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Keskusteluaiheita
Discussion papers

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FACTOR PRODUCTIVITY AND TECHNICAL CHANGE IN THE FINNISH IRON FOUNDRY INDUSTRY, 1978-1985

No 270 26.09.1988

ISSN-0781-6847

KARKO, JUSSI, FACTOR PRODUCTIVITY AND TECHNICAL CHANGE IN THE FINNISH
IRON FOUNDRY INDUSTRY, 1978-1985. Helsinki : ETLA, Elinkeinoelämän
Tutkimuslaitos, The Research Institute of the Finnish Economy, 1988.
77 p. (Keskusteluaiheita, Discussion Papers, ISSN 0781-6847 ; 270).

The study deals with measurement of the rate of factor productivity and technical progress in the Finnish iron foundry industry during 1978-85. The measurements are carried out first at the micro level in individual foundries by using new methods introduced in the paper. The approach is based on descriptive index theory, where no optimising behaviour or equilibrium conditions are needed. A great dispersion in the rates of productivity is found. At the second stage an aggregation of individual foundries to the industry level is performed. The approach is based on the Forsund-Hjalmarsson short-run production function. The rate of technical progress at the industry level is found to be quite slow, though there are some differences in the rates between the most efficient and the rest of the capacity.

KEY WORDS: Total factor productivity, technical change, structural change, descriptive index theory, foundry industry

Preface

The purpose of this paper is to study technical progress, structural change and productivity growth in the Finnish iron foundry industry with the tools of economic theory. Here micro level progress is analysed initially by using descriptive methods outlined for the first time in this paper instead of the neoclassical mainstreams widely applied in the literature. At industry level we utilise also the Johansenian framework of the short run production function operationalised by Forsund and Hjalmarsson (1984) for empirical industry analysis. These methods are also new and virtually not used outside a small circle of economists in Nordic Countries.

The methods applied here are nonparametric and constructive by nature as opposed to the conventional parametric approaches based econometrics and the theory of representative firm. It is advocated that the approach taken here allows a richer and more realistic approach to the measurement of productivity at industry level than do the traditional methods.

It is hoped that the paper opens up new perspectives to the methodology in the Finnish TES program and to the empirical micro as well as to industry level data analysis.

The author wishes to express his gratitude to Dr. T. Summa, formelly at the Federation of Finnish Metal and Engineering industries for the interesting analytical data, and especially to professors F.R. Forsund Oslo and L. Hjalmarsson from Gothenburg for their empirical calculations of the short run functions. Several parts of this study have been presented in TES seminars held by SITRA. The author is appreciative of the comments received from the participants.

Mrs. Tuula Ratapalo has skillfully performed the word processing and Mrs. Arja Virtanen has finished the figures.

Helsinki, August 1988

Jussi Karko

Contents

1. INTRODUCTION

1.1. General, the purpose of the paper

Attention in economic research has been gradually shifting from total economic growth at macro level towards the structural problems and development patterns of individual industries. This may partly be due to the slowing down in productivity growth and employment problems in stagnating industries, which has led to large government subsidies in some countries to keep employment at an acceptable level under circumstances of sharpened competition, weak demand and rapid technological progress. A discretionary and selective industrial and employment policy as well as management of firms, economic organisations and financial institutions require more exact knowledge about the structure, structural change, efficiency and related concepts of technological progress. There are however a multitude of viewpoints and theories regarding structure, efficiency, productivity and related concepts, along with numerous tools for analysing them.

In this paper we attempt to analyse critically the various approaches to the measurement of technological change and related topics as well as to develop and introduce new means with an emphasis to apply the methods to the analysis of structural change and technological progress of iron foundry industry, an industry typical of mature technologies and stagnating output markets. The study will be carried out in two main steps, the first consisting of interferences at micro level and the second interferences made at industry level.

The structure of the study is the following.

First we introduce briefly the industry under study. Then it is described from various standpoints using the representations of Salter and Heckscher diagrams and their analytical underpinnings are discussed.

In chapter 3 the concepts of economic and descriptive index numbers are introduced the theories are discussed and simple methods are outlined to measure technological change and total factor productivity by means of descriptive index theory instead of the conventional approach based on economic index numbers with restrictive optimising asumptions. When working with descriptive framework we do not need such asumptions, and moreover the problem of aggregation is easily solved. At the end of the chapter some empirical calculations at micro level are derived.

In chapter 4 we introduce the concepts of the short-run production function and related cost functions at industry level, discuss rather lengthily but fundamentally the methods applied in constructing them and finally apply the approach to make an industry-wide analysis focusing on the structure of and technological change in the foundry industry.

The final versions of this paper further discuss casting technologies and endeavour to draw conclusions on the basis of their characteristics. At present stage of the study the view is highly technical, and new methodological issues are underscored.

1.2. Finnish iron foundry industry from 1978-1985, data and general developments

Although the foundry industry constitutes only a fraction of the total metal and engineering industry, it is important and worth studying as one of the basis branches of production in the sector.

During the last ten years the casting industry has faced major difficulties because of increasing input prices and slack demand. For this reason considerable substitution of casts has occurred by other components in the machine industry, while the building industry has expanded the application of plastics in particular. This has led the industry to the point of weak economic performance, substantial overcapacity and into a restructuring process. The industry has responded to the challenge mainly by changing its product mix but not by greatly replacing renewing production technologies. Thus the technological level may be considered only satisfactory on average. Some new and modern capacity has been added. At the same time long-term subcontracting arrangements for both the domestic and export markets have been made to wider markets.

In principle the metal and especially the engineering industries produce a very heterogeneous range of products; the output of the basic metal industries is by branch more homogeneous (various metals). The output of the foundry industry is problematic in this respect. In this study, however, an output measurement of pure tonnes is used, restricted only to the iron foundry industry. In general, the foundry industry may be classified in three categories according to the material used in casting.

These groups are
- iron foundries
- steel foundries
- non-ferrous metal foundries

In 1985 the turnover of the entire iron foundry industry amounted to 742 MFIM. The turnover of the iron foundry industry was 499.8 MFIM and the steel foundry industry 140 MFIM. The iron foundry industry was thus the largest branch of the whole foundry industry.

The data on iron foundry industry used in this study is based on 12 iron foundry plants, covering about 90 % of the branch in terms of turnover. The data consist of a time series from the year 1978 and are mostly obtained from a questionnaire first put out by SITRA in the middle of the 1970's and later updated and analysed by the Federation of the Finnish Metal and Engineering Industries annually along the lines of the traditional industry study framework with emphasis on the economic performance of the industry. The data on individual foundries is confidential, so that this study presents only certain aspects of it.

The data has been checked and supplemented from other sources and by conducting corporate interviews. It covers all large-scale plants in the industry and the major independent corporations not integrated with any engineering industry company. The set of plants remained the same during the study period. Only small plants not answering the questionnaire every year were omitted.

The data are mostly economic in nature, providing information on economic performance but also on energy and labour force, capacity utilisation, investment, value of other inputs, output prices and, according to a specific engineering classification, technical data on the products of individual plants. The opportunity existed to investigate the influence of product mix, in addition to production technologies, on economic performance at plant level, but this lay beyond the scope of this study.

Table 1.2.1. Finnish iron foundries (1985)

Unit No.	Output ton.	Personnel	Turnover mil.FIM
1	6 866	256	50.7
2	7 649	243	69.9
3	9 332	323	96.2
4	1 915	70	14.0
5	6 706	42	17.1
6	1 391	104	16.4
7	2 926	131	26.4
8	3 859	123	32.9
9	3 871	121	27.3
10	4 550	130	32.6
11	17 639	303	90.1
12	86	10	9.5
Total	66 704	1846	428.6

Total energy consumption is measured by plant in gigajoules (GJ), consisting of all fuels and elecricity used by the whole plant. Labour demand is measured in hours worked by white collar employees. The average yearly prices of these inputs is also listed by plant.

Investment data are also itemised according to a classification of investment in machinery, buildings and other investment. Occupational safety investment is also separated from these figures. The rate of investment has been very low on average, and thus capital embodied development is slow. The data of capital stock are based on fire insurance statistics, but this information turns out to be weak as is later explained, and not used here.

In order to attain some insight into the size distribution of the plants, plants are listed in Table 1.2.1 in random order. A more detailed view of the development of individual foundries with respect to relevant study variables is given in the following sections.

Figure 1.2.1 Turnover, production and average sales price of iron castings of the Finnish iron foundry industry 1978-1985. (1978=100)

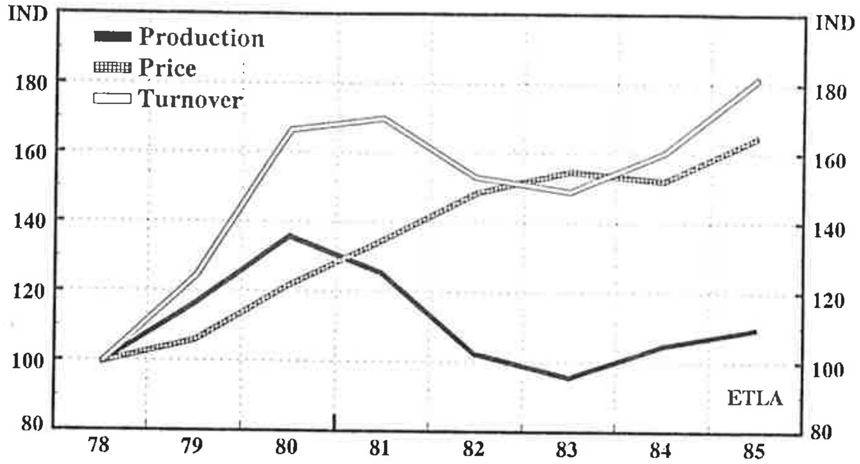


Figure 1.2.2 Structure of investment in the Finnish iron foundry industry in selected years.

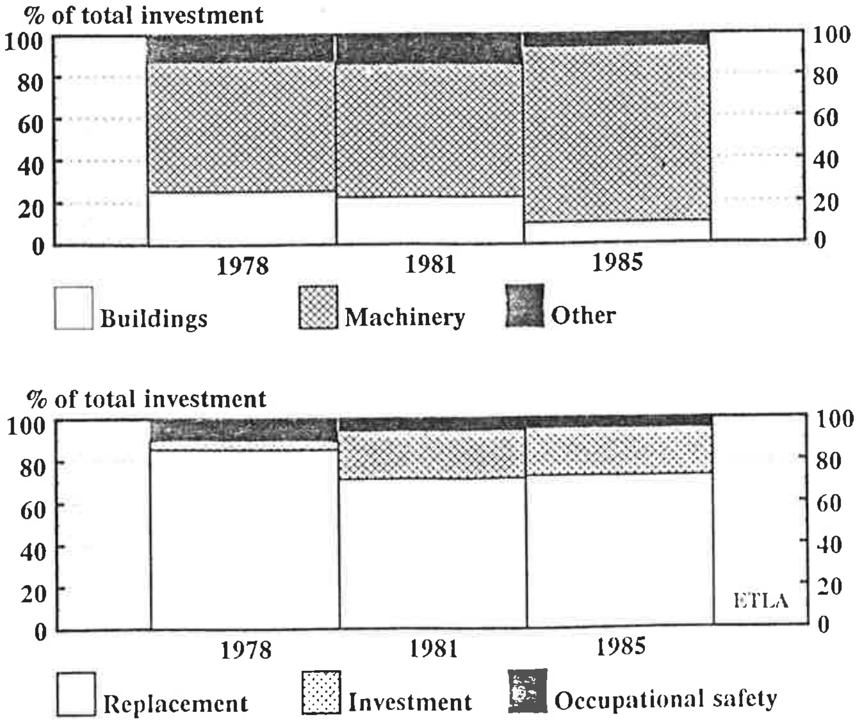


Figure 1.2.1 summarises the development of total production in the iron foundry industry. During the observation period the production of iron castings in tonnes rose only about 1.1 fold. In the same time, the production of the engineering industry grew about 1.7 fold and that of all basic metal industries over 2 fold. The production of iron castings has thus grown considerably slower than production in other metal industries. During the three first years of the observation period, however, the rate of growth in production closely followed that of other metal industries. At the beginning of the 1980′s a strong structural change appeared in market demand that severely altered the casting intensity of metal and engineering industry production.

