LOOP CALCULATING MAN HOUR INDEX MH(I) USING FISHER APP
      DO 5190 I=1,NPER
      MHI(I)=SQRT((SNM(I)*SNMF(I))/(SDM(B)*SDMF(I)))*100.
 5190 CONTINUE
C CALCULATING INDIRECT LABOUR INPUT INDEX INLI(I)
```

```
C DO LOOP FOR CALCULATING THE NUMERATOR
      DO 5210 I=1,NPER
      SNS(I)=0.0
      SNSF(I)=0.0
      DO 5200 J=1,NSET
      SNS(I)=SNS(I)+AVS(B,J)*NEMP(I,J)
      SNSF(I)=SNSF(I)+AVS(I,J)*NEMP(I,J)
 5200 CONTINUE
 5210 CONTINUE
C TWO DO LOOPS REQUIRED FOR CALCULATING THE DENOMINATOR
      DO 5230 I=B,B
      SDS(I)=0.0
      DO 5220 J=1,NSET
      SDS(I)=SDS(I)+AVS(I,J)*NEMP(I,J)
 5220 CONTINUE
 5230 CONTINUE
      DO 5250 I=1,NPER
      SDSF(I)=0.0
      DO 5240 J=1,NSET
      SDSF(I)=SDSF(I)+AVS(I,J)*NEMP(B,J)
 5240 CONTINUE
 5250 CONTINUE
C DO LOOP CALCULATING INDIRECT LABOUR INPUT INLI(I) USING FISHER APP
      DO 5260 I=1,NPER
      INLI(I)=SQRT((SNS(I)*SNSF(I))/(SDS(B)*SDSF(I)))*100.
 5260 CONTINUE
      GO TO 8000
C CALCULATING THE OUTPUT INDEX OUTP(I) USING EDGWORTH APP
C DO LOOP FOR CALCULATIMG THE NUMERATOR AND DENOMINATOR
 2000 PRINT,"CALCULATIONS ARE BASED ON EDGWORTH ARITHMATIC FORMULATION"
      PRINT,"-------------------------------------------------------------"
      DO 5310 I=1,NPER
      SNE(I)=0.0
      SDE(I)=0.0
      DO 5300 J=1,NPRO
      P(I,J)=(PP(B,J)+PP(I,J))/2.0
      SNE(I)=SNE(I)+P(I,J)*PQ(I,J)
      SDE(I)=SDE(I)+P(I,J)*PQ(B,J)
 5300 CONTINUE
 5310 CONTINUE
C DO LOOP CALCULATING OUTP(I) EDGEWORTH APPP
      DO 5320 I=1,NPER
      OUTP(I)=SNE(I)/SDE(I)*100.
 5320 CONTINUE
C CALCULATING THE MAT VOL INDEX MATV(I) USING EDGWORTH APP
C DO LOOP FOR CALCULATING THE NUMERATOR AND DENOMINATOR
      DO 5340 I=1,NPER
      SNIE(I)=0.0
      SDIE(I)=0.0
      DO 5330 J=1,NMT
      PM(I,J)=(MP(B,J)+MP(I,J))/2.0
```

```
      SNIE(I)=SNIE(I)+PM(I,J)*MQ(I,J)
      SDIE(I)=SDIE(I)+PM(I,J)*MQ(B,J)
 5330 CONTINUE
 5340 CONTINUE
C DO LOOP CALCULATING MATV(I)
      DO 5350 I=1,NPER
      MATV(I)=SNIE(I)/SDIE(I)*100.
 5350 CONTINUE
C CALCULATING MAN HOUR INDEX USING THE EDGWORTH APP MH(I)
C DO LOOP FOR CALCULATING THE NUMERATOR AND DENOMINATOR
      DO 5370 I=1,NPER
      SNME(I)=0.0
      SDME(I)=0.0
      DO 5360 J=1,NHET
      RH(I,J)=(HR(B,J)+HR(I,J))/2.0
      SNME(I)=SNME(I)+RH(I,J)*MH(I,J)
      SDME(I)=SDME(I)+RH(I,J)*MH(B,J)
 5360 CONTINUE
 5370 CONTINUE
C DO LOOP CALCULATING MH(I) MAN HOUR INDEX
      DO 5380 I=1,NPER
      MHI(I)=SNME(I)/SDME(I)*100.
 5380 CONTINUE
C CALCULATING INDIRECT LABOUR INPUT INLI(I) USING EDGWORTH APP
C DO LOOP FOR CALCCULATING THE NUMERATOR AND DENOMINATOR
      DO 5400 I=1,NPER
      SNSE(I)=0.0
      SDSE(I)=0.0
      DO 5390 J=1,NSET
      S(I,J)=(AVS(B,J)+AVS(I,J))/2.0
      SNSE(I)=SNSE(I)+S(I,J)*NEMP(I,J)
      SDSE(I)=SDSE(I)+S(I,J)*NEMP(B,J)
 5390 CONTINUE
 5400 CONTINUE
C DO LOOP CALCULATING INLI(I)
      DO 5410 I=1,NPER
      INLI(I)=SNSE(I)/SDSE(I)*100.
 5410 CONTINUE
      GO TO 8000
C CALCULATING THE OUT PUT INDEX OUTP(I) USING EDGWOTH GEOMETRIC APP
C DO LOOP FOR CALCULATING THE NUMERATOR AND DENOMINATOR
 3001 PRINT,"CALCULATIONS ARE BASED ON EDGWORTH GEOMETRIC FORMULATION"
      PRINT,"-------------------------------------------------------------"
      DO 5430 I=1,NPER
      SNOEG(I)=0.0
      SDOEG(I)=0.0
       DO 5420 J=1,NPRO
      P(I,J)=SQRT(PP(B,J)*PP(I,J))
      SNOEG(I)=SNOEG(I)+P(I,J)*PQ(I,J)
      SDOEG(I)=SDOEG(I)+P(I,J)*PQ(B,J)
 5420 CONTINUE
```

```
 5430 CONTINUE
C DO LOOP CALCULATING OUTP(I) EDGWORTH GEOMETRIC APP
      DO 5440 I=1,NPER
      OUTP(I)=SNOEG(I)/SDOEG(I)*100.
 5440 CONTINUE
C CALCULATING THE MAT VOL INDEX MATV(I) USING EDGWORTH GEOMETRIC APP
C DO LOOP FOR CALCULATING THE NUMERATOR AND DENOMINATOR
      DO 5460 I=1,NPER
      SNIEG(I)=0.0
      SDIEG(I)=0.0
      DO 5450 J=1,NMT
      PM(I,J)=SQRT(MP(B,J)*MP(I,J))
      SNIEG(I)=SNIEG(I)+PM(I,J)*MQ(I,J)
      SDIEG(I)=SDIEG(I)+PM(I,J)*MQ(B,J)
 5450 CONTINUE
 5460 CONTINUE
C DO LOOP FOR CALCULATING MATV(I)
      DO 5470 I=1,NPER
      MATV(I)=SNIEG(I)/SDIEG(I)*100.
 5470 CONTINUE
C CALCULATING MAN HOUR INDEX MH(I) USING THE EDGWORTH GEOMETRIC APP
C DO LOOP FOR CALCULATING THE NUMERATOR AND DENOMINATOR
      DO 5490 I=1,NPER
      SNMEG(I)=0.0
      SDMEG(I)=0.0
      DO 5480 J=1,NHET
      RH(I,J)=SQRT(HR(B,J)*HR(I,J))
      SNMEG(I)=SNMEG(I)+RH(I,J)*MH(I,J)
      SDMEG(I)=SDMEG(I)+RH(I,J)*MH(B,J)
 5480 CONTINUE
 5490 CONTINUE
C DO LOOP CALCULATING MAN HOUR INDEX MH(I)
      DO 5500 I=1,NPER
      MHI(I)=SNMEG(I)/SDMEG(I)*100.
 5500 CONTINUE
C CALCULATING INDIRECT LABOUR INPUT INLI(I) USING EDGWORTH GEOMETRIC
C DO LOOP FOR CALCULATING THE NUMERATOR AND DENMINATOR
      DO 5520 I=1,NPER
      SNSEG(I)=0.0
      SDSEG(I)=0.0
      DO 5510 J=1,NSET
      S(I,J)=SQRT(AVS(B,J)*AVS(I,J))
      SNSEG(I)=SNSEG(I)+S(I,J)*NEMP(I,J)
      SDSEG(I)=SDSEG(I)+S(I,J)*NEMP(B,J)
 5510 CONTINUE
 5520 CONTINUE
C DO LOOP CALCULATING INLI(I)
      DO 5530 I=1,NPER
      INLI(I)=SNSEG(I)/SDSEG(I)*100.
 5530 CONTINUE
C CALCULATION NECCSSARY FOR INDEXING CAPACITY NET FIXED INVESTMENT
```

```
C TOTAL MATERIALS COST,TOTAL FIXED COST,TOTAL REVENUE,PROFITS
C TOTAL WORKING CAPITAL,TOTAL INVESTMENT,DIRECT WAGES,INDIRECT WAGES
C TOTAL WAGES,INDIRECT INPUTS,AND TOTAL COST
 8000  DO 7000 I=1,NPER
       TI(I)=NFI(I)+TWC(I)
       TW(I)=DW(I)+INDW(I)+FB(I)
       TOC(I)=TFC(I)+DW(I)+INDW(I)+FB(I)+TMC(I)+OTC(I)+DEP(I)
 7000 CONTINUE
       DO 5600 I=1,NPER
       CAP(I)=MPOU(I)/MPOU(B)*100.
       NFINI(I)=NFI(I)/NFI(B)*100.
       TMCI(I)=TMC(I)/TMC(B)*100.
       TFCI(I)=TFC(I)/TFC(B)*100.
       TRI(I)=TR(I)/TR(B)*100.
       PROFI(I)=PROF(I)/PROF(B)*100.
       TWCI(I)=TWC(I)/TWC(B)*100.
       TII(I)=TI(I)/TI(B)*100.
       DWI(I)=DW(I)/DW(B)*100.
       INDWI(I)=INDW(I)/INDW(B)*100.
       TEWI(I)=TW(I)/TW(B)*100.
       INII(I)=INI(I)/INI(B)*100.
       OTCI(I)=OTC(I)/OTC(B)*100.
       TOCI(I)=TOC(I)/TOC(B)*100.
 5600 CONTINUE
C CALCULATING THE DIRECT INPUT PRODUCTIVITIES
       DO 5610 I=1,NPER
       MATP(I)=OUTP(I)/MATV(I)*100.
       DLP(I)=OUTP(I)/MHI(I)*100.
       FCP(I)=CAP(I)/NFINI(I)*100.
 5610 CONTINUE
C CALCULATING INDIRECT INPUT PRODUCTIVITIES
       DO 5620 I=1,NPER
       INLP(I)=OUTP(I)/INLI(I)*100.
       WOC(I)=OUTP(I)/TWCI(I)*100.
       INP(I)=OUTP(I)/INII(I)*100.
 5620 CONTINUE
C CALCULATING FACTOR PROPORTIONS
       DO 5630 I=1,NPER
       AUIF(I)=NFINI(I)*OUTP(I)/CAP(I)
       FPMM(I)=MATV(I)/MHI(I)*100.
       FPMF(I)=AUIF(I)/MATV(I)*100.
       FPMHF(I)=AUIF(I)/MHI(I)*100.
 5630 CONTINUE
C CALCULATING FACTOR PRICES
       DO 5640 I=1,NPER
       AVWR(I)=DWI(I)/MHI(I)*100.
       AVMP(I)=TMCI(I)/MATV(I)*100.
       AVSR(I)=INDWI(I)/INLI(I)*100.
       RCFI(I)=TFCI(I)/NFINI(I)*100.
 5640 CONTINUE
C CALCULATION OF UNIT COSTS
```

```
      DO 5650 I=1,NPER
      UDWC(I)=DWI(I)/OUTP(I)*100.
      UIWC(I)=INDWI(I)/OUTP(I)*100.
      UTWC(I)=TEWI(I)/OUTP(I)*100.
      UMC(I)=TMCI(I)/OUTP(I)*100.
      UFC(I)=TFCI(I)/OUTP(I)*100.
      OUC(I)=OTCI(I)/OUTP(I)*100.
      TUC(I)=TOCI(I)/OUTP(I)*100.
 5650 CONTINUE
C CALCULATING COST PROPORTIONS
      DO 5660 I=1,NPER
      WAGE(I)=DW(I)/TOC(I)*100.
      SALA(I)=INDW(I)/TOC(I)*100.
      TEMC(I)=TW(I)/TOC(I)*100.
      MATE(I)=TMC(I)/TOC(I)*100.
      FIXC(I)=TFC(I)/TOC(I)*100.
      OTCOS(I)=OTC(I)/TOC(I)*100.
      DEPR(I)=DEP(I)/TOC(I)*100.
 5660 CONTINUE
C CALCULATION OF MANAGERIAL CONTROL RATIOS
      DO 5670 I=1,NPER
      REOU(I)=TRI(I)/OUTP(I)*100.
      COOU(I)=TOCI(I)/OUTP(I)*100.
      OUCA(I)=OUTP(I)/CAP(I)*100.
      CANE(I)=CAP(I)/NFINI(I)*100.
      NFTI(I)=NFINI(I)/TII(I)*100.
      PRTO(I)=PROFI(I)/TII(I)*100.
      PROU(I)=PROFI(I)/OUTP(I)*100.
      OUTO(I)=OUTP(I)/TII(I)*100.
 5670 CONTINUE
      WRITE (6,9001)
 9001 FORMAT (1H1)
      PRINT,"  PHYSICAL OUTPUT AND INPUT MEASURES  "
       PRINT,"--------------------------------- "
       PRINT,"          "
      PRINT," PER       OUTPUT       CAPACITY       MAT-VOL       MAN-HO
     1UR      FIX-INV       IND-LAB      "
      DO 400 I=1,NPER
      WRITE (6,500) I,OUTP(I),CAP(I),MATV(I),MHI(I),NFINI(I),INLI(I)
  500 FORMAT (1X,I4,6(7X,F7.3))
  400 CONTINUE
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
      WRITE (6,9002)
 9002 FORMAT (1H1)
      PRINT,"  DIRECT INPUTS PRODUCTIVITES "
      PRINT,"--------------------------"
       PRINT,"          "
      PRINT," PER        DIR-MAT-PRO    DIR-LAB-PRO     FIX-INV-PRO "
```

```
      DO 420 I=1,NPER
      WRITE (6,520) I,MATP(I),DLP(I),FCP(I)
  520 FORMAT (1X,I4,3(9X,F7.3))
  420 CONTINUE
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
      WRITE (6,9003)
 9003 FORMAT (1H1)
      PRINT," INDIRECT INPUTS PRODUCTIVITIES  "
      PRINT,"  ----------------------------  "
      PRINT,"                              "
      PRINT," PER          IND-LAB-PRO   WOR-CAP-PRO     IND-INP-PRO"
      DO 430 I=1,NPER
      WRITE (6,530) I,INLP(I),WOC(I),INP(I)
  530 FORMAT (1X,I4,3(9X,F7.3))
  430 CONTINUE
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
      WRITE (6,9004)
 9004 FORMAT (1H1)
      PRINT,"  FACTOR PROPORTIONS   "
      PRINT,"  ----------------   "
      PRINT,"    "
      PRINT," PER        MATV/MAN-HR       AUIF/MATV       AUIF/MAN-HR "
      DO 440 I=1,NPER
      WRITE (6,540) I,FPMM(I),FPMF(I),FPMHF(I)
  540 FORMAT (1X,I4,3(9X,F7.3))
  440 CONTINUE
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
      WRITE (6,9005)
 9005 FORMAT (1H1)
      PRINT,"  FACTOR PRICES "
      PRINT,"  --------------   "
      PRINT,"   "
      PRINT," PER      AV-WAG-RATE     AV-MAT-PRIC     AV-SAL-RATE     RA
     1T-CH-FIX-INV  "
      DO 450 I=1,NPER
      WRITE (6,550) I,AVWR(I),AVMP(I),AVSR(I),RCFI(I)
  550 FORMAT (1X,I4,4(9X,F7.3))
  450 CONTINUE
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
       PRINT,"          "
```