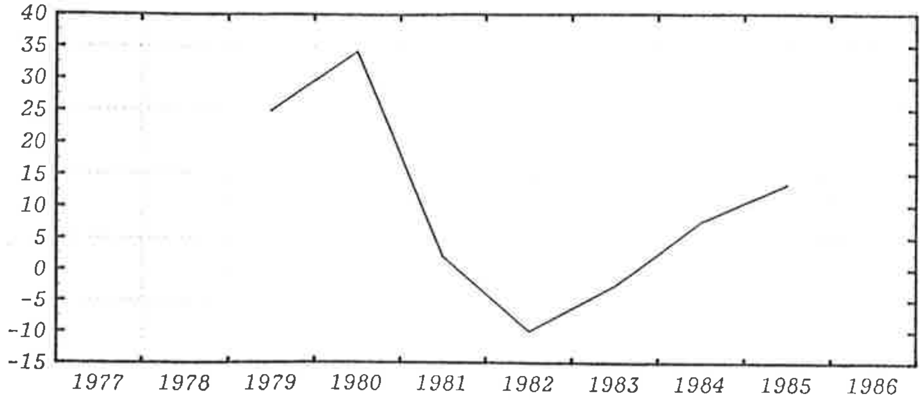
The development of the sales prices of castings has followed more narrowly the general trends. The average sales price of iron castings increased about 1.65 fold in the observation period. This price change is about the same as the rise in producers' price in the metal and engineering industries, measured by the index published by the Central Statistical Office of Finland.

Figure 1.2.3. represents the development of employment, relative changes of turnover and rate of investment. The general trend in these series follows the development of production.

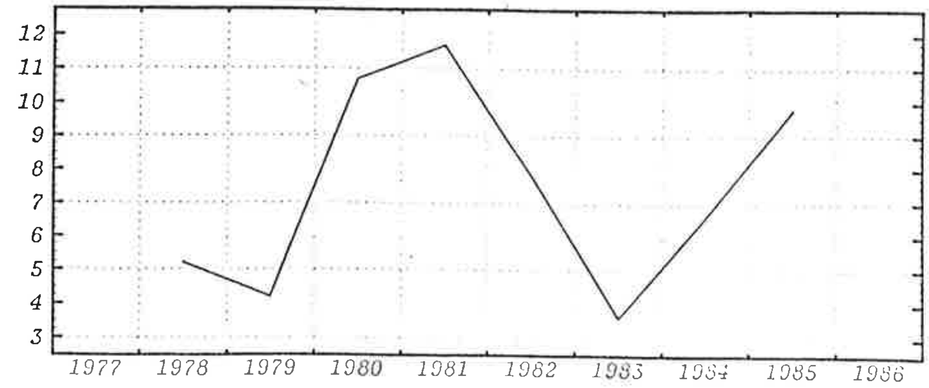
Figure 1.2.4 summarises the average cost structure of the iron foundry industry. Although production has increased only gradually, the cost structure turns out to be stable, reflecting that the technologies applied are highly capital embodied, leaving little room for adapting in the short run to changing market conditions.

Figure 1.2.3 Changes in turnover, rate of investment (percent of turnover) and personel in the Finnish iron foundry industry 1978–1985.

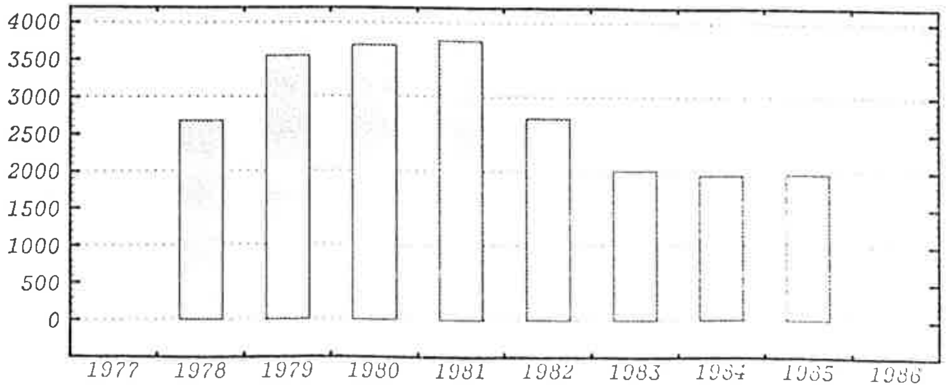
TURNOVER, YEARLY %-CHANGES



RATE OF INVESTMENT; % TURNOVER

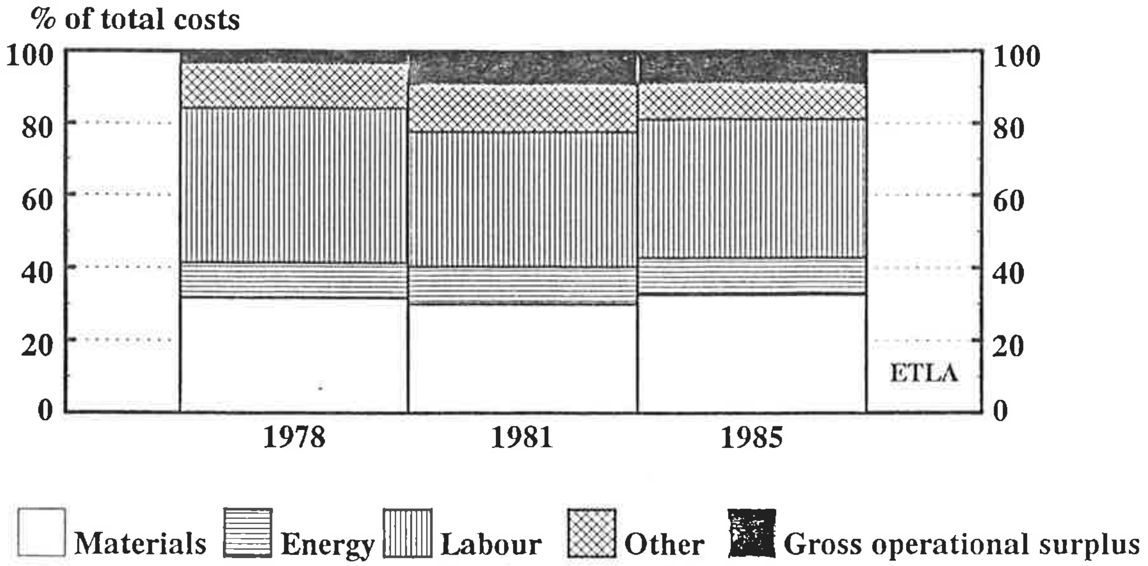


PERSONEL 1978-85



Economic performance as measured by gross operating surplus has been poor in every year of the observation period; plants have in reality made losses when relevant depriciation rate is taken into account. On average losses have amounted about 5 to 10 % of turnover, which also partially

Figure 1.2.4 Cost structure of production in the Finnish iron foundry industry in selected years.



explains the low investment rate, in spite of the fact that a large part of capacity is found in bigger metal and engineering companies with stronger financial potential. Notable differences are evident between individual foundries, but in general these are the exception.

2. PARTIAL PRODUCTIVITY AND VARIABLE UNIT COST DISTRIBUTIONS OF THE INDUSTRY

2.1. Salter and Heckscher diagrams

A useful descriptive presentation of the structure of an industry may be obtained by so-called Salter diagrams. These give the distribution of individual input coefficients of the micro units within to the industry considered. In histograms of this kind, the plants of an industry producing a homogeneous product are generally represented in the order of increasing values of the input coefficients on the ordinate axis. If the units face the same input prices, the diagram exhibits the technical efficiency distribution of the units from the partial viewpoint of the input coefficient considered. Each plant has its own rectangle in the diagram, displaying its share of the total production (capacity) of the industry in the abscissa direction.

In spite of their clarity the Salter diagrams of the distributions of certain input coefficient may not provide an unified picture of the structure of an industry, because in the diagrams of the different input coefficients the ranking of individual plants may differ. The gravest limitation of the Salter illustration of structure is the partial character of the analysis. The input coefficients of the individual inputs are separately analysed, and not the total impact of all inputs together. The latter, or total factor productivity, would be of vital importance, but the level of total factor productivity is especially difficult to obtain.

A histogram with the unit costs of plant production on the ordinate axis in place of input coefficients serves as a kind of total analysis. It is called a Heckscher diagram and is constructed along the same principles as Salter diagrams. It should be noted that the Salter and Heckscher diagrams are employed here as descriptive tools to analyse structure, and they are also closely related to the analytical concept of the short-run production function of an industry presented later. If a cost-minimising character is assumed for a part of individual producers, a unit cost ranking yields the same ranking as total factor productivity ranking, assuming that producers face the same prices. Meaningful also is that in principle the information given by unit costs is in a different scale than productivity measurements. These two measurements, however, are consistent.

In spite of its simplicity, the Salter and Heckscher diagrams provide a basis for a variety of empirical analyses. The management of each plant is interested in the plant's "ranking" in the distribution. An industrial policy maker may find important information at both ends of the distribution. The devitations expressed by the distribution often reveal potential pressures towards change in the industry. The information on the abscissa axis often remains unchanged in certain cross-section descriptions, but the shape of the distribution in the ordinate direction may vary. The form of a distribution in an industry undergoing rapid production growth may contrast sharply with that of a declining or technologically mature industry. In the latter case the distribution is flat, while in the former strongly distinctly s-shaped.

The technological level in each plant under observation can be illustrated by the difference between the latest best-practice plant to enter the industry and the older ones in the diagrams. The distribution also gives information on the connection between productivity and plant size, i.e. whether small/ large plants are concentrated at the same end of the distribution.

Further aspects, important from the point of view of empirical analysis in each individual case, may be added to the histograms, such as some aspect of technology (e.g. the process applied), the owner of the plant in the case of multiplant firms, the vintage of the plant and geographical area. Statistical parameters may also be used in analysing the distributions.

Among partial productivities, labour and energy are analysed most closely as examples of variable inputs, while capital is an example of a fixed input in the short run. Together with raw materials, these inputs account for the highest expenditures. It is generally supposed that there are distinctly smaller differences in the productivity of raw material input between the plants than in the labour, energy and capital inputs. Even though the cost share of raw materials is high, their input is not a vital productivity factor in the industry under observation, and since there is practically no way to substitute raw materials for other inputs, raw materials are not generally included in the productivity analyses.

Among the many factors, the productivity of labour has traditionally been studied intensively. This interest does not entirely depend on the large share of labour costs in total production costs. An approach often resorted to in competitiveness analysis is that the firms buy their raw materials at an identical (world) market price and can only have a slight influence on the productivity of raw material inputs because, for technical reasons, the input-output relationships are fixed and nearly identical in all the competing plants. The wage and labour skill levels, on the other hand, may vary from plant to plant and, furthermore, management is assumed to be able to exert some influence on the productivity of labour. Continued efforts to increase the productivity of labour have been partly the result of the increase in the relative price of labour compared to that of the other inputs. But when the productivity increase is due to more advanced mechanisation and automation, savings in raw materials are obvious. Important features are also the stable level of product quality and shorter delivery time.

Even empirically significant differences in the productivity of labour have been found ex post between plants which ex ante, in terms of technology chosen, have been practically identical. Differences in competitiveness between various firms and especially plants in the same industry across countries are often explained by reference to major differences in the productivity of labour. The focus on labour is further explained by the availability of detailed and realiable data on labour inputs in comparison to other inputs, but in our case only the working hours of blue collar workers is available.

2.2. Empirical Salter and Heckscher diagrams of the foundry industry

The Salter diagrams of the labour input coefficient is illustrated in Figure 2.2.1 for the years 1978, 1980, 1982 and 1985. The year 1978 was a year of economic recovery, the year 1980 the best year in the research period with respect to market demand and 1982 was a bottom year. The year 1985 was again an improving year in business climate; cf. Fig. 1.2.1, 1.2.3.

The labour productivity differences are relatively high between the plants. This especially held true at the beginning of the period. In 1978 it is apparent that the big foundries were situated in the middle section of the labour input coefficient distribution. Roughly speaking, their coefficients are about equal. However, in 1978 the average value of the labor coefficient was about four times lower than the coefficient for the best plant, and the worst have relative coefficients of about the same magnitude higher than the best ones. Here it should be stressed that a large dispersion would also follow from output measurement in terms of pure metric tonnes.

The typical shape of the distributions has remained about the same in the other years. Especially the year 1980 resembles the year 1978, but the distribution in 1982 is a little bit more irregular. Compared to 1978, however, a remarkable change has taken place in the relative position of the foundries. In 1982 the biggest plant in the industry, which in 1978 was seventh, rose to second place. In every year the same unit has stayed in first place. The shape of the distribution evened again in 1985. In this year the average labour productivity of the sample was about 45 % higher than in 1978. However in the best units, labour productivity was about two times higher than the average, but productivity declined in the weakest units, these being more or less the same units every year.

Energy-use intensity is, to a fairly high degree, linked with the technology determined by the investments made. In the short run the volume of energy used is partly fixed (heating, lighting etc.) and partly dependent on output volume. Energy may thus be considered a semifixed production factor. In a process industry, energy intensity is often also a good indicator of the type and vintage of the technology applied. The foundry industry may be considered similar to the process industry but in the period considered, no clear decline in energy intensity is observed in spite of its increasing relative price with respect to other inputs, especially at the beginning of the period. Here we measure energy consumption in GJ's encompassing oil fuels and electricity.

The ranking of individual foundries with respect to an energy input coefficient in the figure 2.2.2. is quite different in energy diagrams compared with the ranking with respect to the labour coefficient. In the latter diagram the plants are in certain groups, but this tendency is not seen in the energy coefficient distribution. The energy coefficient dia-

Figure 2.2.1. Salter diagrams of labour coefficient in the Finnish iron foundry industry for selected years.

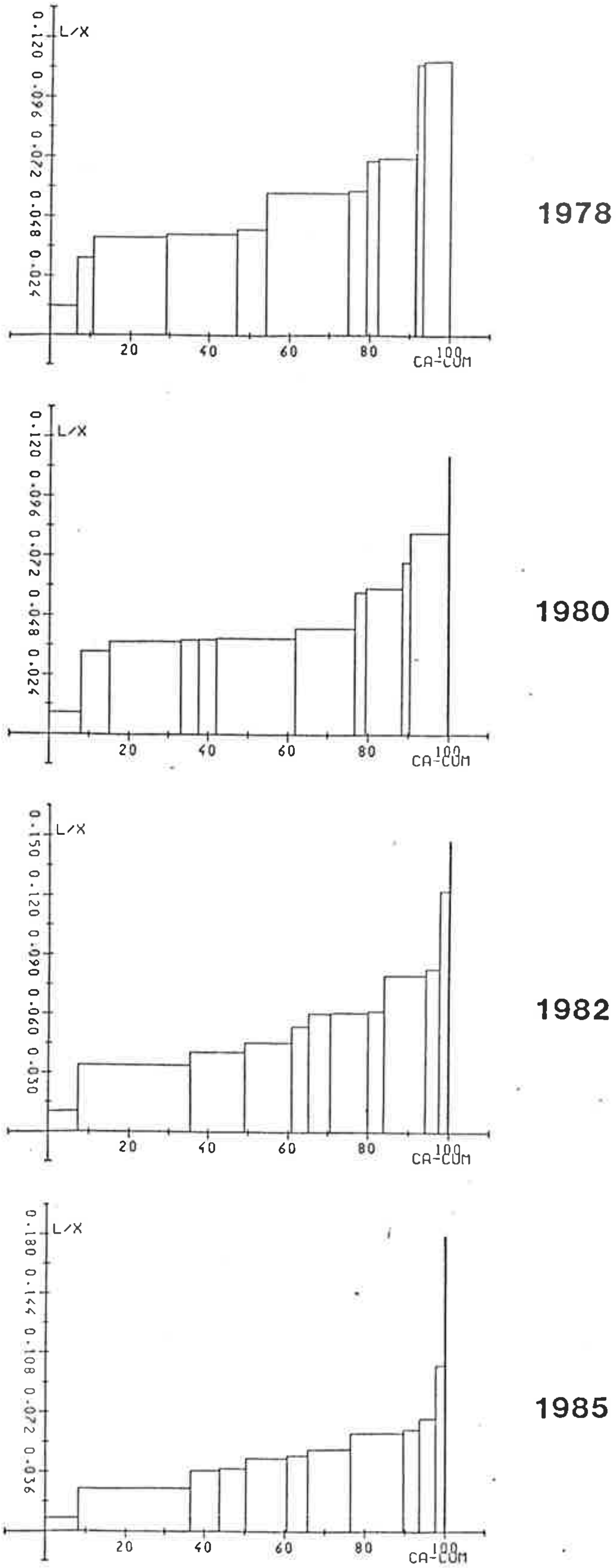
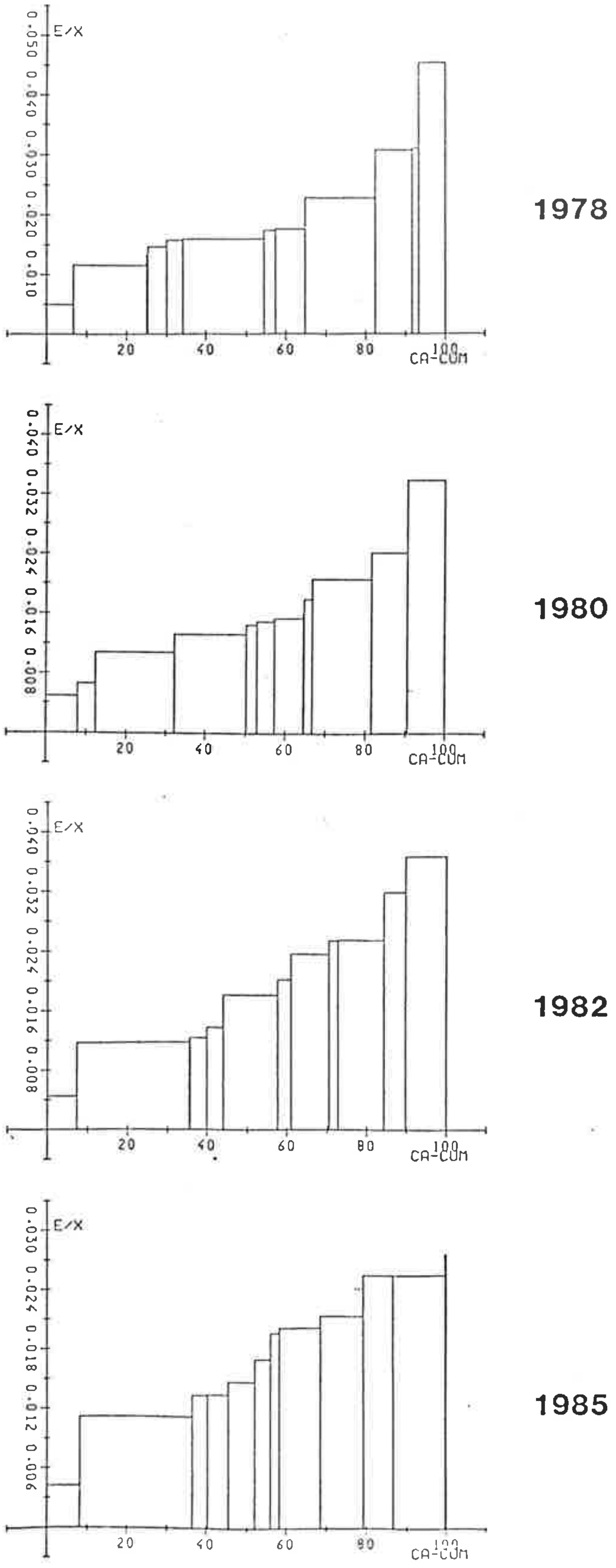


Figure 2.2.2. Salter diagrams of energy coefficients in the Finnish iron foundry industry for selected years.



gram is observed to change its shape gradually from the year 1978 from a half U-shape to on S-shape. This advocates that energy-saving efforts have been made and some units have succeeded relatively better than others.

The dispersion of the energy input coefficient in the panel was in the year 1978 almost as high as that of the labour coefficient. From 1978 to 1985 the average energy input coefficient decreased only slightly so that it was practically at the same level in the last year than at the beginning of the period. During the weak output demand years of 1981-1983 even the average productivity of energy decreased, perhaps mainly for technical reasons due to the low capacity coefficient.

Moreover, during the period the ranking of the individual plants altered rapidly, and no particular dependency can be distinquished between the size of the foundries and the magnitude of the energy coefficient, except in the end of the period when small-size plants are typically situated in the middle sections of the distribution. The foundry with the highest energy coefficient in 1985 had also the highest labour coefficient. This small unit has lost its relative position during the period with respect to both coefficients. The most energy-efficient plant has defended its ranking well and the biggest unit was second in 1985 with about a 30 % lower energy coefficient than in 1978.

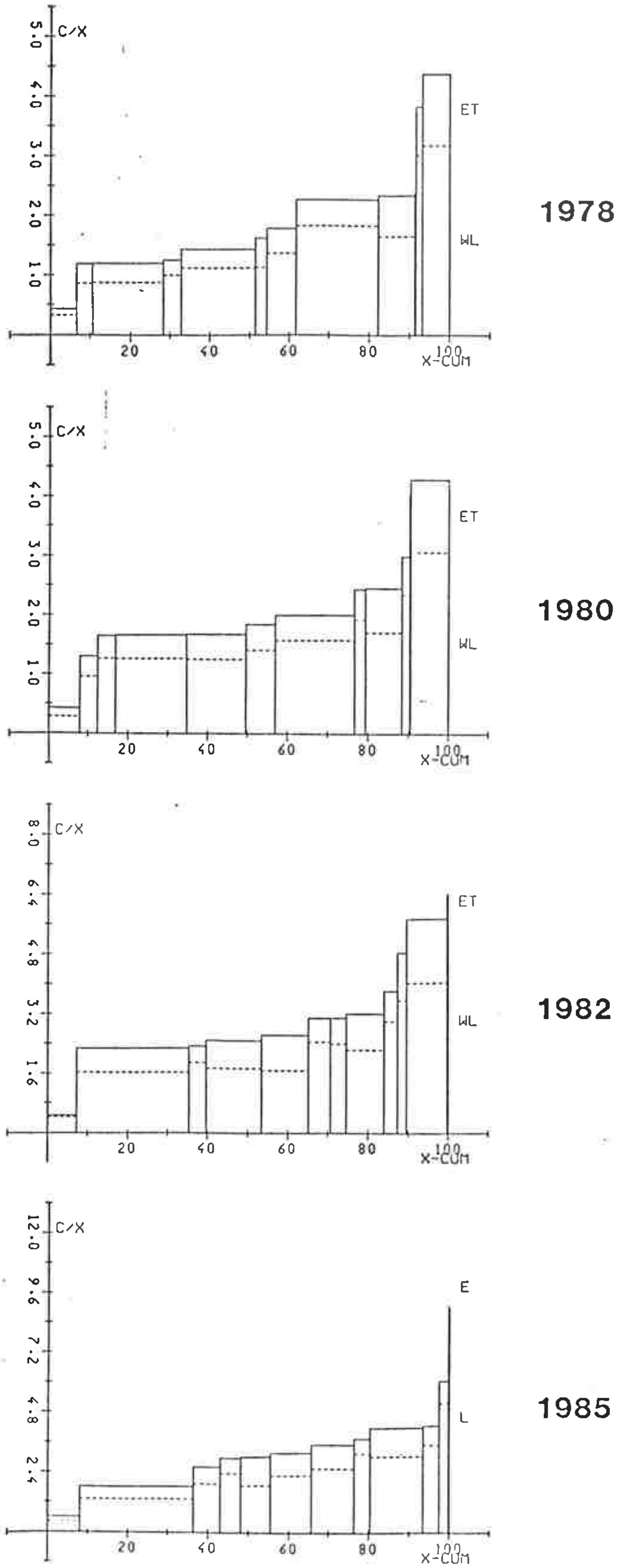
The Heckscher diagrams summarise the partial information from the Salter diagrams presented above. The unit costs presented in the Figure 2.2.3. are calculated at current average labour and energy prices of the sample in every year. The diagrams contain again a very different ranking of individual foundries compared with labour or energy diagram rankings.