```
      WRITE (6,9006)
 9006 FORMAT (1H1)
      PRINT," UNIT COST "
      PRINT,"  ---------  "
       PRINT,"          "
      PRINT," PER   UN-WA-CO   UN-IN-WA-CO   UN-TO-WA-CO   UN-MA-CO   UN
     1-FIX-CO  OT-UN-CO  TOT-UN-COS   "
      DO 460 I=1,NPER
      WRITE (6,560) I,UDWC(I),UIWC(I),UTWC(I),UMC(I),UFC(I),OUC(I),TUC(I
     1)
  560 FORMAT (1X,I4,3X,F7.3,6X,F7.3,7X,F7.3,5X,F7.3,4X,F7.3,4X,F7.3,6X,F
     17.3)
  460 CONTINUE
      PRINT,"     "
      PRINT,"     "
      PRINT,"     "
      PRINT,"     "
      PRINT,"  COST PROPORTIONS "
      PRINT,"  ----------------   "
       PRINT,"          "
      PRINT," PER      DIR-WAG      SALARIE      TO-EM-CO      DIR-MAT
     1    FIX-COS      OT-COST      DEPRECI  "
      DO 480 I=1,NPER
      WRITE (6,580) I,WAGE(I),SALA(I),TEMC(I),MATE(I),FIXC(I),OTCOS(I),D
     1EPR(I)
  580 FORMAT (1X,I4,7(6X,F7.3))
  480 CONTINUE
      PRINT,"     "
      PRINT,"     "
      PRINT,"     "
      PRINT,"     "
      PRINT,"  REVENUE,INVESTMENT AND PROFITS  "
      PRINT,"  ----------------------------  "
      PRINT,"     "
      PRINT," PER    REVVNUE    TOT-COS    PROFITS    NE-F-IN    WOR-CAP
     1    TOT-CAP  "
      DO 491 I=1,NPER
      WRITE (6,600) I,TRI(I),TOCI(I),PROFI(I),NFINI(I),TWCI(I),TII(I)
  600 FORMAT (1X,I4,6(4X,F7.3))
  491 CONTINUE
      PRINT,"     "
      PRINT,"     "
      PRINT,"     "
       PRINT,"          "
      PRINT,"MANEGERIAL CONTROL RATIOS   "
      PRINT,"-------------------------   "
      PRINT,"   "
      PRINT," PER     REV/OUT     COS/OUT     OUT/CAP     CAP/NFI     NF
     1I/TOI     PRO/TOI     PRO/OUT     OUT/TOI"
      DO 492 I=1,NPER
      WRITE (6,610) I,REOU(I),COOU(I),OUCA(I),CANE(I),NFTI(I),PRTO(I),
```

```
    1PROU(I),OUTO(I)
 610 FORMAT (1X,I4,8(4X,F8.3))
 492 CONTINUE
     M=1
     PRINT," COMPONENTS IN RELATIVE CHANGE IN RATE OF RETURN"
     PRINT," ----------------------------------------------"
     PRINT,"COMPARISON"
     PRINT,"  PERIOD"
     PRINT," PER V PER    CH-IN-R     CH-IN-A     CH-IN-E     CH-IN-Z
    1      AE          EZ          AZ          AEZ          "
     DO 2120 B=1,NPER-2
     DO 2100 I=M,NPER-1
     R=(PRTO(I+1)-PRTO(B))/PRTO(B)
     A=(PROU(I+1)-PROU(B))/PROU(B)
     E=(OUCA(I+1)-OUCA(B))/OUCA(B)
     W=CAP(I+1)/TII(I+1)*100.
     X=CAP(B)/TII(B)*100.
     Z=(W-X)/X
     AE=A*E
     EZ=E*Z
     AZ=A*Z
     AEZ=A*E*Z
     WRITE (6,2110) I+1,B,R,A,E,Z,AE,EZ,AZ,AEZ
2110 FORMAT (I4,I6,8(5X,F7.3))
2100 CONTINUE
2120 CONTINUE
      DO 7100 I=1,NPER
     DEPI(I)=DEP(I)/DEP(B)*100.
     UDEP(I)=DEPI(I)/OUTP(I)*100.
7100 CONTINUE
      PRINT,"COMPONENTS OF RELATIVE CHANGE OF TOTAL UNIT COST"
      PRINT,"-----------------------------------------------"
      PRINT,"COMPARISON"
      PRINT,"  PERIOD"
     PRINT,"PER V PER      CH-TUC      CH-EMC      CH-MAC      CH-FIX
    1   CH-OTC      CH-CAPC"
     DO 7600 B=1,NPER-2
     DO 7500 I=M,NPER-1
     CTUC=TUC(I+1)-TUC(B)
     W=UTWC(I+1)-UTWC(B)
     AMA=UMC(I+1)-UMC(B)
     FC=UFC(I+1)-UFC(B)
     COUC=OUC(I+1)-OUC(B)
     CD=UDEP(I+1)-UDEP(B)
     WRITE (6,9025) I+1,B,CTUC,W,AMA,FC,COUC CD
9025 FORMAT (I4,I6,6(3X,F9.4))
7500 CONTINUE
7600 CONTINUE
     PRINT,"COMPARISON"
     PRINT,"  PERIOD"
     PRINT,"PER V PER      CH-TUC     CP*CEMC     CP*CMAC     CP*CFIX
```

```
     1CP*COTC       CP*CCAP"
      DO 7300 B=1,NPER-2
      DO 7200 I=M,NPER-1
      CTUC=(TUC(I+1)-TUC(B))/100.
      W=UTWC(I+1)-UTWC(B)
      CEMC=W*TEMC(B)/10000.
      AMA=UMC(I+1)-UMC(B)
      CMAC=AMA*MATE(B)/10000.
      FC=UFC(I+1)-UFC(B)
      CFC=FC*FIXC(B)/10000.
      COUC=OUC(I+1)-OUC(B)
      COT=COUC*OTCOS(B)/10000.
      CD=UDEP(I+1)-UDEP(B)
      CDEP=CD*DEPR(B)/10000.
      WRITE (6,2140) I+1,B,CTUC,CEMC,CMAC,CFC,COT,CDEP
 2140 FORMAT (I4,I6,6(3X,F8.4))
 7200 CONTINUE
 7300 CONTINUE
      STOP
      END
      SUBROUTINE SIMUL
      REAL MP,MQ,MH,NEMP,MPOU,NFI,INDW,INI
      REAL MHC
      COMMON/A/ PP(20,50),PQ(20,50),MP(20,50),MQ(20,50),
     1 HR(20,50),MH(20,50),AVS(20,50),NEMP(20,50),MPOU(20),
     2 NFI(20),TMC(20),TFC(20),TR(20),PROF(20),TWC(20),DW(20),
     3INDW(20),FB(20),INI(20),DEP(20),TOC(20),NSIM,NPRO,NPER,NMT,NHET,
     4NSET,OTC(20)
      EQUIVALAN (PCO(1,1),QCO(1,1),PCM(1,1),QCM(1,1),PCHR(1,1),MHC(1,1),
     1PCAVS(1,1),CNE(1,1),PCCAP(1),PCNFI(1),PCTFC(1), PCTWC(1),PCFB(1),
     2PCINI(1),PCOTC(1))
      DIMENSION PCO(10,50),QCO(10,50),PCM(10,50),QCM(10,50),PCHR(10,50),
     1MHC(10,50),PCAVS(10,50),CNE(10,50),PCCAP(10),RDEP(10),PCNFI(10),
     2PCTFC(10),PCTWC(10),PCFB(10),PCINI(10),PCOTC(10)
      DIMENSION M(20)
C  CALCULATING SIMULATED OUTPUT PRICES
      DO 6000 I=1,NSIM
      READ (5,*) M(I),PCO(I,1)
      DO 5900 J=2,NPRO
      IF (J.LE.M(I)) THEN
      PCO(I,J)=PCO(I,J-1)
      ELSE
      READ (5,*) PCO(I,J)
      ENDIF
 5900 CONTINUE
 6000 CONTINUE
   10 FORMAT (10F7.3)
      DO 1100 I=NPER+1,NPER+NSIM
      DO 1000 J=1,NPRO
      PP(I,J)=PP(I-1,J)*PCO(I-NPER,J)
 1000 CONTINUE
```

```
 1100 CONTINUE
C  CALCULATING SIMULATED OUTPUT QUANTITIES
       DO 6200 I=1,NSIM
       READ (5,*) M(I),QCO(I,1)
       DO 6100 J=2,NPRO
       IF (J.LE.M(I)) THEN
       QCO(I,J)=QCO(I,J-1)
       ELSE
       READ (5,*) QCO(I,J)
      ENDIF
 6100 CONTINUE
 6200 CONTINUE
   20 FORMAT (10F7.3)
      DO 1300 I=NPER+1,NPER+NSIM
      DO 1200 J=1,NPRO
      PQ(I,J)=PQ(I-1,J)*QCO(I-NPER,J)
 1200 CONTINUE
 1300 CONTINUE
C CALCULATING SIMULATED REVENUE
      DO 1600 I=NPER+1,NPER+NSIM
      TR(I)=0.0
      DO 1500 J=1,NPRO
      TR(I)=TR(I)+PP(I,J)*PQ(I,J)
 1500 CONTINUE
 1600 CONTINUE
C CALCULATING SIMULATED PRICES OF MATERIALS INPUT
        DO 6400 I=1,NSIM
       READ (5,*) M(I),PCM(I,1)
       DO 6300 J=2,NMT
       IF(J.LE.M(I)) THEN
       PCM(I,J)=PCM(I,J-1)
       ELSE
       READ (5,*) PCM(I,J)
      ENDIF
 6300 CONTINUE
 6400 CONTINUE
   30 FORMAT (10F7.3)
      DO 1800 I=NPER+1,NPER+NSIM
      DO 1700 J=1,NMT
      MP(I,J)=MP(I-1,J)*PCM(I-NPER,J)
 1700 CONTINUE
 1800 CONTINUE
C CALCULATING SIMULATED QUANTITES OF MATERIAL INPUTS
          DO 6600 I=1,NSIM
          READ (5,*) M(I),QCM(I,1)
       DO 6500 J=2,NMT
       IF (J.LE.M(I)) THEN
       QCM(I,J)=QCM(I,J-1)
       ELSE
       READ (5,*) QCM(I,J)
      ENDIF
```

```
 6500 CONTINUE
 6600 CONTINUE
   40 FORMAT (10F7.3)
      DO 2000 I=NPER+1,NPER+NSIM
      DO 1900 J=1,NMT
      MQ(I,J)=MQ(I-1,J)*QCM(I-NPER,J)
 1900 CONTINUE
 2000 CONTINUE
C CALCULATING SIMULATED MAT COST
      DO 2200 I=NPER+1,NPER+NSIM
       TMC(I)=0.0
      DO 2100 J=1,NMT
       TMC(I)=TMC(I)+MP(I,J)*MQ(I,J)
 2100 CONTINUE
 2200 CONTINUE
C CALCULATING SIMULATED HOURLY RATES
      DO 6800 I=1,NSIM
      READ (5,*) M(I),PCHR(I,1)
      DO 6700 J=2,NHET
      IF (J.LE.M(I)) THEN
      PCHR(I,J)=PCHR(I,J-1)
      ELSE
      READ (5,*) PCHR(I,J)
      ENDIF
 6700 CONTINUE
 6800 CONTINUE
   50 FORMAT (10F7.3)
      DO 2400 I=NPER+1,NPER+NSIM
      DO 2300 J=1,NHET
       HR(I,J)=HR(I-1,J)*PCHR(I-NPER,J)
 2300 CONTINUE
 2400 CONTINUE
C CALCULATING SIMULATED NUMBER OF HOURS WORKED
      DO 7000 I=1,NSIM
      READ (5,*) M(I),MHC(I,1)
      DO 6900 J=2,NHET
      IF (J.LE.M(I)) THEN
      MHC(I,J)=MHC(I,J-1)
      ELSE
      READ (5,*) MHC(I,J)
      ENDIF
 6900 CONTINUE
 7000 CONTINUE
   60 FORMAT (10F7.3)
      DO 2600 I=NPER+1,NPER+NSIM
      DO 2500 J=1,NHET
      MH(I,J)=MH(I-1,J)*MHC(I-NPER,J)
 2500 CONTINUE
 2600 CONTINUE
C CALCULATING SIMULATED DIRECT WAGES
      DO 2800 I=NPER+1,NPER+NSIM
```

```
      DW(I)=0.0
      DO 2700 J=1,NHET
      DW(I)=DW(I)+HR(I,J)*MH(I,J)
 2700 CONTINUE
 2800 CONTINUE
C CALCULATING SIMULATED SALARY RATES
       DO 7200 I=1,NSIM
      READ (5,*) M(I),PCAVS(I,1)
      DO 7100 J=2,NSET
      IF (J.LE.M(I)) THEN
      PCAVS(I,J)=PCAVS(I,J-1)
      ELSE
      READ (5,*) PCAVS(I,J)
      ENDIF
 7100 CONTINUE
 7200 CONTINUE
   70 FORMAT (10F7.3)
      DO 3000 I=NPER+1,NPER+NSIM
      DO 2900 J=1,NSET
      AVS(I,J)=AVS(I-1,J)*PCAVS(I-NPER,J)
 2900 CONTINUE
 3000 CONTINUE
C CALCULATING SIMULATED NUMBER OF EMPLOYEES
      DO 7400 I=1,NSIM
      READ (5,*) M(I),CNE(I,1)
      DO 7300 J=2,NSET
      IF (J.LE.M(I)) THEN
      CNE(I,J)=CNE(I,J-1)
      ELSE
      READ (5,*) CNE(I,J)
      ENDIF
 7300 CONTINUE
 7400 CONTINUE
   80 FORMAT (10F7.3)
      DO 3200 I=NPER+1,NPER+NSIM
      DO 3100 J=1,NSET
       NEMP(I,J)=NEMP(I-1,J)+CNE(I-NPER,J)
 3100 CONTINUE
 3200 CONTINUE
C CALCULATING SIMULATED COST OF SALARIES
      DO 3400 I=NPER+1,NPER+NSIM
      INDW(I)=0.0
      DO 3300 J=1,NSET
      INDW(I)=INDW(I)+AVS(I,J)*NEMP(I,J)
 3300 CONTINUE
 3400 CONTINUE
C CALCULATING SIMULATED CHANGE IN CAPACITY
      READ (5,*) (PCCAP(I),I=1,NSIM)
   90 FORMAT (10F7.3)
      DO 3500 I=NPER+1,NPER+NSIM
      MPOU(I)=MPOU(I-1)*PCCAP(I-NPER)
```