This of course is due to the ranking differences between these two last diagrams, for the energy and labour prices in particular years do not greatly differ from foundry to foundry.

From Figure 2.2.3. one may argue in general that the best and the weakest foundries differ significantly the middle section of the distribution. Diagrams for the late 1970s appear different from that of 1985. In this year there is an extensive flat section in the distribution of foundry unit costs, implying that no remarkable differences exist between techniques when measured by unit costs. In the 1978 diagram the distribution contains clear steps but clear groups of foundries are not readily distinquishable in 1985, indicating that technical differences were relatively greater in 1978 than in 1985. The gradual evening of the Heckscher diagrams during the last years of the period are explained by the fact that considerable differences in energy and labour coefficients partly compensate each other and at the same time that the coefficients have somewhat decreased.

In the sample, however, even the large units are as a rule a mixture of more recent vintages and older production techniques (except the two best). It may be supposed that in general the largest units use more up-to-date technology than the small ones to benefit from the effects of scale and increased mechanisation. Process automation in the modern sense is not used even in the biggest plants. In general, however, no clear groups stand out even in 1985 according to plant size, but instead the small foundries are ranked on the right-hand tail of the unit cost diagram.

Figure 2.2.3. Heckscher diagrams of the Finnish iron foundry industry for selected years.



This may also be interpreted in that the production techniques used in the majority of the foundries are maturing, so that the unit variable costs of individual foundries are equalising. Further developments can be most likely obtained with old tools, but on the other hand the new technologies applied may be most advantageous. Because the financial resources of the foundries are inequal and in general weak, it may be assumed that only the most daring companies begin to apply new technologies first and this in turn yields a new configuration for the foundries in the Salter- and Heckscher diagrams, while changing their form back to a more S-shaped configuration.

2.3. Capacity distributions

Another illustrative but simple description of industry dynamics is obtained by using so-called capacity distributions. Capacity distribution is depicted by a diagram in which each production unit is characterised by its input coefficients and capacity. The input coefficients are measured along the axes. The size of each square is proportional to the capacity of the corresponding plant, so that the variation of the input coefficients plant by plant is shown simultaneously. Interesting to note is whether capacity lies in a southwest/northeast direction. By putting the observations of selected years into the same diagram, changes in the structure of the sample between two different points of time can be seen.

Illuminating different development processes at plant or industry (sample) level with capacity distribution diagrams is also possible. For instance (Hicks) neutral technical change or increased exploitation of economies of scale can be expressed as the simultaneous equal proportional reduction of the input coefficients towards the origin. On the other hand, if structural change has been characterised by a transformation of the sample location generally in the northwest/southeast direction, there should be a substitution process going on between this structural change due to the development of relative prices influencing the scrapping of and the choice of technology in new equipment.

Changes in the capacity distribution clearly illustrate the development of intraindustry ranking patterns by plant, while the main characteristics of development patterns relating to interindustry structural changes over time can be observed from the shift of the whole scatter diagram.

From pure descriptive reasoning it may be argued that input coefficients and capacity are "statistics" characterising the techniques applied by individual plants. On the contrary individual plants may be identified by their techniques from the capacity distributions, allowing by definition explicitly non-neutral technical differences between the units. Due to the long history of the plants, e.g. once the investment decisions are carried out, the technology of the plant is fixed to technology choices for an extended time and the plant is a captive of its technology and the related capital stock. Thus differences between plants are more likely to be deterministic than stochastic.

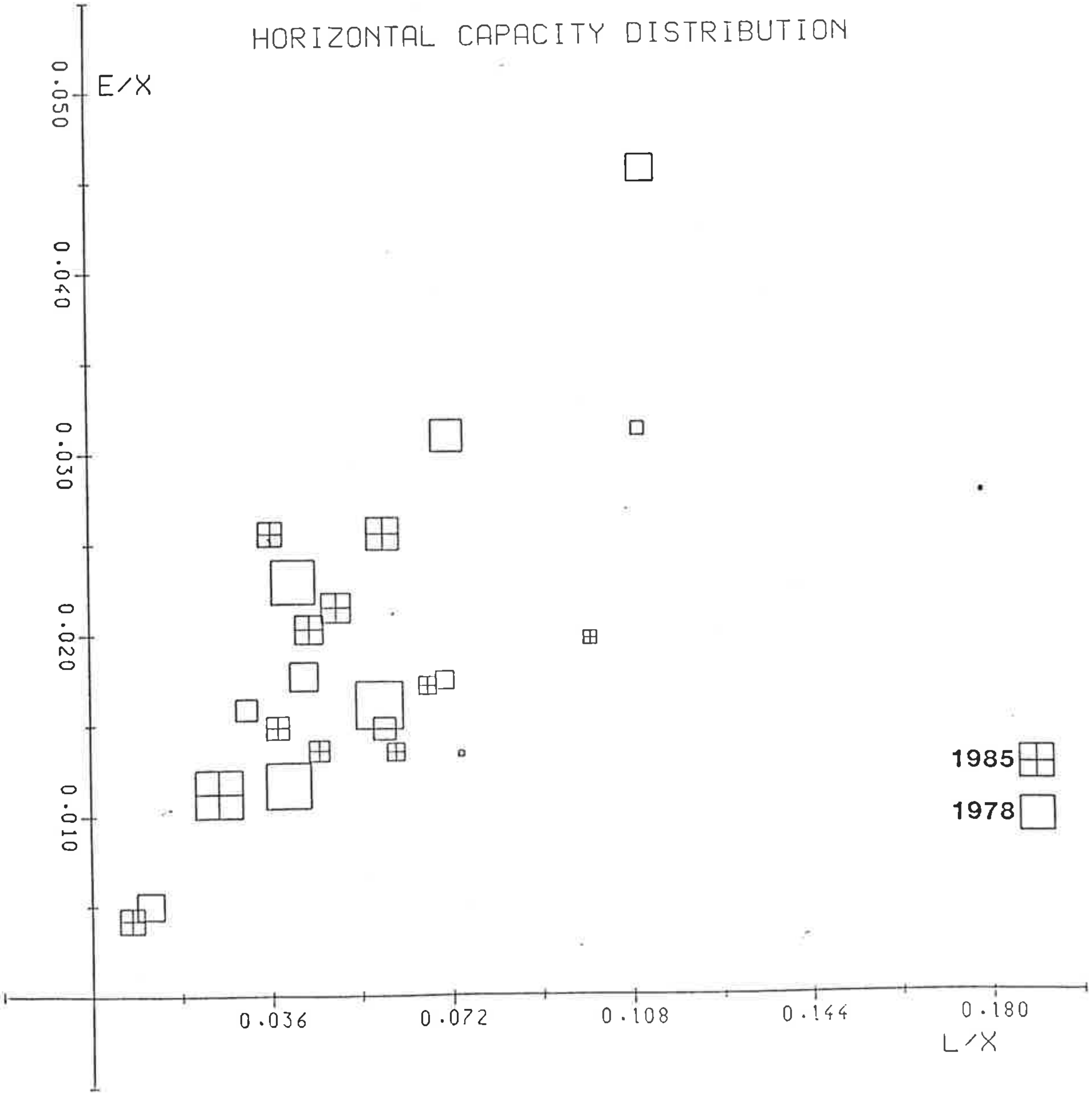
The non-neutral differences between plants are excluded from the dominating theory of growth, the neoclassical one. For further aggregate-level analysis of industry it must be pointed out in this theory that the differences between the micro-units are allowed only to be neutral so that just one "average" technology is spanned by the production function of the representative firm. This function may shift over time, and the devitations of the units from the representative technology are random. The technology and its shifts are estimated by the means supplied by econometrics. In an analysis of this nature, we first face technical obstacles, for there are too few observations and the theory of the representative firm is not held to be empirically relevant. For this reason, the neoclassical approach is avoided, both to micro- and industry-level analysis.

2.4. Empirical capacity distributions

The previous section related that the capacity distribution shows the dispersion of individual units and by observing the distributions over time a good understanding may be attained of the development patterns of individual units and the industry as a whole. Figure 2.4.1. portrays simply the capacity distributions of the Finnish iron foundry industry in the years 1978 and 1985.

It may be argued from the figure that little noteworthy development of the micro units has occurred (at least compared to the picture of the development of Nordic cement industries or Finnish breweries; Cf. Førsund, Hjalmarsson, Eitheim, Karko, Summa (1985) or Summa (1986) (in these studies similar approach is applied). Compared with the distribution for 1978, the 1985 distribution has generally moved more in the southwestern direction, reflecting mainly the gradual increase in labour productivity and to a lesser degree the progress in the energy coefficient. The information yielded by the Salter diagrams and summarised by the Heckscher diagrams is of course again revealed, namely that a change has taken place in the ranking patterns of individual foundries. The smallest foundry has

Figure 2.4.1 Capacity distributions of the Finnish foundry industry in the years 1978 and 1985. The square size of a unit is proportional to its capacity.



lost in its relative ranking and declined with respect to both input coefficients. The data for this foundry is confirmed to ensure that it is not an outlier.

An uneven shift in the plant scatter towards the origin, corresponding in particular to decreases in labour coefficients, reflects in general that there has been a mild so-called labour-saving bias dominating in the development. This development has commonly been discovered in industry studies conducted in the neoclassical spirit and mirroring the fact that labour is becoming a more expensive factor of production than energy.

3. RATE OF TECHNICAL CHANGE AND TOTAL FACTOR PRODUCTIVITY AT MICRO LEVEL

This section focuses on analysing the development of factor productivities of individual foundries. First the method of measuring total factor productivity and technical change at micro level is outlined without any reference to the aggregation of individual plants to, say, industry level. In particular we show that the concept of total factor productivity is also possible to be developed without any reference to the production function or an optimising behaviour. These are essential to the approach based on the theory of economic index numbers, prevailing in the literature on measuring technical change and total factor productivity; cf. e.g. Diewert (1980).

In our approach the techniques of individual plants are described by the set of their individual factor coefficients, or equivalently by the set of their individual partial factor productivities. The higher the partial productivities are, the more efficient is the production process, i.e. fewer inputs are used per unit of output. In other words this means that the higher the productivity, the smaller are the unit costs at certain factor prices.

Loosely speaking, total factor productivity is defined as a weighted average of individual factor productivities. Here we are especially interested in the rate of change in total factor productivity. Because partial productivities are used to define technique, and total factor productivity is defined to be a kind of weighted average of individual partial productivities, a change in total factor productivity is at the same time a change in technique.

3.1. The approach based on economic index numbers

It is well known that there is two mainstreams in the theory of index numbers. The first, widely applied also to productivity measurements and called the economic, exact or functional theory of index numbers is based on cost minimisation under the production function restriction and leads to the comparision of the values of cost functions measured in specific standardised circumstances. In this approach technology is defined by the production function and by so-called duality the corresponding cost function conveys the same information on technology than the production function. In some cases it is possible to develop a certain index function representing standardised cost change. A price index of production cost is usually defined through a cost ratio measured at some same output level but at different prices in the two situations to be compared. A cost volume index is defined at the same prices but different output levels in the two situations to be compared. Because there is a one-to-one correspondence between the cost function ratio and the index function, the latter is basically fully determined by the production function. Thus economic index numbers are called "true" index numbers (supposing of course that the production function is known to be "true" for some reason).

In the conventional theory of economic index numbers the production function remains the same between the two situations to be compared. If factor prices and/or the output level changes by the minimum cost principle this leads to a change in the optimal factor combination within the technology spanned by the production function. Thus the partial productivities alter as do production costs. A new factor combination is at the same time a new technique within the production function, but technique change is a consequence of modified price or output situation within the same technique.

In a more profound sense a technical change is a change in technology, or a production possibility set, represented by a production function. The purpose of measuring technical change is to eliminate production function changes from alterations in input combination due to movements in input prices and output. Therefore, pure technical changes due to shifts in production functions are left. The measurements may be made either on the production function side or on the cost function side. The former case concerns productivity measurement, but the same information is also conveyed by cost advantage measurement. In the latter case measurements of the rate of technical change are performed by comparing the production costs at some observed or hypothetical, but same, output levels and input prices between the techniques spanned by the different technologies. If in situations $r=1,0$, observed (full capacity) output levels are Q^r, the corresponding input prices are p^r and the cost functions generated by technologies f^r are C^r, $r=1,0$, four different types of local measures are obtained.

$$(3.1.1)\quad \frac{C^1(Q^0,p^0)}{C^0(Q^0,p^0)}\ ;\ \frac{C^1(Q^0,p^1)}{C^0(Q^0,p^1)}\ ;\ \frac{C^1(Q^1,p^0)}{C^0(Q^1,p^0)}\ ;\ \frac{C^1(Q^1,p^1)}{C^0(Q^1,p^1)}$$

In these measures the rate depends on the values of the arguments in the cost functions. The form of the functions must be known in order to calculate the values of the functions at selected argument values.

The corresponding total factor productivity indices can be given as follows:

$$(3.1.2)\quad \Sigma C_i^1(Q^0,p^0)\ \frac{Q^0/X^1(Q^0,p^0)}{Q^0/X^0(Q^0,p^0)}\ ;\ \Sigma C_i^1(Q^0,p^1)\ \frac{Q^0/X^1(Q^0,p^1)}{Q^0/X^0(Q^0,p^1)}\ ;$$

$$\Sigma C_i^1(Q^1,p^0)\ \frac{Q^1/X^1(Q^1,p^0)}{Q^1/X^0(Q^1,p^0)}\ ;\ \Sigma C_i^1(Q^1,p^1)\ \frac{Q^1/X^1(Q^1,p^1)}{Q^0/X^0(Q^1,p^1)}$$

These measures are alternative but consistent with the former measures and are also of local character. The demand functions $x^r(..)$ in the above measures must be known in both situations to be compared in order that the values of the comparison functions can be calculated (Cf. Karko (1987)) for rigorous treatment of these general measures and their formal links to the functional index number theory in highly general circumstances.

The conventional approach found in the literature presupposes that the production function is linearly homogeneous with respect to inputs. This assumption makes the above cost-based measures of output independent but reduces the intricacy of production technologies: i.e. the differences in scale. In this case it is possible to obtain the rate of technical change or total factor productivity by the so-called residual method, where a change in the true input index is subtracted from a change in output. By way of example, if two translog technologies which differ in a smooth way are compared, the rate of technical change may be calculated without knowledge of any parametres of the technologies as a residual $\ln T^T$:

$$(3.1.3)\quad \ln T^T = \ln \frac{Q_i^1}{Q_i^0} - \Sigma \frac{C_i^1 + C_i^0}{2} \ln \frac{X_i^1}{X_i^0} \text{ ,}$$

where X_i^r represents inputs and C_i^r, $r=1,0$; $i=1,2,\ldots,n$ corresponding cost shares. The input index here is simply the Törnqvist index of total factor input. Nearly all theoretical and empirical literature focuses on applying this approach and especially advocates the Törnqvist index for its superlativity. Econometric versions of the approach are also widely applied.

The greatest drawback to an approach based on economic index numbers is that inputs are immediately adjusted according to a cost-minimising behaviour so that full equilibrium is unrealistically assumed in this respect at every moment of time. The essential and restrictive condition in the approach outlined is also the requirement that production, cost, or equivalently factor demand functions must be known in the comparision situations, although some nonparametric approaches are developed as well; cf. Førsund & Hjalmarsson (1987), Karko (1987).

3.2. Descriptive approach

In the descriptive approach no assumption on the production function or optimising behaviour is made. The goal of the descriptive index theory is to seek such index formulae that are best in the sense that they fulfil a maximum number of the requirements of the so-called Fisher's tests, or better to say desirata. This consists of a set of nearly common sense properties a good index formula is to fulfil. The theory was called formally mechanistic, atomistic or the theory invariant approach of index numbers; Cf. e.g. Eichhorn & Voeller (1977), Vartia (1976), but it has been long known that the original Fisherian desirata is controversial in that no best and unique formulae exist, and the noncontroversial subsets of the desirata do not determine uniformly the index function. For these reasons it may be argued that the descriptive index theory is not an economic theory, merely a doctrine. In a mathematical sense it endeavours to encompass too much.So the theory in modern sense is collapsed to investigate the mathematical properties of index formulae, not to determine the best one.

Selecting some of the set of various descriptive index formulae considered to be good formulae fulfiling many of Fisher's original or other more modern subcombinations of the postulates and having other good properties is, however, possible. (Cf. e.gg. Eichorn & Voeller (1977), Eichhorn (1978), Vartia (1976)). As examples, the so-called Vartia I and II and the widely used Törnqvist formulae are such weighting schemes. They are also referred to as chain indices. The first formula is consistent in agregation (Cf. Diewert (1978), Vartia (1976)) and fulfils the socalled Fisher's factor reversal test and many other desirata, but its weights do not sum up to unity. The weights of the second and third index formulae sum up to unity, while the second weighting scheme fulfils Fisher's reversal test, but the third does not. The second and third are not consistent in aggregation, but because the Vartia I indices are, it has been proved that the others are approximately consistent in aggregation; Cf. Diewert (1978). This indicates that group indices can be calculated only with the information offered by the group and calculating a "macro index" from the groups using "macro information" yields the same index numbers as does computing the macro index directly with individual items from the basket (i.e. not using grouping).

It so happens that the Vartia I and II and the Törnqvist indices are exact in the theory of economic index numbers for the Cobb-Douglas, CES and, respectively, Translog production functions. Because the latter production function is a so-called flexible production function, i.e. it may provide a second-order local approximation to any production function under certain circumstances, the Törnqvist index is a so-called superlative index formula, i.e. it approximates any index formula exact to some functional form up to second order. Since the other production functions can provide only first order approximation, the corresponding exact indices are termed pseudosuperlative. The superlative and pseudosuperlative indices do not exaggerate the rate of inflation but settle down near the middle tines of the index fork as shown by Vartia (1978). Therefore they measure the change in the price and volume of cost levels at least adequately.

Although the indices discussed are good indices both in terms of descriptive and economic index number theory, it should be stressed that both theories have in principle nothing in common but prices and volumes. The Törnqvist indices, based on exactness for translog functions and in turn the theory of economic index numbers, are widely applied to calculate the rate of technical change or total factor productivity, but the approach based on the descriptive doctrine is not employed in such calculations. The theoretical point in this approach is that no optimising nor equilibrium condition in the minimum cost sense is needed as is the case in the former approach. The problem remains of how to define technology or technique within the descriptive framework, however.

In the following we outline how to use the descriptive approach to define the rate of technical change and total factor productivity.

Because Vartia I index formulae are consistent in aggregation and possess other good properties, it is selected as a basic weighting scheme. Other above mentioned schemes are investigated in details in Karko (1988).

A point of departure to an application of the descriptive theory to the measurement of total factor productivity is provided by the conventional cost identity

$$(3.2.1)\quad C_i = \sum_j C_{ij} = \sum_j p_{ij}x_{ij};\ i = 1,2,\ldots,n$$

where i refers to individual plant, i=1,2,...,n, j to inputs at plant i, j=1,2,...,m. C_i is production cost at plant i, due to the use of factor inputs x_{ij}, whose prices are p_{ij}. Cost components $C_{ij} = p_{ij}x_{ij}$ are simply the costs due to the use of individual inputs x_{ij} with prices p_{ij}.

New consider situation 0 and 1 with the corresponding variables and apply the Vartia L-function defined by

$$(3.2.2)\quad L(x,y) = (x-y)/\ln(x/y);\quad \text{(in general terms);}$$

cf. Vartia (1976), to the both sides of (3.2.1) to obtain

$$(3.2.3)\quad L(C_i^1,C_i^0)\ln\frac{C_i^1}{C_i^0} = \sum_j L(C_{ij}^1,C_{ij}^0)\ln\frac{C_{ij}^1}{C_{ij}^0} = \sum_j L(C_{ij}^1,C_{ij}^0)\ln\frac{p_{ij}^1}{p_{ij}^0}\frac{x_{ij}^1}{x_{ij}^0}$$

Further simple rearrangements yield

$$(3.2.3)\quad \ln\frac{C_i^1}{C_i^0} = \sum_j \frac{L(C_{ij}^1,C_{ij}^0)}{L(C_i^1,C_i^0)}\ln\frac{p_{ij}^1}{p_{ij}^0} + \sum_j \frac{L(C_{ij}^1,C_{ij}^0)}{L(C_i^1,C_i^0)}\ln\frac{x_{ij}^1}{x_{ij}^0}\ ;\ i=1,2,\ldots,n$$

The above derivation of a log-change decomposition of the production cost ratio into the log changes (an indicator of relative change, which is very near to per cent change) of Vartia I-type input price and cost volume indices is essentially up to this stage the same than in Vartia (1976). The above identity shows that Vartia I input price and cost volume indices in log changes display the classical Fisher's factor reversal property. The cost ratio in log changes is decomposed into log changes of price and cost volume indices.

In the above nothing extraordinary concerning technique or technical change is used, and the device is the one usually applied in the conventional theory of descriptive index numbers. To extend the measurement of total factor productivity defined next, a technique by means of set of partial input productivities applied in production in plant i=1,2,...,n is

$$(3.2.4)\ \{\frac{Q_i}{x_{ij}} = t_{ij};\ i=1,2,\dots,n;\ j=1,2,\dots,m\}$$

The technique applied in every plant is allowed to vary and is characterised only by the set of partial productivities of the inputs used in production to obtain the amount of Q_i of the product. This definition fits well with the individual cells defining the capacity distribution taken together.

Consider next a specific plant. A change in any one of the partial productivities or all of the partial productivities is defined as a change in production technique of this plant. At this stage of the analysis we are not interested in the reason why a possible change occurs, because at this measurement stage only the observations and not the causality are of interest.

Take now any two situations 1 and 0 (in general t and t-1) with possible different partial productivities.

Solve from (3.2.4)

$$\ln(x_{ij}^1/x_{ij}^0) = \ln(Q_i^1/Q_i^0) - \ln(t_{ij}^1/t_{ij}^0)$$

$$\forall i = 1,2,\dots,n;\ j = 1,2,\dots,m,$$

insert in (3.2.3) and proceed as before to obtain

$$(3.2.5)\quad \ln\frac{C_i^1}{C_i^0} = \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{L(C_i^1,C_i^0)}\ln\frac{p_{ij}^1}{p_{ij}^0} + \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0}{L(C_i^1,C_i^0)}\ln\frac{Q^1}{Q^0}$$

$$+\ \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{L(C_i^1,C_i^0)}\ln\frac{t_{ij}^1}{t_{ij}^0}\ ;\ i = 1,2,\dots,n\ .$$

Because the values of equations (3.2.3) and (3.2.5) are identical with the same data, we may solve from this equation

$$(3.2.6)\quad \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{L(C_i^1,C_i^0)}\ln\frac{Q_i^1}{Q_i^0} = \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0}{L(C_i^1,C_i^0)}\ln\frac{x_{ij}^1}{x_{ij}^0} + \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{L(C_i^1,C_i^0)}\ln\frac{t_{ij}^1}{t_{ij}^0}$$

to obtain

$$(3.2.7)\quad \ln\frac{Q_i^1}{Q_i^0} = \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{\sum_k L(C_{ij}^1,C_{ij}^0)}\ln\frac{x_{ij}^1}{x_{ij}^0} + \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{\sum_k L(C_{ij}^1,C_{ij}^0)}\ln\frac{t_{ij}^1}{t_{ij}^0}\ ;\ i = 1,2,\dots,n.$$

The new weighting scheme determined here is studied in greater detail in Karko (1988). It seems natural to define the total rate of technical change or total factor productivity plant by plant i=1,2,...,n to be the residual

$$(3.2.8)\quad \ln\frac{Q_i^1}{Q_i^0} - \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{\sum_k L(C_{ij}^1,C_{ij}^0)}\ln\frac{x_{ij}^1}{x_{ij}^0} = \Sigma\,\frac{L(C_{ij}^1,C_{ij}^0)}{\sum_k L(C_{ij}^1,C_{ij}^0)}\ln\frac{Q_i^1/x_{ij}^1}{Q_i^0/x_{ij}^0}$$

$$(3.2.8) = \sum \frac{L(C^1_{ij},C^0_{ij})}{\sum\limits_k L(C^1_{ij},C^0_{ij})} \ln \frac{t^1_{ij}}{t^0_{ij}} = \ln T^U_{01,i} \text{ (say); } i = 1,2,\ldots,n \ .$$

Another alternative may be obtained from (3.2.6). Both presentations of total factor productivity are weighted sums of the partial productivities, but in the former definition the weights do not sum up to unity and a residual is not represented by a pure difference between output change and weighted input change, which holds true in the latter definition. We prefer and utilise the latter definition. By this definition the rate of total factor productivity is the same than the total rate of technical change; a general result similar to the corresponding result obtained by economic index numbers assuming linear homogeneity of production function.