```
 3500 CONTINUE
C CALCULATING SIMULATED CHANGES IN DEP AND FIX-INV
      READ (5,*) (RDEP(I),I=1,NSIM)
  100 FORMAT (10F7.3)
      READ (5,*) (PCNFI(I),I=1,NSIM)
  110 FORMAT (10F7.3)
      DO 3600 I=NPER+1,NPER+NSIM
      NFI(I)=NFI(I-1)*PCNFI(I-NPER)
      DEP(I)=NFI(I)*RDEP(I-NPER)
      NFI(I)=NFI(I)-DEP(I)
 3600 CONTINUE
C CALCULATE SIMULATED CHANGES IN FIX COSTS
      READ (5,*) (PCTFC(I),I=1,NSIM)
  120 FORMAT (10F7.3)
      DO 3700 I=NPER+1,NPER+NSIM
      TFC(I)=TFC(I-1)*PCTFC(I-NPER)
 3700 CONTINUE
C CALCULATING SIMULATED WORKING CAPITAL
      READ (5,*) (PCTWC(I),I=1,NSIM)
  130 FORMAT (10F7.3)
      DO 3800 I=NPER+1,NPER+NSIM
      TWC(I)=TWC(I-1)*PCTWC(I-NPER)
 3800 CONTINUE
C  CALCULATING SIMULATED FRINGE BENEFITS
      READ (5,*) (PCFB(I),I=1,NSIM)
  140 FORMAT (10F7.3)
      DO 3900 I=NPER+1,NPER+NSIM
      FB(I)=FB(I-1)*PCFB(I-NPER)
 3900 CONTINUE
C  CALCULATING SIMULATED CHANGES IN INDIRECT INPUTS
      READ (5,*) (PCINI(I),I=1,NSIM)
  150 FORMAT (10F7.3)
      DO 4000 I=NPER+1,NPER+NSIM
      INI(I)=INI(I-1)*PCINI(I-NPER)
 4000 CONTINUE
C CALCULATE SIMULATED CHANGE IN OTHER COSTS
      READ (5,*) (PCOTC(I),I=1,NSIM)
  160 FORMAT (10F7.3)
      DO 5000 I=NPER+1,NPER+NSIM
      OTC(I)=OTC(I-1)*PCOTC(I-NPER)
 5000 CONTINUE
C  CALCULATING SIMULATED TOTAL COSTS AND PROFITS
      DO 4100 I=NPER+1,NPER+NSIM
      TOC(I)=TFC(I)+DW(I)+INDW(I)+FB(I)+TMC(I)+OTC(I)+DEP(I)
      PROF(I)=TR(I)-TOC(I)
 4100 CONTINUE
      NPER=NPER+NSIM
      RETURN
      END
```

APPENDIX II

LISTING OF PROGRAM "PRODUCTIVITY COSTING"

```
      PROGRAM RAMEN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      REAL NWH,MFOH
     INTEGER OPTO
     COMMON/PROC/ PCRM(30),MFOH(30),PECR(30),DLHRM(30),NPED(20),
    1TSE,NDEP
     COMMON/AAA/ NMAC
     COMMON/ACCM/ NPRO
     COMMON/OPMA/ TSOC
      DIMENSION NWH(30),PEPV(30),TDEV(20),PTEVD(30),
    1PTEVS(30),DEPE(20),DEAPE(30),SEAPE(30),TPECR(30)
    2,DLHR(20)
     READ(5,*) OPTO
      READ (5,*) NPRO,NMAC,NDEP
      READ(5,*) (NWH(J),J=1,NMAC)
      READ(5,*) (MFOH(J),J=1,NMAC)
      READ(5,*) (PEPV(J),J=1,NMAC)
      READ(5,*) (NPED(K),K=1,NDEP)
      DO 10 I=1,NDEP
      TDEV(I)=0.
   10 CONTINUE
      J=1
      I=1
      L=0
      WHILE (I.LE.NDEP) DO
      IF(NPED(I).GE.1) THEN
      L=NPED(I)+L
      WHILE (J.LE.L) DO
      TDEV(I)=TDEV(I)+PEPV(J)
      J=J+1
      ENDWHILE
      ENDIF
      J=L+1
      I=I+1
      ENDWHILE
      J=1
      I=1
      L=0
      DO 30 I=1,NDEP
      IF (NPED(I).GE.1)THEN
      L=NPED(I)+L
      DO 20 K=J,L
      PTEVD(K)=PEPV(K)/TDEV(I)
   20 CONTINUE
      ENDIF
      J=L+1
   30 CONTINUE
      TPEPV=PEPV(1)
      DO 40 J=2,NMAC
      TPEPV=TPEPV+PEPV(J)
   40 CONTINUE
```

```
      DO 50 J=1,NMAC
      PTEVS(J)=PEPV(J)/TPEPV
 50 CONTINUE
      READ(5,*) (DEPE(K),K=1,NDEP)
      READ(5,*) GSE
      J=1
      I=1
      L=0
      DO 70 I=1,NDEP
      IF (NPED(I).GE.1) THEN
      L=NPED(I)+L
      DO 60 K=J,L
      DEAPE(K)=PTEVD(K)*DEPE(I)
 60 CONTINUE
      ENDIF
      J=L+1
 70 CONTINUE
      DO 80 J=1,NMAC
      SEAPE(J)=GSE*PTEVS(J)
 80 CONTINUE
      DO 90 J=1,NMAC
      TPECR(J)=DEAPE(J)+SEAPE(J)
      PECR(J)=(DEAPE(J)+SEAPE(J))/MFOH(J)
 90 CONTINUE
      READ(5,*) (DLHR(K),K=1,NDEP)
      J=1
      I=1
      L=0
      DO 110 I=1,NDEP
      IF (NPED(I).GE.1)THEN
      L=NPED(I)+L
      DO 100 K=J,L
      PCRM(K)=PECR(K)+DLHR(I)
100 CONTINUE
      ENDIF
      J=L+1
110 CONTINUE
     J=1
     I=1
     L=0
     DO 170 I=1,NDEP
     IF (NPED(I).GE.1) THEN
     L=NPED(I)+L
     DO 160 K=J,L
     DLHRM(K)=DLHR(I)
160 CONTINUE
     ENDIF
     J=L+1
170 CONTINUE
      TDE=DEPE(1)
      DO 120 K=2,NDEP
```

```
      TDE=TDE+DEPE(K)
 120 CONTINUE
      TSE=TDE+GSE
      READ(5,*) TDLCPD
      TPCRM=PCRM(1)
      DO 130 J=2,NMAC
      TPCRM=TPCRM+PCRM(J)
 130 CONTINUE
     PRINT,"          SUMMARY OF SYSTEM EXPENSES"
     PRINT,"          --------------------------"
      WRITE(6,4000) TDE
4000 FORMAT(1X,*TOTAL DEPARTEMENTAL OPERATING EXPENSES*,11X,F9.1)
      WRITE(6,4010) GSE

4010 FORMAT(1X,*TOTAL GENERAL SYSTEM OPERATING EXPENSES*,10X,F9.1)
     WRITE(6,4020) TSE
4020 FORMAT(1X,*TOTAL OPERATING SYSTEM EXPENSES*,18X,F9.1)
     WRITE(6,4030) TDLCPD
4030 FORMAT(1X,*TOTAL DIRECT LABOUR COST PER DAY*,17X,F9.1)
      WRITE(6,4040) TPCRM
4040  FORMAT(1X,*PROD COSTING RATE PER PROCESSING HOUR OF SYSTEM*,
    12X,F9.1)
     PRINT,"       DEVELOPMENT OF PRODUCTIVE FACILITIES COSTING RATE FO
    1R PRODUCTIVITY COSTING"
     PRINT,"       ==================================================
    1====================="
     PRINT," PFN      MFOH          PEVD          PEVS          DEAPE       SE
    1  SEAPE         TOEAPE        PECR/H        DLC/H         PCRPPH"
      DO 140 J=1,NMAC
      WRITE(6,4050) J,MFOH(J),PTEVD(J)*100.,PTEVS(J)*100.,DEAPE(J),
    1SEAPE(J),TPECR(J),PECR(J),DLHRM(J),PCRM(J)
 140 CONTINUE
4050  FORMAT(1X,I3,9(3X,1PE10.3))
     CALL PROC
     CALL ACCO
     IF (OPTO.GT.0) THEN
     TSOC=0.0
     DO 201 J=1,NMAC
     TSOC=TSOC+MFOH(J)*PCRM(J)
 201 CONTINUE
     CALL OPSTE
     ENDIF
      STOP
      END
     SUBROUTINE PROC
     REAL MFOH,IFC
     COMMON/PROC/ PCRM(30),MFOH(30),PECR(30),DLHRM(30),NPED(20),
    1TSE,NDEP
     COMMON/AAA/ NMAC
     COMMON/ACCM/ NPRO
     COMMON/ACCS/ TFOC(50),TIFC,TOLCNA,TFP(50),TTFPM,TTPWHM
```

```
      COMMON/SOPT/ TMFOHA
      COMMON/OPTI/ PWH(50,30)
      DIMENSION TPWH(50),FOH(50,30),TFOH(30),FP(50,30),
     1 FOC(50,30),TPWHM(30),TFPM(30),TFOCM(30),
     2FUH(30),IFC(30),TFC(30),FU(30),TFAPR(30),DLC(20),OLC(30),
     3TDOLC(20),DOLU(20),DOLUM(30),TFOHM(30)
      TMFOHA=0.0
      DO 302 J=1,NMAC
      TMFOHA=TMFOHA+MFOH(J)
  302 CONTINUE
      READ(5,*) TFCONC
      DO 200 I=1,NPRO
      PRINT,"                    ************************************
     1****"
      WRITE (6,5000) I
 5000 FORMAT(18X,*AVERAGE PRODUCTION PER DAY FOR PRODUCT*,I4)
      PRINT,"                    ************************************
     1****"
      PRINT,"              PFN        PWH            FOH            FP
     1        FOC"
      READ(5,*) (PWH(I,J),J=1,NMAC)
      DO 300 J=1,NMAC
      PWH(I,J)=PWH(I,J)/TFCONC
  300 CONTINUE
      TPWH(I)=0.0
      DO 10 J=1,NMAC
      TPWH(I)=TPWH(I)+PWH(I,J)
   10 CONTINUE
      READ(5,*) (FOH(I,J),J=1,NMAC)
       DO 310 J=1,NMAC
      FOH(I,J)=FOH(I,J)/TFCONC
  310 CONTINUE
      TFOH(I)=0.0
      DO 30 J=1,NMAC
      TFOH(I)=TFOH(I)+FOH(I,J)
   30 CONTINUE
      SMALL=1.E-30
      DO 50 J=1,NMAC
      FP(I,J)=PWH(I,J)/(FOH(I,J)+SMALL)
   50 CONTINUE
      TFP(I)=TPWH(I)/TFOH(I)
      DO 70 J=1,NMAC
      FOC(I,J)=FOH(I,J)*PCRM(J)
   70 CONTINUE
      TFOC(I)=0.0
      DO 80 J=1,NMAC
      TFOC(I)=TFOC(I)+FOC(I,J)
   80 CONTINUE
      DO 90 J=1,NMAC
      WRITE(6,5010) J,PWH(I,J),FOH(I,J),FP(I,J),FOC(I,J)
   90 CONTINUE
```

```
 5010 FORMAT(14X,I3,4(4X,1PE10.3))
      WRITE(6,5020) TPWH(I),TFOH(I),TFP(I),TFOC(I)
 5020 FORMAT(12X,*TOTAL*,4(4X,1PE10.3))
  200 CONTINUE
      PRINT,"                                  ***************"
      PRINT,"                                  PRODUCTS TOTALS  "
      PRINT,"                                  ***************"
      PRINT,"                PFN        PWH            FOH              FP
     1       FOC"
      DO 110 J=1,NMAC
      TPWHM(J)=0.0
      TFOHM(J)=0.0
      DO 100 I=1,NPRO
      TPWHM(J)=TPWHM(J)+PWH(I,J)
      TFOHM(J)=TFOHM(J)+FOH(I,J)
  100 CONTINUE
      TFPM(J)=TPWHM(J)/(TFOHM(J)+SMALL)
      TFOCM(J)=TFOHM(J)*PCRM(J)
  110 CONTINUE
      TTPWHM=0.
      TTFOHM=0.
      TTFOCM=0.
      DO 120 J=1,NMAC
      TTPWHM=TTPWHM+TPWHM(J)
      TTFOHM=TTFOHM+TFOHM(J)
      TTFOCM=TTFOCM+TFOCM(J)
  120 CONTINUE
      TTFPM=TTPWHM/TTFOHM
      DO 130 J=1,NMAC
      WRITE(6,5030) J,TPWHM(J),TFOHM(J),TFPM(J),TFOCM(J)
  130 CONTINUE
 5030 FORMAT(14X,I3,4(4X,1PE10.3))
      WRITE(6,5040) TTPWHM,TTFOHM,TTFPM,TTFOCM
 5040 FORMAT(12X,*TOTAL*,4(4X,1PE10.3))
      PRINT,"                    PRODUCTIVITY COSTING-PRODUCT PROCESSING
     1 FACILITIES AND LABOUR SUMMARY"
      PRINT,"                    ------------------------------------------
     1----------------------------"
      PRINT,"                          -------------------------"
      PRINT,"                          SYSTEM UTILISATION SUMMARY"
      PRINT,"                          -------------------------"
      PRINT,"                PFN        PWH            FOH              FP
     1       FOC"
      DO 140 J=1,NMAC
      WRITE(6,5050) J,TPWHM(J),TFOHM(J),TFPM(J),TFOCM(J)
  140 CONTINUE
 5050 FORMAT(14X,I3,4(4X,1PE10.3))
      WRITE(6,5060) TTPWHM,TTFOHM,TTFPM,TTFOCM
 5060 FORMAT(12X,*TOTAL*,4(4X,1PE10.3))
      PRINT,"                          -------------------------"
      PRINT,"                           IDLE FACILITIES SUMMARY "
```

```
      PRINT,"                          ------------------------"
      PRINT,"                            PFN          FIN              IFC"
      DO 150 J=1,NMAC
      FUH(J)=MFOH(J)-TFOHM(J)
      IFC(J)=FUH(J)*PECR(J)
  150 CONTINUE
      DO 160 J=1,NMAC
      WRITE(6,5070) J,FUH(J),IFC(J)
  160 CONTINUE
 5070 FORMAT(24X,I3,2(5X,1PE10.3))
      TFUH=0.
      TIFC=0.
      DO 170 J=1,NMAC
      TFUH=TFUH+FUH(J)
      TIFC=TIFC+IFC(J)
  170 CONTINUE
      WRITE(6,5080) TFUH,TIFC
 5080 FORMAT(22X,*TOTAL*,2(5X,1PE10.3))
      PRINT,"                          ------------------"
      PRINT,"                          FACILITIES SUMMARY"
      PRINT,"                          ------------------"
      PRINT,"                PFN         TFC              FU              MFOH
     1           TFP"
      DO 180 J=1,NMAC
      TFC(J)=MFOH(J)*PECR(J)
      FU(J)=(TFC(J)-IFC(J))/TFC(J)
      TFAPR(J)=TPWHM(J)/MFOH(J)
  180 CONTINUE
      DO 195 J=1,NMAC
      WRITE(6,5090) J,TFC(J),FU(J),MFOH(J),TFAPR(J)
  195 CONTINUE
 5090 FORMAT(14X,I3,4(5X,1PE10.3))
      TFU=(TSE-TIFC)/TSE
      TMFOH=0.
       TTPWHTM=0.
      DO 190 J=1,NMAC
      TMFOH=TMFOH+MFOH(J)
       TTPWHTM=TTPWHTM+TPWHM(J)
  190 CONTINUE
      TTFAPR=TTPWHTM/TMFOH
      WRITE(6,5100) TSE,TFU,TMFOH,TTFAPR
 5100 FORMAT(12X,*TOTAL*,4(5X,1PE10.3))
      PRINT,"                    ----------------------------------"
      PRINT,"                    LABOUR (OPER AND NON OPER) SUMMARY"
      PRINT,"                    ----------------------------------"
      PRINT,"                PFN         ILH              ILC              OLU
     1"
      DO 210 J=1,NMAC
      OLC(J)=FUH(J)*DLHRM(J)
  210 CONTINUE
      READ(5,*) (DLC(K),K=1,NDEP)
```

```
      DO 220 I=1,NDEP
      TDOLC(I)=0.0
  220 CONTINUE
      J=1
      I=1
      L=0
      DO 240 I=1,NDEP
      IF (NPED(I).GE.1) THEN
      L=NPED(I)+L
      DO 230 K=J,L
      TDOLC(I)=TDOLC(I)+OLC(K)
  230 CONTINUE
      ENDIF
      J=L+1
  240 CONTINUE
      DO 250 K=1,NDEP
      DOLU(K)=(DLC(K)-TDOLC(K))/DLC(K)
  250 CONTINUE
      J=1
      I=1
      L=0
      DO 270 I=1,NDEP
      IF (NPED(I).GE.1) THEN
      L=NPED(I)+L
      DO 260 K=J,L
      DOLUM(K)=DOLU(I)
  260 CONTINUE
      ENDIF
      J=L+1
  270 CONTINUE
      DO 280 J=1,NMAC
      WRITE(6,5110) J,FUH(J),OLC(J),DOLUM(J)
  280 CONTINUE
 5110 FORMAT(14X,I3,3(5X,1PE10.3))
      TOLCNA=0.0
      DO 600 J=1,NMAC
      TOLCNA=TOLCNA+OLC(J)
  600 CONTINUE
      TOPLAC=0.0
      DO 610 K=1,NDEP
      TOPLAC=TOPLAC+DLC(K)
  610 CONTINUE
      TOLUS=(TOPLAC-TOLCNA)/TOPLAC
      WRITE (6,5120) TFUH,TOLCNA,TOLUS
 5120 FORMAT (12X,*TOTAL*,3(5X,1PE10.3))
      RETURN
      END
      SUBROUTINE ACCO
      REAL NAOLC,INT
      COMMON/ACCM/ NPRO
      COMMON/ACCS/ TFOC(50),TIFC,TOLCNA,TFP(50),TTFPM,TTPWHM
```

```
      COMMON/SOPT/ TMFOHA
      COMMON/ACCOP/ TODL,SR(50),TMPC,TINT,PMC(50)
      DIMENSION INT(50),TAC(50),ODL(50),OE(50),TOE(50),
     1PP(50),TACM(50),CM(50),CMSR(50),TACP(50),TE(50),TESR(50),CMLR(50),
     2CMLSR(50),PPC(50),PPP(50),ET(50),EP(50),ED(50),EM(50),ESW(50),
     3EPW(50),ETW(50),EMW(50),NRPP(50),NRCM(50),NRCMSR(50),
     4NRET(50),NREP(50),NREM(50),NRED(50)
     5,NRESW(50),NREPW(50).NRETW(50),NREMW(50)
      READ(5,*) (SR(I),I=1,NPRO)
      READ(5,*) (PMC(I),I=1,NPRO)
      READ(5,*) (INT(I),I=1,NPRO)
      SMALL=1.E-30
      TSR=0.
      DO 400 I=1,NPRO
      TSR=TSR+SR(I)
  400 CONTINUE
      TMPC=0.
      DO 410 I=1,NPRO
      TMPC=TMPC+PMC(I)
  410 CONTINUE
      TINT=00.
      DO 420 I=1,NPRO
      TINT=TINT+INT(I)
  420 CONTINUE
      DO 430 I=1,NPRO
      TAC(I)=PMC(I)+INT(I)
  430 CONTINUE
      TTAC=0.
      DO 440 I=1,NPRO
      TTAC=TTAC+TAC(I)
  440 CONTINUE
      READ(5,*) (ODL(I),I=1,NPRO)
      READ (5,*) (OE(I),I=1,NPRO)
      TODL=0.
      TOES=0.
      DO 450 I=1,NPRO
      TODL=TODL+ODL(I)
      TOES=TOES+OE(I)
      TOE(I)=ODL(I)+OE(I)
  450 CONTINUE
      TTOE=TODL+TOES
      DO 460 I=1,NPRO
      PP(I)=SR(I)-TAC(I)-TOE(I)
  460 CONTINUE
      TSP=TSR-TTAC-TTOE
      READ(5,*) UO
      SOP=TSP-UO
      PRINT,"           SYSTEMS PROFITS(OR LOSSES) AS DETERMIND BY CONVE
     1NTIONAL (OVERHEAD ABSORPTION) COSTING"
      PRINT,"            ==========================================
     1==============================="
```

```
      CM(I)=SR(I)-TACM(I)
  500 CONTINUE
      TCM=TSR-TTACM
      DO 510 I=1,NPRO
      CMSR(I)=CM(I)/(SR(I)+SMALL)
  510 CONTINUE
      TCMSR=TCM/(TSR+SMALL)
      READ(5,*) FC
      SOPM=TCM-FC
      WRITE(6,7110) TSR
 7110 FORMAT(1X,*SALES REVENUE (SR)*,23X,F10.1)
      PRINT," LESS AVOIDABLE PRODUCT COSTS :"
      WRITE(6,7120) TMPC
 7120 FORMAT(1X,*A)PRODUCT MATERIALS COST (PMC)*,11X,F10.1)
      WRITE(6,7130) TINT
 7130 FORMAT(1X,*B)INTEREST CHARGES (INT)*,17X,F10.1)
      WRITE(6,7140) TODL
 7140 FORMAT(1X,*C)OPERATING (DIRECT) LABOUR (ODL)*,8X,F10.1)
      WRITE(6,7150) TTACM
 7150 FORMAT(1X,*D)TOTAL AVOIDABLE COST (TAC)*,13X,F10.1)
      WRITE(6,7160) TCM
 7160 FORMAT(1X,*CONTRIBUTION MARGIN (CM)*,17X,F10.1)
      WRITE(6,7170) TCMSR
 7170 FORMAT(1X,*CONTRIBUTION MARGIN/SALES REVENUE (CMSR)*,1X,F10.4)
      WRITE(6,7180) FC
 7180 FORMAT(1X,*LESS FIXED COSTS (FC)*,20X,F10.1)
      WRITE(6,7190) SOPM
 7190 FORMAT(1X,*SYSTEM OPERATING PROFIT (SOP)*,12X,F10.1)
      PRINT,"                    PRODUCTS CONTRIBUTION MARGINS AS DETERMIND
     1BY MARGINAL COSTING"
      PRINT,"                    ==========================================
     1====================="
      PRINT,"                                        LESS AVOIDABLE (PRODUCT)
     1COST"
      PRINT,"                                  ------------------------------
     1---------------------"
      PRINT," PT            SR                PMC                INT
     1ODL            TAC            CM                CM/SR
     2"
      DO 515 I=1,NPRO
      WRITE(6,7200) I,SR(I),PMC(I),INT(I),ODL(I),TACM(I),CM(I),CMSR(I)
  515 CONTINUE
      CALL RANK1(CM,NRCM,NPRO)
      CALL RANK1(CMSR,NRCMSR,NPRO)
 7200 FORMAT(1X,I3,6(5X,F10.1),5X,F10.4)
      PRINT,"                    TOTAL EARNINGS,CONTRIBUTION MARGINS,COSTS A
     1AND PROFITS AS DETERMIAND BY PRODUCTIVITY COSTING"
      PRINT,"                    ==========================================
     1==========================================="
      DO 525 I=1,NPRO
      TACP(I)=PMC(I)+INT(I)
```

```
  525 CONTINUE
      STACP=0.
      DO 530 I=1,NPRO
      STACP=STACP+TACP(I)
  530 CONTINUE
      DO 540 I=1,NPRO
      TE(I)=SR(I)-TACP(I)
  540 CONTINUE
      STE=TSR-STACP
      DO 550 I=1,NPRO
      TESR(I)=TE(I)/(SR(I)+SMALL)
  550 CONTINUE
      STESR=STE/(TSR+SMALL)
      DO 560 I=1,NPRO
      CMLR(I)=TE(I)-ODL(I)
      CMLSR(I)=CMLR(I)/(SR(I)+SMALL)
  560 CONTINUE
      SCMLR=STE-TODL
      SCMLSR=SCMLR/(TSR+SMALL)
      DO 570 I=1,NPRO
      PPC(I)=TFOC(I)*1.
  570 CONTINUE
      SPPC=0.
      DO 580 I=1,NPRO
      SPPC=SPPC+PPC(I)
  580 CONTINUE
      DO 590 I=1,NPRO
      PPP(I)=TE(I)-PPC(I)
  590 CONTINUE
      TPPP=STE-SPPC
      TIFCPC=TIFC*1.
      NAOLC=TOLCNA*1.
      TNPFC=TIFCPC+NAOLC
      SOPPC=TPPP-TNPFC
      WRITE(6,7300) TSR
 7300 FORMAT(1X,*SALES REVENUE (SR)*,23X,F10.1)
      PRINT," LESS AVOIDABLE (PRODUCT) COSTS :"
      WRITE(6,7310) TMPC
 7310 FORMAT(1X,*A)PRODUCT MATERIALS COST (PMC)*,11X,F10.1)
      WRITE(6,7320) TINT
 7320 FORMAT(1X,*B)INTEREST CHARGES (INT)*,17X,F10.1)
      WRITE(6,7330) STACP
 7330 FORMAT(1X,*C)TOTAL AVOIDABLE COST (TAC)*,13X,F10.1)
      WRITE(6,7340) STE
 7340 FORMAT(1X,*TOTAL EARNING (TE)*,23X,F10.1)
      WRITE(6,7350) STESR
 7350 FORMAT(1X,*TOTAL EARNING/SALES REVENUE (TE/SR)*,6X,F10.4)
      WRITE(6,7360) TODL
 7360 FORMAT(1X,*LESS OPERATING (DIRECT) LABOUR COST (ODL)*,F10.1)
      WRITE(6,7370) SCMLR
 7370 FORMAT(1X,*CONTRIBUTION MARGIN (LONG RANGE) (CMLR)*,2X,F10.1)
```

```
      WRITE(6,7380) SCMLSR
 7380 FORMAT(2X,*CONTIBUTION MARGIN (CMLR)/SALES REVENUE*,2X,F10.4)
      WRITE(6,7390) SPPC
 7390 FORMAT(1X,*PRODUCT FACILITES OCCUPANCY COSTS (FOC)*,2X,F10.1)
      WRITE(6,7400) TPPP
 7400 FORMAT(1X,*PRODUCT PROFIT (PP=TE-FOC)*,15X,F10.1)
      PRINT," LESS NON-PRODUCING FACILITES COST :"
      WRITE(6,7410) TIFCPC
 7410 FORMAT(1X,*A)IDLE FACILITES COST (IFC)*,14X,F10.1)
      WRITE(6,7420) NAOLC
 7420 FORMAT(1X,*NON APPLIED OPERATING LABOUR COSTS (NALC)*,F10.1)
      WRITE(6,7430) TNPFC
 7430 FORMAT(1X*,C)TOTAL NON-PRODUCING FACILITES COST (TNPFC)*,F10.1)
      WRITE(6,7440) SOPPC
 7440 FORMAT(1X,*SYSTEM OPERATING PROFIT (SOP)*,12X,F10.1)
      PRINT,"                PRODUCTS EARNINGS,CONTRIBUTION MARGINS,COSTS
     1AND PROFITS AS DETERMIND BY PRODUCTIVITY COSTING"
      PRINT,"                ==========================================
     1==========================================="
      PRINT,"                    LESS AVOIDABLE COSTS"
      PRINT,"                  ----------------------------"
      PRINT," PT       SR          PMC         INT         TAC         TE
     1     TE/SR     LODL         CM          CM/SR      LFOC        PP"
      DO 600 I=1,NPRO
      WRITE(6,7450) I,SR(I),PMC(I),INT(I),TACP(I),TE(I),TESR(I),ODL(I),
     1CMLR(I),CMLSR(I),PPC(I),PPP(I)
  600 CONTINUE
 7450 FORMAT(1X,I3,5(1X,F10.1),1X,F10.4,2(1X,F10.1),1X,F10.4,2(1X,F10.1
     1))
      DO 650 I=1,NPRO
      ET(I)=TE(I)/(PPC(I)+SMALL)
      EP(I)=(TE(I)-PPC(I))/(PPC(I)+SMALL)
      ED(I)=TE(I)/(PPC(I)*TFP(I)+SMALL)
      EM(I)=CMLR(I)/PPC(I)
      ESW(I)=SR(I)/(PMC(I)+INT(I)+PPC(I)+SMALL)
      EPW(I)=(SR(I)-PMC(I)-INT(I)-PPC(I))/(PMC(I)+INT(I)+PPC(I)+SMALL)
      ETW(I)=TE(I)/(PMC(I)+INT(I)+PPC(I)+SMALL)
      EMW(I)=(TE(I)-ODL(I))/(PMC(I)+INT(I)+PPC(I)+SMALL)
  650 CONTINUE
      ETT=STE/SPPC
      EPT=(STE-SPPC)/(SPPC+SMALL)
      EDT=STE/(SPPC*TTFPM+SMALL)
      EMT=SCMLR/(SPPC+SMALL)
      ESWT=TSR/(TMPC+TINT+SPPC+SMALL)
      EPWT=(TSR-TMPC-TINT-SPPC)/(TMPC+TINT+SPPC+SMALL)
      ETWT=STE/(TMPC+TINT+SPPC+SMALL)
      EMWT=(STE-TODL)/(TMPC+TINT+SPPC+SMALL)
      PRINT,"        ------------------------------------------------------
     1------------"
      PRINT,"        PRODUCT PRODUCTIVITY INDEXES AS DETERMIND BY PRODUCT
     1IVITY COSTING"
```

```
      PRINT,"        ------------------------------------------------------
     1-------------"
      PRINT,"           ***************************"
      PRINT,"           (A)BASED ON PROCESSING COST"
      PRINT,"           ***************************"
      PRINT,"   PT              ET                EP                EF
     1      ED               EM"
      DO 660 I=1,NPRO
      WRITE(6,7500) I,ET(I),EP(I),TFP(I),ED(I),EM(I)
  660 CONTINUE
 7500 FORMAT(3X,I3,5(6X,F10.4))
      WRITE(6,7510) ETT,EPT,TTFPM,EDT,EMT
 7510 FORMAT(1X,*TOTAL*,5(6X,F10.4))
      CALL RANK1(ET,NRET,NPRO)
      CALL RANK1(EP,NREP,NPRO)
      CALL RANK1(EM,NREM,NPRO)
      CALL RANK1(ED,NRED,NPRO)
      CALL RANK1(ESW,NRESW,NPRO)
      CALL RANK1(EPW,NREPW,NPRO)
      CALL RANK1(ETW,NRETW,NPRO)
      CALL RANK1(EMW,NREMW,NPRO)
      PRINT,"           ************************************"
      PRINT,"           (B)BASED ON WORKING CAPITAL INVESTMENT"
      PRINT,"           ************************************"
      PRINT,"   PT              ESW               EPW               ETW
     1      EMW"
      DO 670 I=1,NPRO
      WRITE(6,7520) I,ESW(I),EPW(I),ETW(I),EMW(I)
  670 CONTINUE
 7520 FORMAT(3X,I3,4(6X,F10.4))
      WRITE(6,7530) ESWT,EPWT,ETWT,EMWT
 7530 FORMAT(1X,*TOTAL*,4(6X,F10.4))
      CFI=SPPC+TNPFC
      ETS=STE/(CFI+SMALL)
      EPS=(STE-CFI)/(CFI+SMALL)
      EFS=TTPWHM/(TMFOHA+SMALL)
      EDS=STE/(EFS*CFI+SMALL)
      EMS=(STE-TODL)/(CFI+SMALL)
      PRINT,"        ------------------------------------------------------
     1-----------"
      PRINT,"        SYSTEM PRODUCTIVITY INDEXES AS DETERMIND BY PRODUCTI
     1VITY COSTING"
      PRINT,"        ------------------------------------------------------
     1-----------"
      PRINT,"           ****************************"
      PRINT,"           (A) BASED ON PROCESSING COST"
      PRINT,"           ****************************"
      WRITE(6,7540) ETS
 7540 FORMAT(1X,*TOTAL EARNING (/COST) PRODUCTIVITY (ETS)*,6X,F10.4)
      WRITE(6,7550) EPS
 7550 FORMAT(1X,*PROFIT (/COST) PRODUCTIVITY (EPS)*,13X,F10.4)
```