3.3. Empirical calculations of total factor productivity at plant level

This section presents the total factor productivity calculations obtained by the formula (3.2.8) of previous section. We restrict ourselves to aggregating labour and energy input productivities and apply the foundry data at this stage of the art without any corrections for capacity utilisation.

The capital data consists of a separate timeseries for buildings and for machinery and is based on fire insurance values. It turned out that at some foundries fire insurance values did not indicate adequate measure of capital stock. At some old plants these values are apparently too low compared at least to the volume of the buildings used in production. In one case the buildings are leased and values are not available.

No volume or price information exists regarding the other inputs. Their cost in total is available, however, but because price information is missing, no means are found to construct directly the missing input volumes. One implicit method was tried related to a method outlined in Vartia (1979), but the volumes obtained turned out to be highly sensitive and do not realistically contribute to total factor productivity (at this stage of the experimentation). We shall perhaps return to this problem in forthcoming versions of this report.

Table 3.3.1 presents the results of the total factor productivity calculations utilising formula (3.2.8) with labour and energy inputs in terms of average yearly log-percent changes. As mentioned earlier this measurement of relative change is numerically very near to the conventional percentage change, at least when changes are relatively small.

The table consists of four columns, the first giving the yearly average log-change in output. The second and third columns show the contribution of labour and energy to the change in output, and the fourth column presents

Table 3.3.1. Yearly average contributions of total factor productivity and factor inputs to output growth in 1978-85 in the Finnish iron foundry industry (in log-percentages)

Unit number	Change in output	Contribution of labour	Contribution of energy	Total factor productivity
1	3.22	-1.52	- 0.66	5.40
2	-6.70	-4.13	-2.21	-0.36
3	-5.09	0.54	1.57	-7.20
4	-13.00	8.75	3.15	1.10
5	2.50	-2.31	0.47	4.39
6	6.25	3.96	-0.16	2.46
7	16.08	13.00	3.36	-0.28
8	3.65	-8.73	-1.07	13.45
9	1.78	-1.17	0.17	2.78
10	-0.26	-1.78	-0.65	2.17
11	6.81	-3.23	0.19	9.85
12	-10.86	1.72	0.20	-12.79

the change of total factor productivity. Represented in this way the change in output is the sum of the three other columns.

The most distinctive feature in the table is the large diversities in total factor productivity between the plants. The rate of change of output also varies greatly as do the contributions of factor inputs. This is naturally to be expected on the basis of the Salter and Heckscher diagrams and capacity distributions. Moreover, the sign of the rate of total factor productivity seems to be the same in general than that of output changes, but indications also emerge that firms have not been able to adjust to the rapid and powerful swings in output demand.

Figure 3.3.1 represents the development of productivity plant by plant as an index (1978=100).

In spite of the adjustment of inputs sharply downwards, the rate of total factor productivity in foundry 1 was on the average negative. Its investment rate was extremely low and economic performance measured by operating surplus only slightly positive. This unit was sold during the observation period and closed down in 1986.

In the case of foundry 2 inputs have also not been adjusted downwards enough so that on average a slight decline in total factor productivity has occurred. The investment rate and turnover per employee have been higher in this plant than on average in the foundry industry. Its main products are competitive with substitutes, such as plastics. On the other hand, the opposite development with respect to factor inputs is observed in unit number 12, which is the smallest factory in our panel (see figures 2.2.1-2). In this plant the investment rate was remarkably high during the years 1980-83, but turnover per employee was the smallest in the

Figure 3.1.1 Productivity indices of individual foundries (1978=100)