```
      WRITE(6,7560) EFS
 7560 FORMAT(1X,*TOTAL FACILITIES PRODUCTIVITY (EFS)*,11X,F10.4)
      WRITE(6,7570) EDS
 7570 FORMAT(1X,*PRODUCT PRODUCTIVITY CHARACTRISTIC (EDS)*,6X,F10.4)
      WRITE(6,7580) EMS
 7580 FORMAT(1X,*CONTRIBUTION MARGIN PRODUCTIVITY (EMS)*,8X,F10.4)
      PRINT,"          ************************************"
      PRINT,"          (B) BASED ON WORKING CAPITAL INVESTMENT"
      PRINT,"          ************************************"
      CFIM=TMPC+TINT+SPPC+TNPFC
      ESWS=TSR/(CFIM+SMALL)
      EPWS=(TSR-CFIM)/(CFIM+SMALL)
      ETWS=STE/(CFIM+SMALL)
      EMWS=(STE-TODL)/(CFIM+SMALL)
      WRITE(6,7590) ESWS
 7590 FORMAT(1X,*SALES REVENUE/WORKING CAPITAL PRODUCTIVITY (ESWS)*,7X,
     1F10.4)
      WRITE(6,7600) EPWS
 7600 FORMAT(1X,*PROFIT/WORKING CAPITAL PRODUCTIVITY (EPWS)*,15X,F10.4)
      WRITE(6,7610) ETWS
 7610 FORMAT(1X,*TOTAL EARNING/WORKING CAPITAL PRODUCTIVITY (ETWS)*,
     18X,F10.4)
      WRITE(6,7620) EMWS
 7620 FORMAT(1X,*CONTRIBUTION MARGIN/WORKING CAPITAL PRODUCTIVITY (EMWS)
     1,*1X,F10.4)
      PRINT,"COMPARATIVE PRODUCT RANKING FOR ALTERNATIVE BASES OF MANGEM
     1ENT DECISION MAKING"
      PRINT,"==================================================================
     1==================="
      PRINT,"        RAPP              RACM              RACM/SR
     1RAET              RAEP              RAEM              RAED"
      PRINT,"  ------------      ------------      ------------      ---
     1-------      ------------      ------------      ------------"
      DO 700 I=1,NPRO
      WRITE(6,7630) PP(I),NRPP(I),CM(I),NRCM(I),CMSR(I),NRCMSR(I),
     1ET(I),NRET(I),EP(I),NREP(I),EM(I),NREM(I),ED(I),NRED(I)
  700 CONTINUE
 7630 FORMAT (F10.1,2X,I3,2X,F10.1,2X,I3,2X,F10.4,2X,I3,2X,F10.4,2X,
     1I3,2X,F10.4,2X,I3,2X,F10.4,2X,I3,2X,F10.4,2X,I3)
      PRINT,"RANKING OF VARIABLES CONTINUED"
      PRINT,"==============================="
      PRINT,"        RAESW             RAEPW             RAETW
     1RAEMW"
      PRINT,"  ------------      ----------      ----------      ---
     1--------"
      DO 710 I=1,NPRO
      WRITE(6,7640) ESW(I),NRESW(I),EPW(I),NREPW(I),ETW(I),
     1NRETW(I),EMW(I),NREMW(I)
  710 CONTINUE
 7640 FORMAT(F10.4,2X,I3,2X,F10.4,2X,I3,2X,F10.4,2X,I3,2X,
     1F10.4,2X,I3)
```

```
      RETURN
      END
      SUBROUTINE RANK1(RANK,NRANK,NPRO)
      DIMENSION RANK(50),NRANK(50),SORT(50)
      SMALL=-1.E40
      DO 100 J=1,NPRO
  100 SORT(J)=RANK(J)
      L=1
      DO 200 I=1,NPRO
      SORTY=SORT(L)
      DO 300 J=1,NPRO
      IF (SORT(J).GT.SORTY) THEN
      SORTY=SORT(J)
      L=J
      ENDIF
  300 CONTINUE
      NRANK(L)=I
      SORT(L)=SMALL
  200 CONTINUE
      RETURN
      END

      SUBROUTINE OPSTE
      COMMON/ACCM/ NPRO
      COMMON/OPTI/ PWH(50,30)
      COMMON/OPMA/ TSOC
      COMMON/SOPT/ TMFOHA
      COMMON/ACCOP/ TODL,SR(50),TMPC,TINT,PMC(50)
      COMMON/AAA/ NMAC
      DIMENSION A(9,7),INEQ(7),LAB(13),AA(3),PQP(50),OPWH(50)
      READ(5,*) NTYP
      IF (NTYP.EQ.1) WRITE(6,4000)
      IF (NTYP.EQ.2) WRITE(6,4010)
      SMALL=1.E-30
 4000 FORMAT(1X,*SYSTEM OPTIMIZATION BASED ON REDUCTION OF PRODUCT VARIE
     1TY*)
      PRINT," ==================================================
     1=="
 4010 FORMAT(1X,*SYSTEM OPTIMIZATION WITH NO REDUCTION OF PRESENT PRODUC
     1T QUANTITIES*)
      PRINT," ==================================================
     1==========="
      READ(5,*) MMM,M,N,N1,K,MINX,MAXIT
      NV=N
      NC=M
      READ(5,*)  ((A(I,J),J=1,NV),INEQ(I),A(I,M),I=1,NC),
     1(A(NC+1,J),J=1,NV)
      IFAIL=1
      CALL H01AEF(A,MMM,INEQ,M,N,N1,K,MINX,MAXIT,NUMIT,LAB,IPAR,IFAIL)
      IF (IFAIL.EQ.0) GOTO 20
      WRITE(6,9000) IFAIL
```

```
      RETURN
   20 K=IPAR+1
      GOTO (80,40,60),K
   40 WRITE(6,9100)
      RETURN
   60 WRITE(6,9200)
      RETURN
      PRINT,"VALUES OF VARIABLES IN FINAL BASIS"
      PRINT,"----------------------------------"
   80 WRITE(6,9300) NUMIT
      WRITE(6,200) (LAB(I+NV),A(I,N1),I=1,NC)
      WRITE(6,210) A(M+1,N1)
 9100 FORMAT(1X,*NO FEASIBLE SOLUTION*)
 9200 FORMAT(1X,*UNBOUNDED SOLUTION*)
 9300 FORMAT(1X,*NUMBER OF ITERATIONS*,I3)
 9000 FORMAT(1X,*SOFT FAIL ERROR*,I2)
  200 FORMAT(1H,1HX,I3,2H=,F17.8)
  210 FORMAT(1X,*OPTIMUM VALUE OF TOTAL EARNING =*,F17.8)
      READ(5,*) NAV
      DO 100 I=1,NAV
      AA(I)=0.0
  100 CONTINUE
      I=1
      WHILE (I.LE.NC) DO
      J=1
      WHILE (J.LE.NAV) DO
      IF (LAB(I+NV).EQ.J) THEN
      AA(J)=A(I,N1)
      ENDIF
      J=J+1
      ENDWHILE
      I=I+1
      ENDWHILE
      READ(5,*) (PQP(I),I=1,NPRO)
      DO 420 I=1,NAV
      OPWH(I)=0.0
      DO 410 J=1,NMAC
      OPWH(I)=OPWH(I)+(PWH(I,J)*AA(I))/(PQP(I)+SMALL)
  410 CONTINUE
  420 CONTINUE
      OSTE=A(M+1,N1)
      OETS=OSTE/(TSOC+SMALL)
      OEPS=OETS-1.0
      TOPWH=0.0
      DO 430 I=1,NPRO
      TOPWH=TOPWH+OPWH(I)
  430 CONTINUE
      OEFS=TOPWH/(TMFOHA+SMALL)
      OEDS=OSTE/((OEFS*TSOC)+SMALL)
      OEMS=(OSTE-TODL)/(TSOC+SMALL)
      PRINT,"     ------------------------------------"
```

```
      PRINT,"      SYSTEM,S OPTIMUM PRODUCTIVITY INDEXES"
      PRINT,"      ------------------------------------"
      PRINT,"         ****************************"
      PRINT,"         (A) BASED ON PROCESSING COST"
      PRINT,"         ****************************"
      WRITE(6,5000) OETS
 5000 FORMAT(1X,*TOTAL EARNING (/COST) PRODUCTIVITY (ETS)*,6X,F10.4)
      WRITE(6,5010) OEPS
 5010 FORMAT(1X,*PROFIT (/COST) PRODUCIVITY (EPS)*,13X,F10.4)
      WRITE(6,5020) OEFS
 5020 FORMAT(1X,*TOTAL FACILITIES PRODUCTIVITY (EFS)*,11X,F10.4)
      WRITE(6,5030) OEDS
 5030 FORMAT(1X,*PRODUCT PRODUCTIVITY CHARACTRISTIC (EDS)*,6X,F10.4)
      WRITE(6,5040) OEMS
 5040 FORMAT(1X,*CONTRIBUTION MARGIN PRODUCTIVITY (EMS)*,8X,F10.4)
      OTSR=0.0
      DO 440 I=1,NPRO
      OTSR=OTSR+(SR(I)*AA(I))/(PQP(I)+SMALL)
  440 CONTINUE
      OTMPC=0.0
      DO 450 I=1,NPRO
      OTMPC=OTMPC+(PMC(I)*AA(I))/(PQP(I)+SMALL)
  450 CONTINUE
      SW=OTMPC+TINT+TSOC
      OESWS=OTSR/(SW+SMALL)
      OEPWS=OESWS-1.0
      OETWS=OSTE/(SW+SMALL)
      OEMWS=(OSTE-TODL)/(SW+SMALL)
      PRINT,"         ****************************************"
      PRINT,"         (B) BASED ON WORKING CAPITAL INVESTMENT "
      PRINT,"         ****************************************"
      WRITE(6,5050) OESWS
 5050 FORMAT(1X,*SALES REVENUE/WORKING CAPITAL PRODUCTIVITY (ESWS)*,
     1F10.4)
      WRITE(6,5060) OEPWS
 5060 FORMAT(1X,*PROFIT/WORKING CAPITAL PRODUCTIVITY (EPWS)*,15X,F10
      WRITE(6,5070) OETWS
 5070 FORMAT(1X,*TOTAL EARNING/WORKING CAPITAL PRODUCTIVITY (EMWS)*,
     18X,F10.4)
      WRITE(6,5080) OEMWS
 5080 FORMAT(1X,*CONTRIBUTION MARGIN/WORKING CAPITAL PRODUCTIVITY (E
     1,*1X,F10.4)
      RETURN
      END
```

REFERENCES

1. Abber, A. "Job Enrichment for Profit". Human Resources Management (U.S.A.), Spring 1979.

2. Arrow, K.J. "The Economic Implications of Learning by Doing". Review of Economic Studies, XXXIX, 1962.

3. Arrow, K.J., Chenery, H.B., Minhâs, B.S. and Solow, R.N. "Capital and Labour Substitution and Economic Efficiency". Review of Economics and Statistics, Vol.XLIII, 1961.

4. Aynadri, L., Kustura, J.J. and Shaver, H.L. "Measuring Engineering Productivity in a Large Instrument and Electrical Department". Advanced Instrumentation, Vol.31, 1976.

5. Amey, L.R. "The Allocation and Utilization of Resources". Operational Research Quarterly, Vol.15, 1964.

6. Abramovitz, J.G. and Shattuch, G.A. "The Learning Curve: A Technique for Planning, Measurement and Control". IBM, Report 31, 1966.

7. Arrow, K.J. "The Measurement of Real Value Added". Academic Press, New York, 1974.

8. Abramovitz, M. "Resource and Output Trends in United States since 1870". American Economic Review, Vol.46, No.2, May 1956.

9. Allen, R.G.D. "Macro-Economics Theory". Macmillan, London, 1967.

10. Anderson, R.L. and Bancroft, T.A. "Statistical Theory in Research". McGraw-Hill, 1952.

11. Bureau of Labour Statistics (US). "Trends in Output per Man-hour and Man-hours per Unit of Output in Manufacturing". Report No.100, Bureau of Labour Statistics.

12. Bureau of Labour Statistics (US). "Productivity, Wages and Prices". Bureau of Labour Statistics, issued quarterly.

13. Bureau of Labour Statistics (US). "Productivity: A Bibliography". BLS, Bulletin 1226.

14. Bureau of Labour Statistics (US). "Trends in Output per Man-hour in Private Economy, 1909-1958". BLS, Bulletin, 1249.

15. Bowey, A.M. and Lupton, T. "Productivity Drift and the Structure of Pay Packet". J. of Management Studies, Vol.7, 1970.

16. Bosworth, D.L. "Production Functions". Saxon House, D.C.Heath Ltd., England, 1976.

17. Beatti, D.M. "Value Added and Return on Capital as Measures of Efficiency". J. of Business Finance, Summer 1970.

18. Bell, D.W. "Profit Sharing and Productivity Plans". Industrial Participation (UK), Winter 1977/78.

19. Broster, E.J. "Measuring Productivity the Delusion of Value Added". Certified Accountants J. (U.K.), February 1971.

20. Byrd, J. "Measure Productivity from Payroll Records". Ind.Engineering, 11(8), August 1979.

21. Brown, J.L. and Howard, L.R. "Principles and Practice of Management Accounting". Macdonald & Evans Ltd., London, 1975.

22. Boyd, J.M. "Is Industrial Democracy Compatible with Efficiency". The Production Engineer, January 1968.

23. Brown, M. "The Theory and Empirical Analysis of Production". National Bureau of Economic Research, 1967.

24. Brown, M. and Conrad, A.M. "The Influence of Research and Education in C.E.S. Production Relations". Studies in Income and Wealth, Vol.31, National Bureau of Economic Research, New York, 1967.

25. Ball, R.J. "The Use of Added Value in Measuring Managerial Efficiency". Business Ratios, Summer, 1968.

26. Bahiri, S. "Evaluating and Developing Productivity Costing Models". M.Sc.Thesis, University of Birmingham, 1967.

27. Bahiri, S. and Martin, H.W. "Effective Management through Productivity Costing". Industrial & Commerical Technique Ltd., London, 1968.

28. Bahiri, S., Jenney, B.W. and Norman, R.G. "How to Measure Productivity". Management Tech., July 1970.

29. Balk, W.L. "Technological Trends in Productivity Measurement". Public Personnel Management, Vol.2, Part 2, March 1975.

30. Bureau of Labour Statistics (US). "Summary of Proceedings of Conference on Productivity". BLS, Bulletin 913, 1947.

31. Center for Interfirm Comparisons. "Your Yard Stick of Performance". Published Accounts, 1968.

32. Cox, B.C. "Added Value and the Corporate Report". J. of Cost and Management Accounting, April 1976.

33. Craig, C.E. and Harris, R.C. "Total Productivity Measurement at Firm Level". Sloan Management Review, Spring, 1973.

34. Cobb, C.W. and Douglas, P.H. "A Theory of Production". Am.Economic Review, Vol.XVIII, 1928.

35. Cocks, D.L. "The Measurement of Total Factor Productivity for a Large U.S. Manufacturing Corporation". Business Economics, Vol.9, Part 4, 1974.

36. Corlet,E.N. and Hollier, R.H. "Work Sampling using Extended Observation". Int.J.Prod.Res., Vol.4, No.1, 1964.

37. Cotton, F.E. In Productivity "Planning is Everything". Ind.Eng., November 1976.

38. Chenery, H.B. "Engineering Production Function". Quarterly J. of Economics, Vol.LXIII, 1949.

39. Cunningham, J.B. "Approaches to the Evaluation of the Organizational Effectiveness". Academy of Management Review, July 1977.

40. Christensen, L.R. and Jorgenson, D.W. "Measurement of U.S. Real Capital Input 1927-1967". Review of Income and Wealth Series, No.4, December 1969.

41. Cobian, M.J. and Lele, P.T. "Long Range Multi-Plant Capacity Expansion". Technical Papers, 21st A.I.I.E. Amercian Convention, Cleveland, May 1970.

42. Clay, M.J. "The Measurement of Productivity in Individual Company". Work Study, November 1965.

43. Cannon, M.J. and Paine, F.T. "Factors Affecting Productivity in the Public Service: A Managerial Viewpoint". Proc. of Academy of Management, August 1975.

44. Chamberlain, N.W. "The Firm: Micro Economic Planning and Action". McGraw Hill, New York, 1962.

45. Cornes, R.B. "Productivity and Technology in the Electric Lamp Industry". Monthly Labour Review, No.101, August 1978.

46. Conway, R.W. and Schultz, A. "Manufacturing Progress Function". J. of Industrial Engineer, U.S.A., 1959.

47. Dyson, B.H. "Measurement of Productivity". The Institution of Production Engineers Journal, January 1953.

48. Denison, E.F. "Sources of Economic Growth in U.S." Comm. for Economic Development, Supp.Paper 13, Washington, D.G., 1962.

49. Durand, D. "Some Thoughts of Marginal Productivity with Special Reference to Professor Douglas' Analysis". J. of Political Economy, Vol. XLV, 1937.

50. Dar—El, E.M. and Young, L.F. "System Incentives: Three Ways to Better Productivity". Industrial Engineering, April 1977.

51. David, P. "The Deflation of Value Added". The Review of Economics, May 1962.

52. Drucher, P.F. "The Practice of Management". Pan Books Ltd., 1977.

53. Douglas, P.H. and Handsaker, M.L. "Theory of Marginal Productivity Tested by Data for Manufacturing in Victoria". Quart.J. of Economics, November 1937.

54. Dunning, J.H. and Barron, M.J. "A Productivity Measure of Business Performance". Business Ratios, Autumn 1967.

55. Dunning, J.H. and Rowan, D.C. "Inter-firm Efficiency Comparisons: US and UK Manufacturing Enterprises in Britain". Banca Nazionale de Lavoro Quart.Rev., Vol.21, 1968.

56. Dudley, N.A. "Comparative Productivity Analysis". Int.J.Prod.Res., Vol.4, 1970.

57. Dudley, N.A. "Industrial Productivity Scope for Improvements". Midlands Tomorrow, No.8, West Midlands Economic Planning Co., 1975.

58. Dudley, N.A. "Engineers Concepts of Productive Efficiency". Printed in "Industrial Efficiency and the Role of Government", Ed. C. Bowe, Department of Industry, HMSO, London 1977.

59. Etzioni, A. "Two Approaches to Organizational Analysis: A Critique and a Suggestion". Administrative Science Quarterly, Vol.5, 1960.

60. Evanson, C.E. and Bolz, R.W. "Automating the Plant for Increased Productivity". Consult Eng., (Barrington) April 1977.

61. English, F.G.S. "A Broader Conception of Productivity and its Measurement". J. of I.P.E., July 1951.

62. Ervin, O.L. "A Conceptual Niche for Municipal Productivity". Public Productivity Review (USA), Vol.3, No.2, 1973.

63. Erickson, P.O.M. "Do You Know How Your Factory is Performing?" Man. & Ind.Eng., Vol.XXX, July 1974.

64. Ellington, R.C. "Preventive Maintenance Pushes Producticity". World Dredging Mar.Const., September 1976.

65. Eilon, S. "Goals and Constraints in Decision Making". Operational Research Quarterly, Vol.23, No.1, 1972.

66. Eilon, S., Gold, B. and Soesan, J. "Applied Productivity Analysis for Industry". Pergamon Press, 1976.

67. Eilon, S. and Teague, J. "On Measures of Productivity". OMEGA, Vol.1, No.5, 1973.

68. Edmunds, S.W. "Capital Productivity, Money Flows and Inflation". Business Economics, May 1978.

69. Easterfield, T.E. "Productivity Measurement in Great Britain". Dept. Sci. & Ind.Res., U.K., 1959.

70. Easterfield, T.E. "British Management Uses of Productivity Indices". The Manager, Vol.21, February 1953.

71. Flander, A. "The Fawley Productivity Agreements". Faber, London, 1964.

72. Fox, A. "Industrial Sociology and Industrial Relations". HMSO, London, 1966.

73. Ferguson, A.R. "An Airline Production Function". Econometrica, VolXIX, 1951.

74. Ferguson, C.E. "Time Series Production Functions and Technological Progress in American Manufacturing Industry". J. of Political Economy, 1965.

75. Fallon, C. "Value Analysis to Improve Productivity". Wiley, 1971.

76. Furst, G., Raabe, K.H. and Sperling, H. "Output per Person Employed in the Major Sectors of German Economy". Productivity Measurement Review, O.E.C.D., 1962.

77. Fenton, G.R. "Measuring Productivity". Machine Shop Magazine, December 1951.

78. Fayol, H. "General and Industrial Management". Pitman, 1949.

79. Fisher, I. "The Making of Index Numbers". Haughton Mufflin Co., New York, 1922.

80. Faraday, J.E. "Total Productivity Measurement". Work Study and Management Services, October 1968.

81. Fein, M. "Improving Productivity by Improved Productivity Sharing". The Conference Board Record, July 1976.

82. Farrell, M.J. "The Measurement of Productive Efficiency". J. of Royal Statistical Soc., Series A, Part III, 1957.

83. Fabricant, S. "Output of Manufacturing Industries, 1899-1937". National Bureau of Economic Research, 1940.

84. Fabricant, S. "Productivity". Random House Inc., New York, 1969.

85. Fabricant, S. "A Primer on Productivity". Random House, New York, 1969.

86. Fabricant, S. "Basic Facts on Productivity Change". National Bureau of Economic Research, No.53, 1958.

87. Fuchs, V.R. "Production and Productivity in the Service Industries". National Bureau of Economic Research, 1969.

88. Fuchs, V.R. and Wilburn, J.A. "Productivity Differences within the Service Sector". National Bureau of Economic Research, 1967.

89. Government of Ontario. "Committee on Government Productivity". Report No.10, A Summary, March 1973.

90. Ghobadian, A. "Implementing an Added Value Payment Scheme". Personnel Review, Vol.10, No.4, 1981.

91. Geare, A.J. "Productivity from Scanlon Type Plans". Academy of Management Review, July 1976.

92. Gold, B. "Foundations of Productivity Analysis". University of Pittsburgh Press, 1955.

93. Gold, B. "Productivity Analysis and System Coherence". Operational Research Quarterly, Vol.16, No.3, 1965.

94. Gold, B. "Technology Productivity and Economics". OMEGA, Vol,1, Part 1, 1973.

95. Gold, B. "New Managerial Control Ratios". Advanced Management, Vol.21, No.4, 1956.

96. Gold, B. "Productivity Analysis". Business Economics, May 1974.

97. Gold, B. "Explorations in Managerial Economics, Productivity, Costs, Technology and Growth". Macmillan, London, 1971.

98. Gold, B. "Productivity, Technology and Capital". Lexington Books, 1979.

99. Gold, B. and Kraus, R.M. "Integrating Physical with Financial Measures for Managerial Control". J. of Academy of Management, June 1964.

100. Goodeve, C. "Development of Productivity Studies as a Science". The Machinist, July 1953.

101. Gowler, D. and Legge, K. "Stress Success and Legitimacy". In Dan Gowler and Karen Legge, Management Stress, 1975.

102. Gunn, G. and Douglas, P.H. "Production Function for Australian Manufacturing". Quarterly J. of Economics, Vol. LVI, 1941.

103. Gunn, G. and Douglas, P.H. "Production Function for American Manufacturing in 1914". J. of Political Economy, 1942.

104. Gunn, G. and Douglas, P.H. "Further Measures of Marginal Productivity". Quarterly J. of Economics, 1940.

105. Ghorpade,J. "Assessment of Organizational Effectiveness: Issues, Analysis and Readings". Pacific Palisades California, 1971.

106. Griliches, Z. and Jorgenson, D.W. "Sources of Measured Productivity Change: Capital Input". American Economic Review, Vol.56, No.2, May 1966.

107. Greenberg, L. "A Practical Guide to Productivity Measurement". The Bureau of National Affairs, Inc., Washington D.C., 1973.

108. Green, M. and Cornwell, R.J. "Added Value - An Important Factor in Financial Control". The Accountant, Vol.15, 1964.

109. Grinyer, P.H. and Batt, C. "Some Tentative Findings on Corporate Financial Models". Operational Research Quarterly, 1974.

110. Grinyer, P.H. and Wooller, J. "Computer Models for Corporate Planning". Long Range Planning, Vol.8, No.1, February 1975.

111. Glendinning, R. "measurement of Productivity". Mass Production, June 1952.

112. Gilchrist, R.R. "Company Appraisal and Control by Added Value Analysis". Certified Accountants Journal, October 1970.

113. Gilchrist, R.R. "Managing for Profit - the Added Value Concept". George Allen & Unwin Ltd., London 1971.

114. Grilliches, Z. "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change". National Bureau of Economic Research (US), 1961.

115. Gupta, S. and Steedman, I. "An Input-Output Study of Labour Productivity in British Economy". Bull. Oxford Un.Inst.Econ.Statist., February, 1971.

116. "How a Big Company Controls Itself". Business Week, December 1952.

117. Hansen, B. "A Proposed Real Net Output Index: A Comment". The Review of Economics and Statistics, August 1975.

118. Horngren, C.T. "Accounting for Managerial Control: An Introduction". Prentice-Hall, 1965.

119. Heathfield, D.F. "Production Functions". Macmillan Press Ltd., London, 1971.

120. Hildebrand, G.H. and Liu, I.C. "Manufacturing Production Function in United States, 1957". Cornell University, New York, 1965.

121. Helps, I.G. "Forecasting Manpower: A Review of some Models used for Forecasting Changes in Total Employment at National and Sectoral Level". Working Paper National Economic Development Office, 1974.

122. Hershauer, J.G. and Ruch, W.A. "Workers Productivity Model and its Use in Lincoln Electric". Interfaces, No.8, May 1978.

123. Hughes, J.J., Hutchinson, G.K. and Gross, K.E. "Flexible Manufacturing Systems for Improved Mid-vol Productivity". System Eng.Conf.Proc., November 1975.

124. Horrigan, J.O. "A Short History of Financial Ratio Analysis". The Accounting Review, April 1968.

125. Hicks, J.R. "Theory of Wages". Macmillan, London, 1963.

126. Hamre, L.A. and Juntti, K.J. "Productivity Measurement". Assembly Engineering, April 1974.

127. Hackamack, L. "Analyse Productivity of Your Machine". Prod. Eng. (USA), November 1978.

128. Hewett, W. "The Measurement of Manufacturing Performance". Mechanical Engineering World and Engineering Records, July 1974.

129. Hancock, W., Merten, A. and Dissen, R. "Example of Simulation to Improve Plant Productivity". AIIE Trans., Vol. 9, March 1977.

130. Hines, W.W. "Guidelines for Implementing Productivity Measurement". Industrial Engineering, June 1976.

131. Improved Tools of Management, Management Association, Financial Management Series, No. III, New York, 1956.