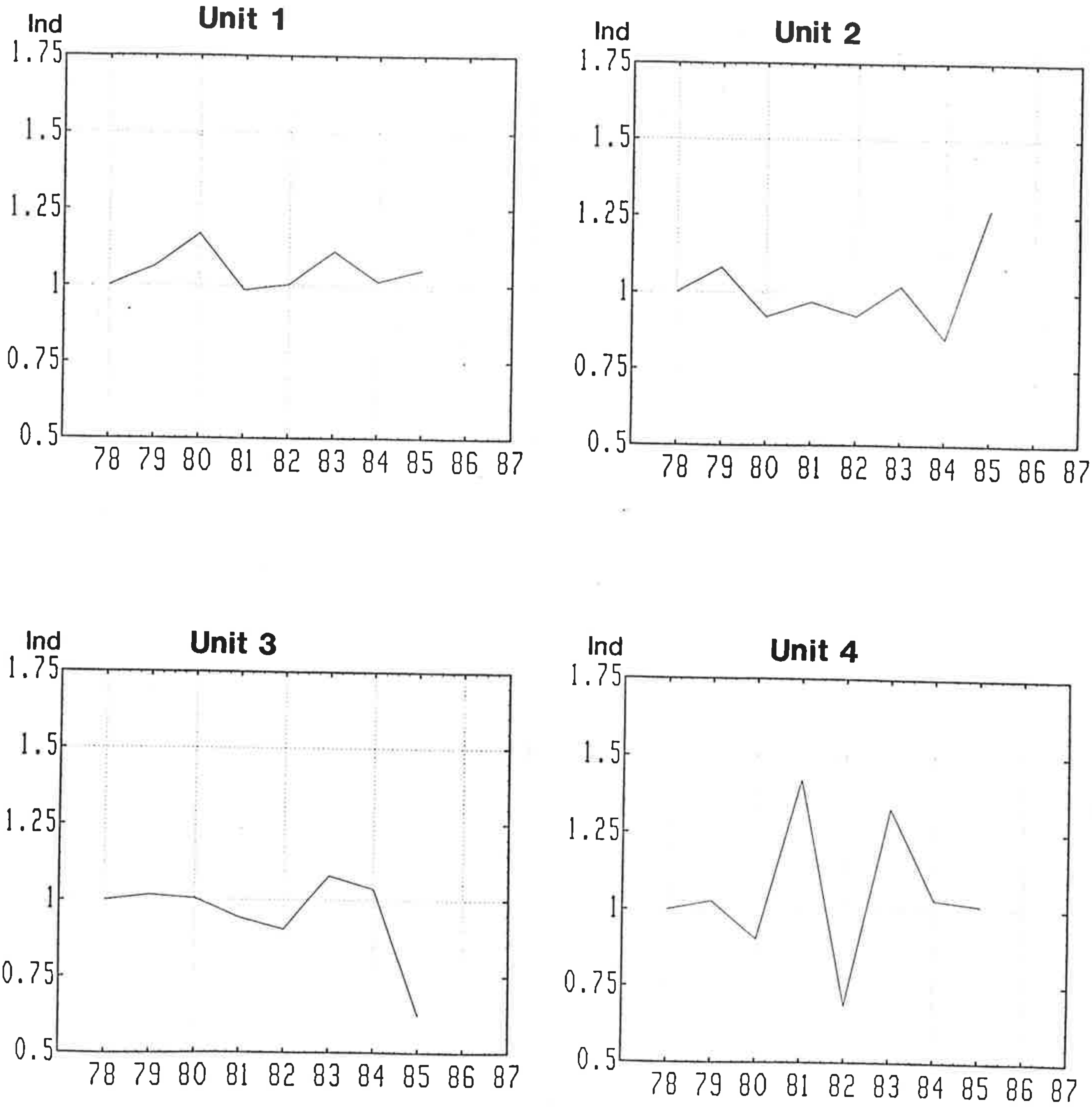


Figure 3.1.1 Continues

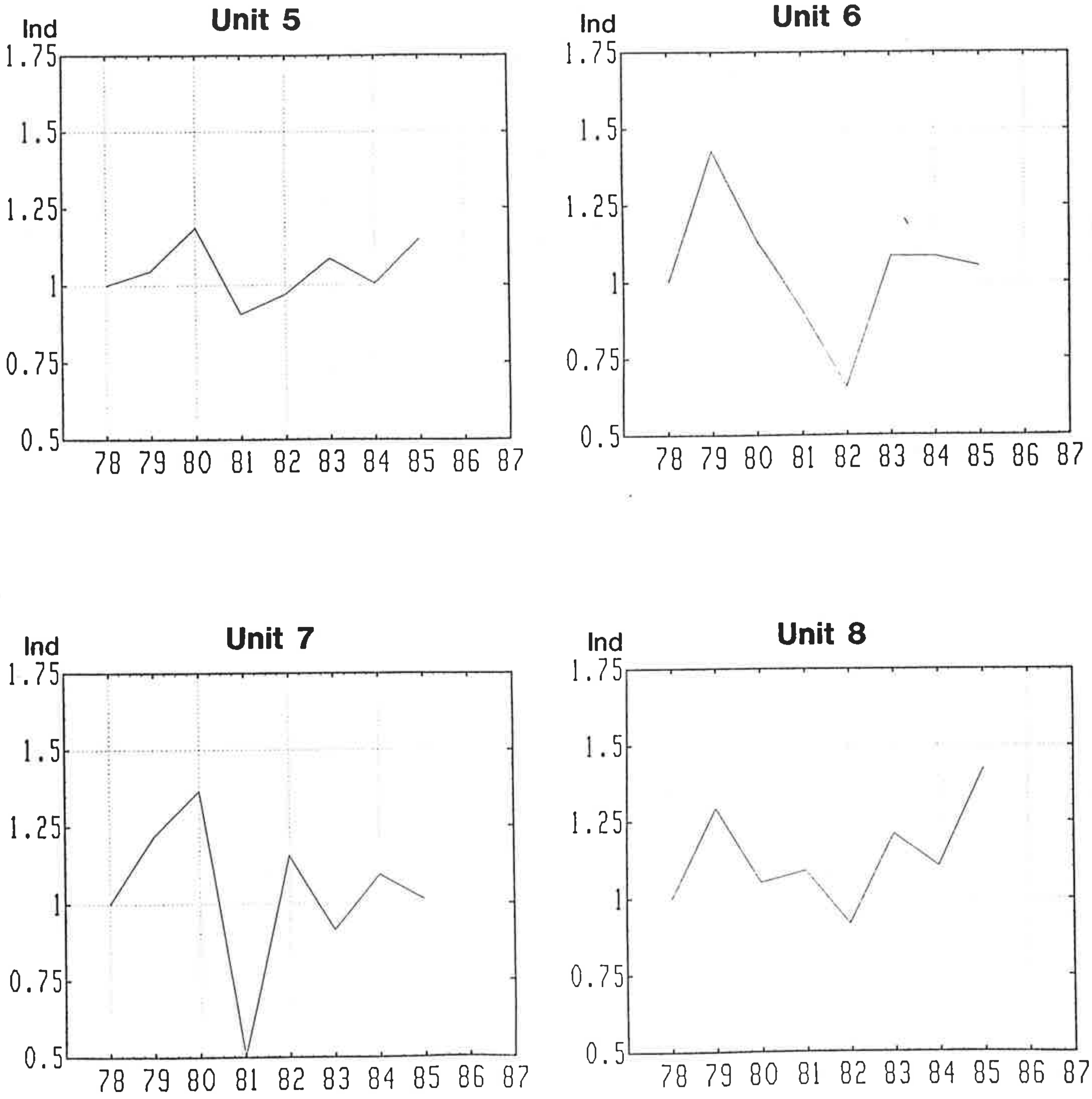
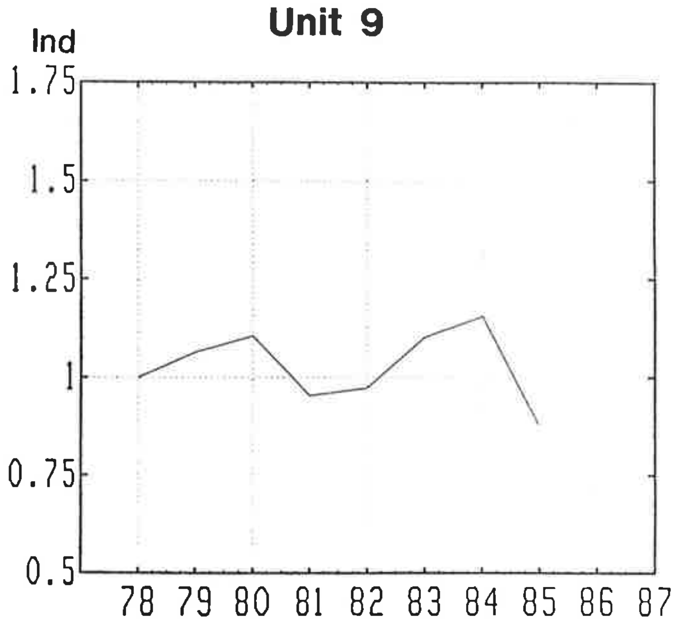
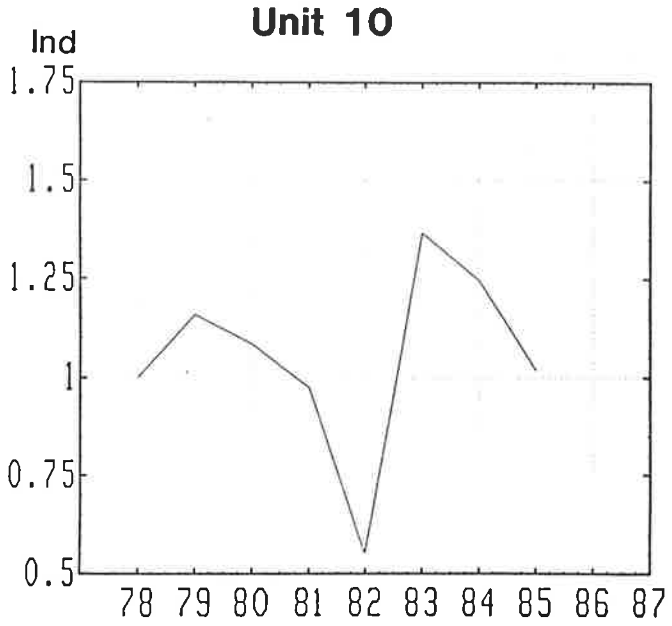
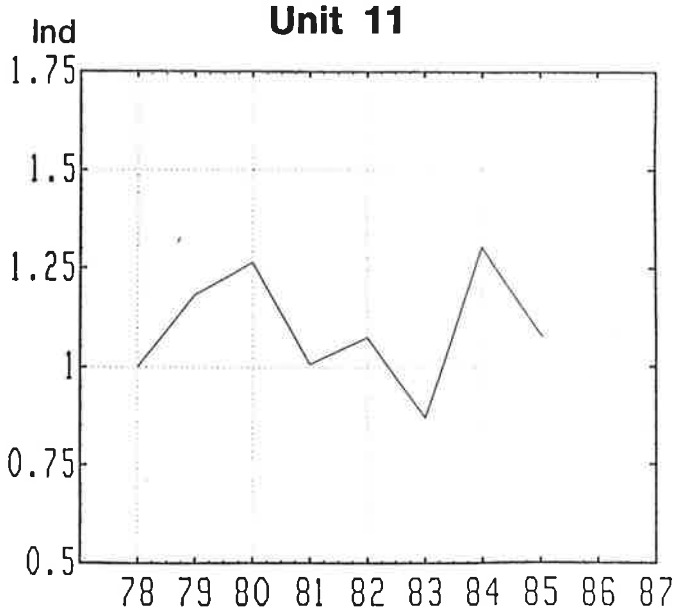
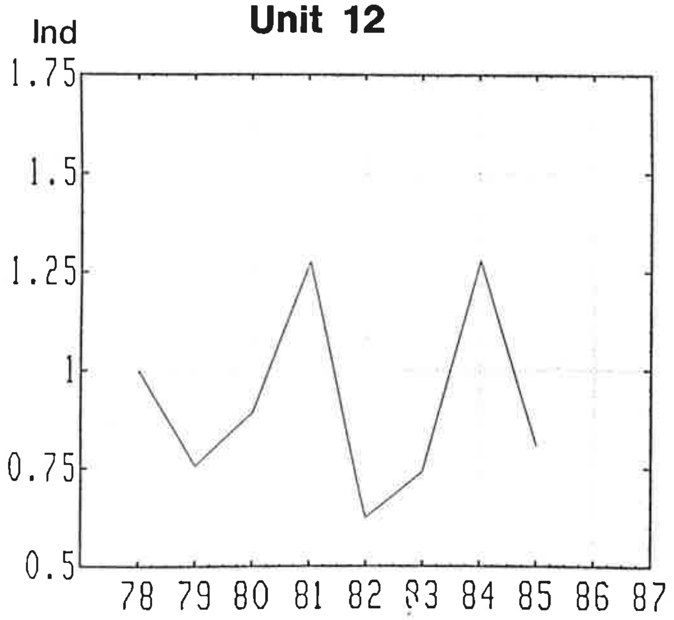


Figure 3.1.1 Continues









sample. The unit is highly specialised, but the operating surplus has been on average negative. Investment in conjunction with a reduction in product range did not lower input coefficients but detracted the economic performance of the plant.

Unit 3 has also shown weak success in total factor productivity, but this is mainly originated to the year 1985, when plant ownership changed along with modifications in output as sortment. The investment rate of this plant has been low compared with the average but turnover per employee a bit higher than on average. Operating surplus has been modest but positive. During the last two years of the research period this figure has increase substantially.

Units 8, 9 and 10, owned by big metal and engineering industry companies, operate as internal supplies. Unit number 11 was built up in the 1970s and has witnessed rapid progress. In this modern unit the investment rate was about 40 % of turnover at the beginning of the 1980s and after these years the labour and energy coefficients fell sharply. The operating surplus has been negative for the two last years of the observation period, however, and was very low before this. Turnover per employee is about the average.

The two other large foundries are old. Their investment rate has been very low during the survey period and turnover per head a bit below the average. Economic performance has been poor and extensive restructuring has been carried out but virtually without investment. As a result the development of total factor productivity has been rigorous, at least in the other one.

The remainder of the factories consist of a group of medium or small-size foundries, by ownership independent of other engineering companies. They are partly specialised and partly subcontract for other metal and engineering firms.

Unit number 6 was specialised but was declared bankrupt and sold to another medium-size foundry firm. Units 5, 9 (and 3) are now owned by the same company. Unit 5 is an exceptionally solid plant regarding economic performance, but the others are near the average. A common feature is a low investment rate so that progress is achieved by organisational restructuring and restricting the output range.

From this a clear relationship cannot be formed between economic performance and a high rate of total factor productivity. On the contrary a positive rate of total factor productivity seems to be linked to investment, but in many cases this detracts from economic performance, at least in the short run. The question thus seems to lie on the output demand side. Demand for castings was the last years of the period very slow, coupled with considerable overcapacity in old plants. New investment may increase capacity, and this acts to decrease economic performance under the demand restriction. It is a difficult spiral to escape from. On the other hand the output measurement used above may be weak in the sense that output in an individual foundry over time and across foundries is not so homogeneous that the measurement of output in metric tonnes is realistic. The time period of obervation may also be too short. Althought labour and energy costs are about half of the value of total factor costs, the volume of other inputs may have a noticeable effect on productivity.

Finally it may be remarked that the index formula applied in the calculations and derived above belongs to the class of so-called pseudosuperlative indices. The popular approach based on economic index numbers, or the Törnqvist index, yields on theoretical reasoning nearly the same numerical results as the one applied here. Thus the problem of major differences - if there is one - may lie mainly in the data, and not in the descriptive approach itself as applied above.

4. TECHNICAL CHANGE AT INDUSTRY LEVEL

4.1. About general methodology

The previous sections discussed the ways to define and measure technical change and total factor productivity at micro level. In this section our attention is turned to macro or industry-level measurements.

Intuitively an analysis at industry or macro level involve a solution to the problem of aggregation. In the context of production theory problem-setting requires the aggregation of micro-level production functions to macro-level production functions at different time points of interests. Comparing the industry-wide production functions then yields something like measurements (3.1.1) or (3.1.2). The pure conditions for this kind of exact aggregation are, however, too rigorous to be empirically relevant, e.g. the production functions of the micro units ought to be nearly identical (Cf. for a rather complete analysis Fisher (1969), Sato (1975)).

Another alternative is to aggregate changes in the production/cost functions of the micro units. Within this framework, called approximate aggregation in an economic index number context, production functions must be also almost identical and technical progress neutral in order to obtain a well-defined aggregative change, which may be interpreted to originate from a change of a well defined macro function and there is also other conditions related to perfect competition and separability concepts etc; Cf. Diewert (1980), Sato (1975), Fischer (1984). All these conditions may be considered too rigorous to be empirically acceptable, thought most of the e.g. country wide calculations a´la Denison & scolars are based on these fallacious assumptions.

The common feature of these approaches is that there is, for some, often undiscovered reason, a well-defined production function at macro level, but this devout belief may not be empirically plausible. An industry can in a statistical accounting sense be a relevant concept, but in practical circumstances the microunits of an industry may have so little in common that they hardly span a common aggregated production function of the neo-classical style or are worth simulating by econometric models based on the concept of the representative firm.

An interesting view to aggregation not applied directly yet connected with total factor productivity analysis is offered by the new descriptive methods outlined earlier in this paper. We apply also these methods. The final purpose is after these calculations to compare the total factor productivity measurement obtained by using descriptive aggregative methods and short-run production function methods, an approach which is also quite novel, and is introduced and applied below.

Given the micro-units or the panel of micro units, our first task is to solve the problem of modeling the production process at macro level on the basis of micro information.

In traditional studies of production analysis based on econometrics, technical change or productivity growth are based on the common practice of estimating the parametres of an a priori chosen parametrized family of functionally specified production relationships or their dual forms. It is typically assumed that the observed data reflect constant returns to scale or at least a homothetic structure of production and a static or, on some ad hoc grounds, a choosen adaptation towards the equilibrium of the firm. If technical change is assumed, it is in some restricted sense neutral (cf. Sato & Beckmann for relevant definitions (1969)). The identification of the model in a cross-section or a cross-section-time series analysis is based on the assumption of the representative firm, which as a theoretical concept is offered to share an identical production function with the micro units. In econometric applications based on data from actual micro units, this means that the firms are supposed to differ in efficiency from each other in a neutral and random way. The presupposition that neutral differences in efficiency are distributed normally for one or another, a reason most usually unexplained, dispenses with the necessity of introducing an aggregation principle for micro production functions to yield a cross-section production function, since all micro production functions can be reduced, after eliminating neutral differences, to a single, average production function. This assumption, with a cost-minimising or a profit-maximising principle, enables us to concentrate on the statistical identification of the function in a simultaneous equation system derived from the first order conditions. Thus the main emphasis is shifted towards problems dealing with simultaneity among the variables, and, as there is only one production function to be concerned about, the problem is greatly simplified.

Althought the approach exerted a profound influence on subsequent developments in econometric methodology, at the same time econometricians paid little attention to the realism of the maintained hypothesis itself. By basic assumption it is irrelevant to pose questions like whether the micro production function really differs in the way postulated by the maintained hypothesis at the cost of identifying production structure. From a methodological viewpoint the operationalisation of the maintained hypothesis also comes into question: is the theoretical groundwork of stationary disturbances valid in real circumstances. This is a relevant but not testable question, for the whole test theory of the related econometrics is built around the hypothesis of normally distributed stationary disturbance terms around the average function, both in the case of the production function and some of its dual functions. The realism of the theory cannot be disguised by new and popular flexible functional forms.

If the asumptions behind neoclassical econometric analysis are in reality violated, then estimates of the parameters, productivity growth or those related to technical change include the effects of scale economies and movements toward or away from equilibrium, in addition to shifts in the structure of production. Inference on productivity growth, and hence attempts to distinguish productivity growth from movements along the representative production function depend heavily on the assumptions made regarding the form of the production function or its dual forms, the behaviour of the representative firm and the type of technical change postulated in this process.