132. Ijiri, Y. "Management Goals and Accounting for Control". North Holland, Amsterdam, 1965.

133. Jones, G.L. "Productivity Bargaining". Personnel Management, January 1978.

134. Johnston, J. "Econometric Methods". McGraw-Hill 2nd Edition, 1972.

135. Johansen, L. "Production Functions". North Holland Amsterdam, 1972.

136. Johnson, T. "New System Evaluates Cost Target". American Machinist, February 1961.

137. Jerome, W.T. "Executive Control". John Wiley, New York, 1961.

138. Koutsoyiannis, A. "Theory of Econometrics". Macmillan, 2nd Edition, 1977.

139. Klotz, B.P. "Productivity Analysis in Manufacturing Plants". US Dept. of Labour, Bureau of Labour Statistics, 1970.

140. Koontz, H. and O'Donnel, L.C. "Principles of Management". McGraw-Hill, 1964.

141. Kraus, J. "Productivity and Profit Models of the Firm". Business Economics, September 1978.

142. Ksansnak, J.E. "Measuring Productivity". Managerial Planning, November-December 1974.

143. Kneip, J.G. "Maintenance Progress Function". J. of Industrial Engineers, November 1965.

144. Katz, J.M. "Production Functions, Foreign Investment and Growth". North Holland Pub.Co., Amsterdam, 1969.

145. Kendrick, J.W. "Long Range Projection, Studies in Income and Wealth". Princeton University Press, 1954.

146. Kendrick, J.W. "Productivity Trends in U.S.". Princeton University Press, 1961.

147. Kendrick, J.W. "Productivity Tends: Captial and Labour". Review of Economics and Statistics, Vol.38, No.3, August 1956.

148. Kendrick, J.W. "Understanding Productivity". John Hopkins University Press, Baltimore, 1977.

149. Kendrick, J.W. "Postwar Productivity Trends in the United States, 1948-1969". National Bureau of Economic Research, N.Y. 1973.

150. Kendrick, J.W. "The Formation and Stocks of Total Capital". National Bureau of Economic Research, N.Y. 1976.

151. Kendrick, J.W. and Creamer, D. "Measuring Company Productivity". The Conference Board: Studies in Business Economics, No.89, 1965.

152. Kurosawa, K. "Fundamental Principles of Productivity Analysis". Jicho-Sha, Tokyo, 1977.

153. Kurosawa, K. "An Aggregate Index for the Analysis of Productivity and Profitability". OMEGA, Vol.3, No.2, 1975.

154. Knayer, M. "Analysis and Comparison of Productivity". Productivity Measurement Review, February 1956.

155. Kaiel, M.L. "Operations Auditing, Management Systems and Productivity Improvement". Internal Auditor, June, 1976.

156. Kirby, P.G. "Productivity Increases Through Feed-Back Systems". Personnel J., October 1977.

157. Keeney, R.L. and Raiffa, H. "Decision with Multiple Objectives: Preferences and Value Trade-Offs". John Wiley & Sons, New York, 1976.

158. Kahn, R.L., Wolfe, D.L., Quinn, R.P., Snoek, J.D. and Rosenthal, R.A. "Organizational Stress: Studies in Role Conflict and Ambiguity". John Wiley & Sons, 1964.

159. Lachenmeyer, C. "Measuring Labour Related Productivity". Managerial Planning, May-June 1977.

160. Law, D.E. "Measuring Productivity". Financial Executive, October 1972.

161. Lorenz, J.D. and Mehle, A.A. "Measuring Machine Utilization". Ind. Eng., February 1979.

162. Lele, P.T. and O'Leary, J.W. "Applications of Production Functions in Management Decisions". A.I.I.E. Transactions, Vol. 4, No. 1, 1972.

163. Likert, R. "Human Resources Accounting: Building and Assessing Productive Organization". Personnel, Vol. 50, No. 3, 1973.

164. Lee, S.J. "Analysing Productivity at Plant ~~Level~~ in the Engineering Industry". Ph.D. Thesis, Loughborough University, 1979.

165. Levine, S. and White, P.E. "Exchange as a Conceptual Framework for the Study of Interorganizational Relationships". Administration Science Quarterly, Vol. 5, 1960.

166. Lester, T. "What Efficiency Really Means". Management Today, October 1971.

167. Langenbury, W. "An Experiment in Productivity Measurement". National Association of Cost Accountants Bulletin, Canada, 1952.

168. Lewellen, W.G. "The Cost of Capital". Belmont, Calif.: Wadsworth, 1969.

169. Leontief, W.W. "The Structure of American Economy, 1919-1939". Oxford University Press, 1951.

170. McMahon, J. "Making the Most of Work Measurement". Production Engr., January 1980.

171. Millard, C.W. "The Development and Application of Behavioural Criteria for Evaluating Manpower Performance at the Micro-level". Proc. of Academy of Management, August 1975.

172. Markell, G.A. "Improving Productivity through Material Handling". Ind.Engin., January 1973.

173. Martin, H.W. "Toward a Common Measure of Productivity". Productivity Measurement Review, No.19, November 1959, OECD.

174. Martin, H.W. "Productivity Measurement and Control". Productivity Measurement Review, No.21, May 1960, OECD.

175. Martin, H.W. "Productivity Costing and Control". Productivity Measurement Review, No.37, May 1964, OECD.

176. Moon, I.D. "Technological Change and Productivity in Input-Output Analysis and the Potential of Sectoral Optimization Models" in Aggregate and Industry Level Productivity Analysis, Ed. by A. Dogramaci, and R. Adam., Mortinus Nijhoff Publicating, 1981.

177. Mark, J.A. "Concepts and Measures of Productivity". Bureau of Labour Statistics, US Department of Labour Bulletin, 1714, September 1971.

178. Mitrofanov, S.P. "The Group Machining Method for Increased Productivity". Opt-Mekh Prom, Ap-1970, English Trans.Cochem:OPMPA.

179. National Board for Prices and Incomes. Productivity Agreements". HMSO Report No.36, London, 1967.

180. Newland, C.A. "Symposium on Productivity in Government". Public Administration Review, Vol.32, November-December, 1972.

181. Nadler, G. "Work Design". Irwin, 1963.

182. Nadler, G. and Smith, W.D. "Manufacturing Progress Functions for Types of Process". Int.J.Prod.Res., March 1963.

183. Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K. and Bent, D.H. "Statistical Package for the Social Sciences". McGraw-Hill, 2nd Edition, 1974.

184. Norman, R.G. "Productivity Measurement in Manufacturing Industry". Works Management, February 1971.

185. Ohi, C.J. "Impact of Maintenance on Productivity". SME Tech.Paper, Series MM, 1976.

186. O'Shaughnessy, J. "Business Organisation". George Allen & Unwin Ltd., 1966.

187. OECD. "Productivity Measurement". Vol. 1, 1955, Vol. 2, 1963, Vol. 3, 1966.

188. Price, J.L. "Organizational Effectiveness: An Inventory of Propositions". Irwin, 1968.

189. Pfiffner, J.M. and Sherwood, F.P. "Administrative Organization". Prentice-Hall, 1960.

190. Parsons, T. "Structure and Process in Modern Society". Glencoe, Ill.: Free Press, 1960.

191. Parsons, T. "Politics and Social Structure". Free Press, New York, 1969.

192. Rees, A. "Improving the Concepts and Techniques of Productivity Measurement". Monthly Labour Review, Vol.102, No.9, September 1979.

193. Robinson, J. "Exercises in Economic Analysis". Macmillan, London, 1960.

194. Risk, J.M.S. "Productivity Yard Sticks". Management Accounting, November 1965.

195. Richardson, L.K. "Productivity - The Controllable Factor". Financial Executive (USA), October 1973.

196. Rosenbloom, R. "The Real Productivity Crisis in Government" Harwad Business Review, Vol32. No.6, September-October 1973.

197. Roll, Y. and Sachish, A. "Productivity Measurement at Plant Level". OMEGA, Vol.9, No.1, 1981.

198. Sahgal, B. "Measures of Productivity and Efficiency - An Empirical Study". M.Sc.Thesis, Imperial College, 1972.

199. Solow, R. "The Technical Change and the Aggregate Production Function". Review of Economics and Statistics, 1957.

200. Samuelson, P. "Economics". McGraw-Hill, 8th Edition, 1970.

201. Samuelson, P. and Swamy, S. "Invariant Economic Index Numbers as a Canonical Duality: Survey and Synthesis". American Economic Review, September 1974.

202. Schlatter, C.F. and Schlatter, W.J. "Cost Accounting". John Wiley, 1960.

203. Schlender, B.H. and Smerilson, H.H. "Low Cost Measurement of Indirect Labour Productivity. A.I.I.E., Annual Conf., 1977.

204. Schneider, R.W. "A Model for Measuring Effectiveness for Support Functions". A.I.I.E. Spring Annual Conf., Spring 1977.

206. Seitz, J.E. "Productivity Patterns and Perspective". Financial Executive, Vol.45, No.4, April 1977.

207. Sato, K. "The Meaning and Measurement of the Real Value Added Index". The Review of Economics and Statistics, Nov. 1976.

208. Selznick, P. "Foundation of the Theory of Organizations". American Sociological Review, Vol.13, 1948.

209. Sims, C. "Theoretical Basis for a Double Deflated Index of Real Value Added". The Review of Economics and Statistics, November 1969.

210. Simon, H.A. "Administrative Behaviour". Macmillan, 1961.

211. Smith, A.R. "Productivity Measurement and Wage Levels". British Management Review, Vol. X, No. 3, December 1951.

212. Smith, B.P. "Managing for Productivity". Management Today, October 1977.

213. Smith, E. and Beeching, R. "Measurement of Effectiveness of the Production Units". B.I.M., No.4, 1949.

214. Smith, E.O. "Productivity Bargaining, A Case Study in Steel Industry". Pan Books, 1971.

215. Smith, G. "Understanding Productivity". Industrial and Commercial Training, December 1976.

216. Smith, G. "The Fundamental Truths of Productivity". Management Services, January 1978.

217. Smith, I.G. "Productivity Agreements and Productivity". Industrial Re.J., January-March, 1971.

218. Smith, I.G. "The Measurement of Productivity". Gower Press, 1973.

219. Speed, D.J. and Lowe, P.H. "The Effectiveness of Production Unit". The Production Engineer, June 1976.

220. Staples, F.W. "Added-Value Ratios and Productivity Deals". The Accountant, December 1972.

221. Stein, H. "The Meaning of Productivity". Bureau of Labour Statistics, Bulletin 1714, September 1971.

222. Stewart, W.T. "A "Yardstick" for Measuring Productivity". Industrial Engineer, Feburary 1978.

223. Suojaren, W.W. "Accounting Theory and the Large Corporation". Accounting Review, Vol.29, July 1954.

224. Taylor, B.W. and Davis, K.R. "Increasing Productivity Through Work In Progress Management". Production Inventory Management, Vol.18, 1977.

225. Taylor, B.W. and Davis, K.R. "Corporate Productivity getting it all Together". Industrial Engineering, March 1977.

226. Tolkowsky, D. "Productivity Costing: a comment on its practical applications". Productivity Measurement Review, 1964, OECD.

227. Thorelli, H.B. "Productivity - Notes on a Tantalizing Concept". Productivity Measurement Review, No.2, 1960.

228. Teague, J. and Eilon, S. "Productivity Measurement a Brief Survey". Applied Economics, No.5, 1973.

229. Tippett, L.H.C. "Productivity in British Industry". The Engineer, No.XIII.

230. Thatcher, R.H. "Designing a Productivity Control Process". Business Horizons, December 1975.

231. Udler, A.S. "Productivity Measurement of Administrative Services". Personnel Journal (USA), December 1978.

232. Usilaner, B. "Productivity - A Management Tool for Controlling Government Spending". Public Productivity Review (USA), Vol.3, No.2, 1978.

233. U.S. Department of Labour. "Productivity, A Selected Anotated Bibliography". Bulletin 1776, US Department of Labour, GPO, Washington, D.C., 1973.

234. U.S. General Accounting Office. "Permanent Measurement System". U.S. General Accounting Office, 1973.

235. Westwick, C.A. "How to Use Management Ratios". Gower Press, 1973.

236. Williamson, D.T.M. "The Anachronistic Factory". Proc. of The Royal Society, March 1974.

237. Wood, G. "How to Add Value". Management Today, March 1974.

238. Weston, J.F. and Bingham, E.F. "Managerial Finance". Holt, Rhinehart and Winston, New York, 1968.

239. Waddington, M. "A Better Way of Measuring Your Factories Production". The Production Engineer, November 1980.

240. Weber, M. "The Theory of Social Economic-Organization, Edited with an Introduction by T. Parsons". Free Press, New York, 1964.

241. Wilmott, R.A. "Measurement of Financial Performance". Managerial Finance, Vol.2, No.3, 1976.

242. Wonnacott, R.J. and Wonnacott, T.H. "Econometrics". Wiley, 1970.

243. Wright, T.P. "Index of Airplane Production Efficiency", Aircraft Production Board, Washington D.C., November 1943.

244. Xirokastas, D.A. and Lioukas, S.K. "Productivity Indices and Personnel Comparative Assessment in a Multi-divisional Corporation". Operation Research Quarterly, Vol.28, 1977.

245. Yuchtman, E. and Seashore, S.E. "A Systems Resource Approach to Organizational Effectiveness". Americal Sociological Review, Vol.32, 1967.

BIBLIOGRAPHY

Ashburn, A. "Devising Real Incentives for Productivity". Am.Machinist, June 1978.

Ainger, D. and Chu, S. "On Estimating the Industry Production Function". Am.Economic Review, Vol.58, No.4, September 1968.

Apple, J.M. "New Approach to Productivity Improvement". Proc.A.I.I.E.,Ann.Conf., Spring 1977.

Adam, N.R. and Dogramaci, A. "Productivity Analysis at Organizational Level". Martinus Nijhoff Publishing, 1981.

Afriat, S.N. "Efficiency Estimation of Production Functions". Int.Economic Rev., Vol.13, No.3, October 1972.

Anderson, W.H.L. "Production Scheduling, Intermediate Goods and Labour Productivity". Am.Econ.Rev., March 1970.

Abernathy, W.J. "The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry". John Hopkins Univ. Press., Baltimore, 1978.

Bureau of Labour Statistics (U.S.). "Productivity and Economy". B.L.S. Bulletin, No.1710, 1971.

Brendt, E.R. and Jorgenson, D.W. "How Energy and its Cost Enter the Productivity Equation". IEEE Spectrum, Vol.15, No.10, October 1978.

Brennan, D.P. "Management Assessing its Role in Improvement of Productivity". Paper Trade Journal, December 1978.

Burdeau, H.B. "Productivity - To be or Not To Be". J.System Manag., Vol.27, No.1, January 1976.

Byrd, J. "Productivity at an Early Age". Ind.Eng., Vol.8, No.8, August 1976.

Bailey, J.E. and Decker, J.P. "Energy Consideration in Productivity Management". A.I.I.E.Ann.Conf., 1977.

Boulden, L.L. and Tomash, M.R. "Productivity Research - Is Uncle Sam's Help Really Needed?". Automation, Vol.23, No.2, February 1976.

Bertha, R.W. "Productivity Everybody Wins". SME Tech.Paper, Ser.AD, October 1975.

Bahiri, S. and Martin, H.W. "Productivity Costing and Management". Management Int.Rev., Vol.10, No.1, 1970.

Chandler, C.H. "Monitor Downtime to Boost Productivity". Ind.Eng., Vol.9, No.6, June 1977.

Clutterbuck, D. "What makes Japanese Car Manufacturers so Productive". Int.Management, April 1978.

Chappell, F. "Economic and Social Importance of Productivity Measurement". Mass Production, May 1962.

Chudyic, G.W. "Cost Reduction or Improved Productivity through Material Handling". SME Tech.Paper, November 1975.

Constable, J. "How to Raise Production". Management Today, June 1974.

Carr, J. "Measuring Productivity". Arthur Andersen, Chronicle 33, 1973.

Coates, J.B. "A Technological Data Base". Management Accounting, December 1976.

Crawford, L. "Productivity Bargaining - Pancea or Palliative". 2 Articles. Personnel and Training Manag., March 1968, April 1969.

Capdevielle, P. and Neef, A. "Productivity and Unit Labour Costs in the U.S.A. and Abroad". Monthly Labour R., July 1975.

Clark, P.K. "Issues in the Analysis of Capital Formation and Productivity Growth". Brookings Papers on Economic Activity, Vol.2, 1979.

Clark, P.K. "Capital Formation and the Recent Productivity Slowdown". J. of Finance, Vol.33, June 1978.

Cox, S.R. "Industrial Performance Evaluation Experiment". J.Ind.Econ., March 1974.

Dogramaci, A. "Productivity Analysis". Martinus Nijhoff Publishing, 1981.

Dennison, E.F. "Explanation of Declining Productivity Growth". Survey of Current Business, Vol.59, No.8, August 1979.

Dennison, E.F. "Some Major Issues in Productivity Analysis: An Examination of Estimates by Jorgenson and Griliches". Survey of Current Business, Vol.49, No.5, May 1969.

Dennison, E.F. "Sources of Economic Growth in the U.S. and the Alternatives Before Us". Com. for Economic Development, Supplementary Paper 13, 1962.

Edgeworth, F.Y. "The Plurality of Index Numbers". Economic Journal, Vol.35, 1925.

Dunning, J.H. "Profitability, Productivity and Measures of Business Performance". The Investment Analyst, June 1969.

Dunning, J.H. and Sutton, M.A. "Measuring Changes in Productivity and Efficiency in U.K. Industry 1954-63". Business Ratio, 1967.

Davies, K. "Added Value Pay and Productivity". Work Study, January 1978.

Dhrymes, P.J. "A Comparison of Productivity Behaviour in Manufacturing and Service Industries". Review of Economics and Statistics, Vol.45, No.1, 1963.

Douglas, R.L. "Improved Productivity through Inspection in Automatic Assembly". SME Tech.Paper, Ser.Ad., October 1976.

Duffy, R.L. "Future of Productivity Management". SME Tech. Paper, SER.MM, December 1976.

Engineering Employers Federation. "Performance and Productivity: In the U.K. Engineering Industry". EEF, July 1979.

Erdilek, A. "Productivity, Technological Change and Input-Output Analysis". In Research, Technological Change and Economic Analysis, Edited by B. Gold, Lexington Books, 1977.

Evans, A.W. and Daniel, R.C. "Model for Manpower Productivity Analysis and Prediction with an Application to the Electrical Engineering Sector of the U.K." Conf. on Manpower Plan. Models, Proc., 1974.

Edwards, H.K. and Shawver, J.L. "New Productivity Horizons in Operations Planning and Facilities Design". AIIE Syst.Eng. Conf. Proc., December 1976.

Eilon, S. "How to Analyse Change in Performance". OMEGA, Vol.6, No.4, 1978.

Faraday, J.E. "Concept of Productivity Science". AIIE 22nd Inst.Conf. and Conv., May 1971.

Farr, J.L. "Incentive Schedules, Productivity and Satisfaction in Work Groups". Org.Behav. and Human Performance, No.17, 1976.

Farnsworth, R.A. "Productivity and the Law". Lexington Books, 1975.

Francis, R.L. and White, J.A. "Facility Layout and Location". Prentice Hall, 1974.

Gold, B. "Technology, Productivity and Economics". OMEGA, Vol.1, No.1, 1974.

Gold, B. "Economic Effects of Technological Innovations". Management Science, Vol.11, No.1, 1964.

Gold, B. and Boylan, M.G. "Capital Budgeting, Industrial Capacity and Imports". Quarterly Journal of Economics and Business, Winter 1975.

Gold, B., Pierce, W.G. and Rosegger, G. "Diffusion of Major Technological Innovations in U.S. Iron and Steel Manufacturing". J. of Industrial Economics, July 1970.

Georgopoulos, B.S., Mahoney, G.M. and Jones, N.W. "A Path Goal Approach to Productivity". J. of Applied Psychology, Vol.41, 1957.

Graham, B.S. and Parvin, S.T. "Total Participation for Productivity". American Management Associations, New York, 1979.

Goux, C. "Productivity and Investment". R.Econ.Pol., September/October 1969.

Grayson, C.J. "Our Lagging Productivity: Too High a Price to Pay". Finance Magazine, July/August 1978.

Gordon, D. "Quality Related Productivity Index". Manuf. Eng., Vol.79, No.5, November 1977.

Gibson, D. "Work Sampling Monitors Job-Stop Productivity". Ind.Eng., Vol.2, No.6, June 1970.

Gunnderson, E.L. "Managers Role in Productivity". ASTME Eng.Conf., 1969.

Glaser, E.M. "Productivity Gains Through Worklife Improvements". Harcourt Brace Jovanovich, New York, 1976.

Gryna, F.M. "Role of Quality Control in Productivity Improvement". AIIE Ann.Conf., 1977.

Gargiulo, G. "Productivity Analysis: Prerequisite to Meaningful Financial Planning". Management Advisor, January/February 1974.

Gill, J. "Payment Systems Productivity and Choice". Management Decision, Autumn 1968.

Gale, J.W. "Freeman's Staff Productivity Scheme". Industrial Participation (U.K.) Summer 1979.

Gray, S.J. and Maunders, K.T. "Value Added Disclosures". Certified Accountant, August 1979.

Gellerman, S.W. "Motivation and Productivity". American Management Associations, New York, 1963.

Griliches, Z. "Issues in Assessing the Contribution of Research and Development to Productivity Growth". Bell Journal of Economics, Vol.10, No.1, 1979.

Griliches, Z. and Jorgenson, D.W. "Sources of Measured Productivity Change: Capital Input". American Economic Review, Vol.56, No.2, May 1966.

Hulten, C.R. "On the Importance of Productivity Change". American Economic Review, Vol.69, No.1, March ~~1979.~~

Haynes, F.L. "Productivity: The Changing Challenge". Ind.Eng., Vol.8, No.3, March 1976.

Heyworth, G. "Productivity". Advanced Management, Vol.16, No.3, 1951.

Hollingum, J. "Incentive Plan Reflects Factory Productivity". The Machinist, April 1955.

Hollingum, J. "Back Up the Workers and Productivity Rises". The Engineer, September 1978.

Hess, J.L. "Productivity-People Participation". A.I.I.E. Ann.Conf., 1977.

Heese, L.A. "Wage Incentives Eliminate "Zombie Time"". Ind.Eng., Vol.9, Nat., October 1977.

Hussian, M., Rathmill, K. and Leonard, R. "Equations Relating Production Control Effectiveness to Total Performance". Int.J.Prod.Res., Vol.16, No.3, 1978.

Hoffmann, R. "Increase Productivity by Analysis". Productivity Measurement Review, February 1956.

Husband, T.M. and Ghobadian, A. "Total Productivity and its Link with Pay". Management Decision, Vol.18, No.6, 1980.

Husband, T.M. and Ghobadian, A. "Measuring Total Productivity in a Batch Production Factory: A Case Study". Int.J.Prod.Res., Vol.19, No.4, 1981.

Harrison, W.E. "Units of Measurement: Key Factor of Production". The Cost Accountant, October 1955.

Judson, A.S. "New Strategies to Improve Productivity". Technol.Rev., Vol.78, No.8, July/August 1976.

Jorgenson, D.W. and Griliches, Z. "The Explanation of Productivity Change". Review of Economic Studies, Vol.34, No.99, 1967.

King, A.S. "Expectation Effects in Organizational Change". Administrative Science Quarterly, Vol.19, No.2, June 1974.

Katugampala, B. "Measuring Management Performance". Management Accounting, April 1979.

Kruger, J.C.L. "Productivity and Factory Layout". Certif. Eng., Vol.49, No.12, December 1976.

Kimberley, J.R. and Nielsen, W.R. "Organization Development and Change in Organizational Performance". Administrative Science Quarterly, Vol.20, No.2, June 1975.

Kendrick, J.W. and Vaccara, B.N. "New Developments in Productivity Measurements". University of Chicago Press, 1980.

Knayer, M. "Group Technology: A New Approach to Manufacturing". Industrial Engineering, September 1970.

Katzell, R.A., Bienstock, P. and Faerstein, P.H. "A Guide to Worker Productivity Experiments in the United States, 1971-1975". New York University Press, 1977.

Kahn, R.L. "The Prediction of Productivity". Social Issues, 1956.

Kearney, W.J. "Pay for Performance? Not Always". MSU Basic Topics, Spring 1979.

Leicester, C. "Changes in Labour Productivity in the British Economy". Management Decision, Vol.17, No.3, 1979.

Lawler, E.E. "New Approaches to Pay: Innovations that Work". Personnel, Vol.53, No.5, September/October 1976.

Lipson, H.A. "Corporate Performance Measurement by Large U.S. Industrial Corporations". Southern Marketing Assoc. Proc., 1974.

London, M. and Oldham, G.R. "A Comparison of Group and Individual Incentive Plans". Academy of Management Journal, Vol.20, No.1, March 1977.

Liäo, S. "Three Step Analysis Measures Productivity". Manag.Acc., Vol.57, No.2, August 1975.

Leontief, W.W. "Input Output Economics". Oxford University Press, 1966.

McConnell, C.R. "Why is U.S. Productivity Slowing Down". Harvard Business Review, March-April 1979.

Mansfield, E. "Technological Change". W.W. Norton, New York, 1971.

Mansfield, E. "The Production Application of New Industrial Technology". W.W. Norton, New York, 1977.

McRoberts, K.L. and Meek, H.D. "Improving Productivity Through Scheduling". Proc.AIIE, Ann.Conf., Spring 1977.

McRoberts, K.L. "Myths of Productivity". ASME Paper, September 1976.

Moski, B.A. "Productivity and the Quality of Life". SAM Advanced Manag.J., July 1973.

Malkiel, B.G. "Productivity - The Problem Behind the Headlines". Harvard Bus.R., No.57, May 1979.

Murakamic, H. "Labour Management to Productivity Improvement - One Approach at Tomoku Co.Ltd.". Corrugated Containers Conf., November 1974.

Mahr, J.A. "Productivity can be Measured in Terms of Marketing Goals". Ind.Mkt., No.59, July 1974.

Mark, J.A. and Ardolini, C.W. "Developments in Measuring Productivity in the Federal Sector". ASA Proc. of the Busi. and Econ., 1974.

Moore, J.G. "Added Value as an Index of Industrial Effectiveness". Work Study and Management Services, January 1973.

Mundel, M.E. "Motion and Time Study". Prentice Hall, 1978.

Mundel, M.E. "Measures of Productivity". Ind.Eng., Vol.8, Nor. , May 1976.

Morley, M.F. "Added Value: The Fashionable Choice". The Accountant's Magazine, January 1979.

Martin, R.K. "Do Not Overlook Clerical Productivity". Ind.Eng., Vol.9, No.2, February 1977.

Melman, S. "Decision Making and Productivity". John Wiley & Sons, 1958.

Melman, S. "Dynamic Factors in Industrial Productivity". John Wiley & Sons, 1956.

Miller, W.R. "Engineering Productivity can be Measured". Machine Design, October 1971.

National Center for Productivity and Quality of Working Life. "Productivity in Changing World of the 1980's". U.S.Government Printing Office, Washington, D.C., 1978.

Natioanl Center for Productivity and Quality of Working Life. "Improving Productivity: A Description of Selected Company Programs". Government Printing Office, Washington, D.C., 1975.

Nadler, G. "The Effect of Design Strategy on Productivity". Int.J.Prod.Res., Vol.9, No.1, 1971.

Nelson, J.B. "Productivity with Performance Measure and a Group Incentive Plan: A Case History". Proc.AIIE Ann.Conf., Spring 1977.

Nadiri, M.I. "Some Approaches to the Theory and Measurement of Total Factor Productivity". J. of Economic Literature, Vol.18, No.4, December 1970.

Nadiri, M.I. and Schankerman, M.A. "The Structure of Production, Technological Change and the Rate of Growth of Total Factor Productivity in the Bell System". National Bureau of Economic Research, Working Paper No.358, June 1979.

Newell, R. "Labour's View of Automation and Productivity". SME Tech.Paper, Ser.AD, October 1975.

Nelson, R.R. and Winter, S.G. "Growth Theory from an Evolutionary Perspective: The Differential Productivity Puzzle". Am.Econ.R., May 1975.

Productivity - A Special Report. Electronics, Vol.48, No.8, April 1975.

Productivity - The Scope for Improvement. Metalwork Prod., Vol.119, No.11, November 1975.

Pratten, C.F. "Labour Productivity Differentials within International Companies". Cambridge University Press, Occasional Paper No.50, 1976.

Peeples, D.E. "Measure for Productivity". Datamation, May 1978.

Patton, J.A. "Productivity - Where Management has Failed". SME Tech.Paper, Ser.AD, October 1975.

Rees, A. "Improving the Concepts and Techniques of Productivity Measurement". Monthly Labour Review, Vol.102, No.9, September 1979.

Rice, A.K. "Productivity and Social Organisation". Tavistock, London, 1970.

Renshaw, E.F. "Productivity". J.Urban Anal., Vol.4, No.2, 1977.

Robertson, E.J. "Productivity Bargaining and the Engineering Industry". Federation Research Paper 1, EEF, 1968.

Ridgway, F.W. "Abrasive Machining Increases Productivity". SME Tech.Paper, SER.MR, April 1976.

Rosegger, G. "Comparing a New Technology with its Predecessor Steel Making".

Riggs, J.L. "One Strike on Productivity". Industrial Engineering, June-July 1980.

Riggs, J.L. "Wa: Personnal Factor of Japanese Productivity". Industrial Engineering, Vol.11, No.4, April 1979.

Riggs, J.L. "Improved Productivity needs Leadership - Yours". Industrial Engineering, Vol.10, No.11, November 1978.

Riggs, J.L. "Production Systems". John Wiley & Sons, 1972.

Riccio, L.J. "Productivity in the Public Sector. Its Measurement and Improvement". AIIE Syst.Eng.Conf.Proc., December 1976.

Reed, R. "Identifying Productivity Opportunities". Ind.Eng., Vol.8, No.10, October 1976.

Roberts, R.M. "Using the "Leverage" Concept to Improve Productivity". SAM Adv.Manage.J., Vol40, No.4, Autumn 1975.

Rice, R.S. "Survey of Work Measurement and Wage Incentives". Ind.Eng., Vol.9, No.7, July 1977.

Ross, T.L. and Jones, G.M. "An Approach to Increased Productivity: The Scanlon Plan". Financial Executive, February 1972.

Ruch, W.A. "Operative Worker Productivity: Demographic and Attitudinal Correlates". Proc. Acad.Manag., August 1975.

Ruch, W.A. and Hershauer, J.C. "Increasing Productivity: Two Different Approaches". Personnel Administrator, September 1975.

Ruehl, W. "Productivity Increase by Integrated Planning of Schedules". Werkstatt Betr., Vol.103, No.1, January 1970.

Swannack, A.R. and Samuel, P.J. "The Added Value of Man and Materials". Personnel Management, February 1974.

Sanders, A.J. "Production Ratios. Measuring the Basic Factors of Productivity". Prod.Eng., Vol.50, No.3, March 1971.

Smith, E. "Productivity Analysis and Measurement". Productivity Measurement Review, November 1957.

Smith, E.A. and Gude, G.F. "Revelation of the Scanlon Plan as Motivational Techniques". Personnel J., December 1971.

Smith, E.L. "Productivity in Research". Chem.Eng., No.227, April 1969.

Sherman, G. "Scanlon Plan Reaps Productivity Bonus for Labour and for Management". Management Review, May 1977.

Salvendy, G. "Effects of Equitable and Inequitable Financial Compensation on Operator's Productivity, Satisfaction and Motivation". Int.J.Prod.Res., Vol.14, No.2, March 1976.

Stolliday, I. and Attwood, M. "Financial Inducements and Productivity Bargaining". Industrial and Commercial Training, June 1978.

Smith, I.G. and Hesketh, P. "Wages and Work: How Pay Systems Can Succeed". Management Today, November 1977.

Schmookler, J. "The Changing Efficiency of the American Economy". Review of Economics and Statistics, 1952.

Stone, J.K. "Measuring Productivity". Iron Steelmaker, Vol.3, No.12, December 1976.

Stein, J.M. "Using Group Process Techniques to Develop Productivity Measures". Pub.Pers.Management, March 1979.

Sato, K. "Theoretical Issues in Production Accounting". In Asian Income and Wealth, Vol.2, Edited by K. Ohkawa, University of Tokyo Press, 1981.

Sato, K. "The Ideal Log Change Index Number". Review of Economics and Statistics, Vol.58, May 1976.

Swann, K. and Waddington, M.E. "Productivity Measurement in Machine Tool Industry". Prod.Eng., Vol.53, No.3-4, March-April 1974.

Stahl, M.J. and Steger, J.A. "Improving R & D Productivity, Measuring Innovation and Productivity. A Peer Rating Approach". Res.Man., Vol.20, No.1, January 1977.

Starr, M.K. "Productivity is the U.S.A.'s Problem". California Management Review, Vol.16, No.2, 1973.

Schmidt, P. and Knox Lovell, C.A. "Estimating Technical and Allocative in Efficiency Relative to Stochastic Production and Cost Frontiers". J. of Econometrics, Vol.19, No.3, February 1979.

Sutermeister, R.A. "People and Productivity". McGraw-Hill, 1976.

Scott, R.F. and Simmons, D.B. "Predicting Programming Group Productivity - A Communications Model". Nat.Conf. on Software Eng.Proc., September 1975.

Shakman, R.J. and Roberts, R.C. "An Evaluation of Management Effectiveness". Univ. of Michigan Basic Rev., Vol.29, No.1, January 1977.

Skeddle, R.W. "Expected and Emerging Actual Results of a Major Technological Innovation-Float Class". OMEGA, Vol.8, No.5, 1980.

Salmons, S. "Total Productivity Bonus". International Management, September 1978.

Sathe,V. "Measures of Organizational Structure: A Conceptual Distinction between Two Major Approaches". Proc.Acad.Manag., August 1975.

Sherrard, W.R. "Labour Productivity for the Firm". Quarterly Review of Economics and Business, Vol.7, No.1, 1967.

Thackray, J. "The Productivity Conundrum". Management Today, June 1977.

Tatom, J.A. "The Productivity Problem". Review of Federal Reserve Bank of St.Louis, September 1979.

Timothy, L.R. and Gardner, M.J. "An Approach to Increased Productivity: Scanlon Plan". Financial Executive, Feb.1972.

Terleckyi, N. "Effects of R & D on the Productivity Growth of Industries: An Exploratory Study". National Planning Association, Report No.140, December 1974.

Tse, P.S. "Evaluating Performance in Multinationals". Management Accounting, June 1979.

Tubbs, S.L. and Widgery, R.N. "Management Communication: Tool for Improving Productivity". Proc.AIIE Ann.Conf., Spring 1977.

United Nations. "Input-Output Tables and Analysis". Department of Economic and Social Affairs Statistical Office, Studies in Methods, Series F, No.14.

Vinod, H.D. "Non-homogeneous Production Functions and Applications to Telecommunications". Bell J.Econ.Man.Sci., Vol.3, No.2, Autumn 1972.

Wilson, B. "The Added Value Approach". Employee Relation, Vol.1, No.1, 1979.

Weinberg, E. "Federal Role in Improving Productivity". Prof.Eng.(Washington D.C.), Vol.47, No.4, April 1977.

Woolf, F. and Allen, J. "Adding Value to U.K. Industry". Management Today, May 1978.

Wykeman, G. "Old and New Ways of Assessing Productivity". J. Iron and Steel Inst., May 1962.

Wolfram, J. "Estimating Work Content and Measuring Productivity". Metal Construction, March 1979.

Wooton, L.M., Tarter, J.L. and Hansen, R.W. "Toward a Productivity Audit". Proc. Academy of Manag., August 1975.

Waterson, M. "Watch for the Pitfalls when you Measure Productivity". The Financial Times, April 17, 1973.

Walbank, M. "How to Research Production". Management Today, September 1978.

Whittaker, M.F. "Ve FAC for Improved Productivity". Proc.AIIE Ann.Conf., Spring 1977.

Willey, P.C.T. "Group Technology. Factors Influencing Success". Charter Mech.Eng.(U.K.), September 1979.

Withers, R.M. "Planning for Increased Productivity". Long Range Planning, Vol.11, August 1978.

York, J. and Brand, H. "Productivity and Technology in the Electric Motor Industry". M.Labour.R., August 1978.

You, J.K. "Capital Utilisation, Productivity and Output Gap". R.Econ. and Stat., No.61, February 1979.