As a description of an industry, the representative firm is a close econometric approximation to the average firm in the sense of least square norm, and the empirical estimation result is basically a micro relation presenting at the same time the average firm of an industry and the whole industry, and is not an aggregate in a pure sense. Such a featureless construction is not useful as a tool for analysing the structure of or structural change in an industry, where differences between firms are not neutral and random consequences of long historical dynamic development, but on the contrary a result of more or less successful conscious actions and autonomous evolution.

In spite of the neoclassical mainstream, it can be questioned whether the neoclassical framework is a suitable tool at all to measure structure, for basically it is the market system of competition that lies at the centre of neoclassical theory, and not the microunit, firm or industry per se. Its main objective is to predict changes likely to take place in the supply of product and demand for inputs when changes occur in the only external variables that the decision unit acts on, namely market prices for output and inputs. The specification of technical change is elementary, for at least for empirical purposes it must be in a wide (Beckmann Sato) sense neutral, disembodied and smooth. Taken to an aggregated level the micro basis of an industry is unclear for empirically too strict aggregation conditions, i.e. the nearly identical production functions of microunits; cf. Summa (1986), Førsund & Hjalmarsson (1987).

The neoclassical theory is, therefore, not a suitable tool, in its present form at least, for analysing such problems as the process of structural change in an industry spanned by changes in the micro basis for the individual plants of an industry in a world where firms differ in size and structure with regard to input coefficients even at the same prices and same time points, plants become obsolete when e.g. the market size changes, an unexpected factor price development takes place and embodied technical progress occurs. However, it may suit the analysis of stationary states and the long-run development of industry at an aggregated level for its smooth substitution potential and choice of optimal scale linked to technical change occurring at a constant rate.

The discussion above attempted to call attention to the shortcomings of the neoclassical theory for empirical analysis especially when the links between the micro and industry levels are considered to be highly relevant. Emphasis on realism and the challence for practicability have created a need for developing a production theory recognising the fact that plants or firms differ in productive efficiency. From the methodological point of view it is also important that the methodology used in empirical work does not filter out the features of difference and that the macro level has a well-defined micro basis and summarises its characteristics. For further discussion, cf. Nelson & Winter (1983).

As an alternative to the neoclassical theory, the putty-clay approach is introduced along with the integrated production theories pioneered by Johansen (1959), (1972): cf. also Sato (1975), Salter (1960).

The Johansen theory of industry production functions combines micro level production and its characteristics with the industry level in a consistent way. The industry function expresses the optimal, hypothetical structure of an industry in terms of a cost-minimising production structure at industry level spanned by the micro units belonging to the industry with their given characteristics and measured by their input coefficients, yielding a more realistic modelling of actual intra-industrial development patterns than the neoclassical approach.

The method provides the means for measuring structural change and one of its most important components, technical change, as well as industrial efficiency at industry level through changes in the short-run function. With the help of duality, the structure can be characterised consistently from several other standpoints as well. Thus it can be studied from the cost or factor demand side as well as from the production function side.

The main idea of the putty-clay production theory was proposed by Johansen (1959), and closely related ones are found in Salter (1960). A cornerstone in the development of the putty-clay production theory is Johansen´s work, Production Functions (1972), in which he develops a dynamic theory of production through the integration of micro and macro and short and long-run aspects. The approach is operationalised by Forsund and Hjalmarsson by series of articles summarised in their 1987-book. This framework provides us with a deeper empirical insight into the concepts of structure and structural change in an industry defined as a macro concept with a clear analytical micro basis, the existing micro units. We maintain that this feature of our tools is more relevant than those yielded in an analysis based on the traditionally estimated putty-putty average production function and the hypothesis of an representative firm as depicting the industry. As noted by Johansen (1972), Sato (1975), Hildenbrand (1981) and Forsund and Hjalmarsson (1987), the concept of the average production function is in principle not well-defined and does not correspond to the production function concepts in the pure theory of production or to those of Johansen's. A sharp distinction between alternative concepts of the production function is essential in avoiding confusion in production analysis.

Johansen's integrated production theory consists of four different concepts of the production function:

1. Ex ante function at the micro level. This is a production function which exists at the moment of planning an investment and from which the choice of techniques for the plant planned is made. We can characterise it as a traditional production function with continuous substitution potential. This is the putty part of the putty-clay hypothesis.
2. Ex post function at the micro level. This is characterised by fixed production coefficients and is the production function that counts after the moment of investment. This is the clay part of the putty-clay hypothesis.
3. A short-run macro production function built up of ex post functions for the micro units. It can be built up (in programming form) on the basis of a discrete distribution or a continuous distribution function.
4. A long-run macro production function which is closely connected to the ex ante function.

The following analysis concentrates mainly on the second and third functions above. For the purposes of structural analysis the third is the most important.

At the micro level the ex ante function is a form of planning function supplying all the potential technologies available at a certain point in time. The ex ante function is in fact the efficient envelope of all the feasible, alternative designs conceived by the engineers and available to the decision-makers when the investment decision is made. At this stage a free choice of capacity and substitution possibilities is assumed between the inputs, depending on the producers' "planning prices", future expectations and subjective opinions.

The ex post function at the micro level sums up the choices made by the firms from available ex ante functions, determining their layout, which may be more or less efficient, depending in the long run how accurate the determinant between the choice of possible ex ante designs has been. Ex post, the plant design is assumed to be frozen in the sense that plant production capacity is fixed and no substitution possibilities exist. The fixed factors (capital equipment) are determined only in the context of the investment decision, but flexible factors can be varied ex post. In the longer term they are quasi-fixed. The relationship between these inputs and the amount of output is determined by the choice of technique embodied in the fixed factors. Thus in general, it is supposed that the ex post function is characterised by fixed production coefficients in the short run, but the coefficients may be changed in the longer run, and there is no reason to assume that the coefficients are the same in individual plants.

In the short-run operation of the plant, the unit is assumed to behave as if it is a price taker facing potential sales constraints. The existence of a sales constraint could mean that trade takes place outside the Walrasian equilibrium. The output market may thus be characterised by some oligopolistic traits, such as price leadership or other types of implicit price contracts among firms, making for varied plant capacity utilisation in the short run; cf. Bosworth (1976).

At plant level various types of interactions may occur between different vintages of capital equipment, for instance in the form that certain basic structures already acquired may facilitate the instalment of new items of machinery, or that modernisation or reconstruction of old equipment may be more profitable than either operating the equipment in its old form or acquiring new machinery. In practice, the equipment of a given plant usually consists of mixed vintages. A pure vintage, different from equipment of any well-defined vintage,is rarely observed, but these vintage effects are also embodied in fixed factors, reflecting plant capacity. This implies no need to aggregate capital, at least in the short run at plant level. On the other hand, the fact remains that production units to be established at the same time may have qualitatively differing capital equipment or consist of different combinations of basic elements according to which factor proportion they are designed.

The crucial assumption is only that the output is to a large degree homogeneous in order to absorb the quantitatively different fixed factors, and that quasi-fixed factors are quantitatively of the same type.

4.2. The short-run industry pruduction function

The concept of the short-run industry production function rests on an assumption of a vintage structure within an industry; i.e., that each unit in the industry, for example a foundry (or a major item of its capital equipment), is characterised by fixed production coefficients with regard to current, variable inputs, and the presence of fixed factors in the form of capital defining plant capacity at the moment considered. The function is defined by maximising the industry's total production for given amounts of total inputs. This also means that the total variable production costs of the industry are minimised for any factor price ratio and any level of production, assuming that all units of production face the same prices.

Consider now an industry consisting of a certain number of micro units. The short-run production function of the industry as a whole is established on the basis of ex ante production functions, determining the full capacity values $\bar{Q}_i$, at plant i, i=1,2,...,n, of output Q, and the current inputs x_{ij}, i=1,2,...,n, j=1,...,m. For the ex post functions at the micro level, following Johansen (1972), a limitational law is assumed to hold:

$$(4.2.1)\quad Q_i = \mathrm{Min}\,\left[\frac{x_{i1}}{a_{i1}}, \frac{x_{i2}}{a_{i2}}, \ldots, \frac{x_{im}}{a_i}, \bar{Q}_i\right] ;\ i=1,2,\ldots,n\ ,$$

where the input coefficients $a_{ij} = \bar{x}_{ij}/\bar{Q}_i$ i=1,2,...,n, j=1,2,...,m are assumed to be constant, i.e. independent of the rate of capacity utilisation.

In the following, we assume that all plants or micro units have the simple structure given by (4.2.1), but with different production capacities and different input coefficients, of course. The input coefficients, a_{ij}, are estimated by the observed coefficients.

The short-run industry function $Q = F(x_1,\ldots,x_m)$ is obtained by solving the following problem:

$$(4.2.2)\quad \mathrm{Max}\ Q = \sum_{i=1}^{n} Q_i \qquad \text{subject to}$$

$$(4.2.3)\quad \sum_{i=1}^{n} a_{ij}x_{ij} \leq x_j\ ;\quad j=1,\ldots,m$$

$$(4.2.4)\quad x^i \in (0,\bar{x}^j)\ ,\quad Q_i \in (0,\ \bar{Q}_i)$$

where $\bar{Q}$ denotes the full capacity output and $x_1,\ldots,x_m$ current inputs for the industry as a whole, and where i=1,...,n refers to plants with a capacity of Q_i. Since, for our purpose, we are only interested in the economic region, it is natural to assume free disposal of inputs as expressed by equation (4.2.4).

In principle, the short-run function can be derived by solving a number of linear programming (LP) problems. However, when the aim is to establish a reasonable number of piecewise linear isoquants in order to reveal their corner points, solving the LP problems (4.2.2-4.2.4) is not practical. Instead a special algorithm leading to an identical result is used. A complete description of this algorithm is presented in Forsund and Hjalmarsson (1984). This yields a complete numerical description of isoquants and provides the whole set of isoquants to obtain a full characterisation of the production function. At every point of the substitution region it is known which micro units are operating. For this reason the approach is interesting from an empirical point of analysis, for it offers simultaneously a sensitivity analysis of the utilisation of units with respect to industry level output and input prices. Due to the linear structure of the problem, the isoquants will be piecewise linear in the two-factor case considered here. In spite of some numerical difficulties, estimates of the usual elasticities of scale and substitution can also be calculated.

The set of ex post input coefficients for plants in an industry in the input coefficient space is called capacity distribution. These distributions have already been discussed earlier above. In fact, the short-run production function is constructed on the basis of such capacity distribution in our approach based on the Førsund-Hjalmarsson algorithm. Transforming the short-run function into the input coefficient space yields the capacity region of the short-run function. The transformed short-run production function reveals the region of feasible input coefficients of the industry production function as a whole, while the capacity distribution shows the dispersion of individual units. Thus the descriptive approach in which plant technologies are characterised by an input coefficient can serve as the groundwork for constructing a short-run function. In this framework, construction of a short-run function is performed exactly along the lines described above. No reference is made to micro level production functions (4.2.1), however, but only to the input coefficients (3.2.4).

The maximising approach applied to construct the short-run function corresponds to the basic definition of a production function, in which an <u>industry</u> is regarded as <u>one</u> production unit as opposed to the traditionally estimated "average function" for an industry.

Moreover, in the approach outlined above the short-run production function explicitly recognises that the technology of individual micro units differs, and utilises all these individual micro technologies when the relationship between the aggregate industry output and micro unit inputs is established by explicit optimisation. As noted in section 4.1 above, the conventional average function is based on the notion of a representative firm (plant), that is, in the latter case it is assumed that all micro units utilise the same underlying production technology, except for a random error term.

In order to compare the structure of an industry between two time points, a well-defined norm, or an optimal structure, of the industry is needed and the short-run function serves this purpose. Because the basic approach is to impose cost minimisation at industry level when deriving industry production functions in order to present industry structures as hypothetically optimal structures based on the existing micro units and their characteristics, the structure of an industry is characterised in the short-run industry production function context by the shape and location of the substitution region and by the shape and spacing of the isoquants. These depend on the distribution of the technical properties of the micro units. Structural change at the industry level is then measured in terms of changes in the optimal industry structures. It follows that no universal measurement nor statistic of structural change exists as this change is as rich in various dimensions as the structures themselfves and moreover of local nature, but measurements do partially illustrate progress. Of interest is that families of cost functions corresponding to the short-run function are another, equivalent way to describe optimal structure, as discussed in the next section.

4.3. The short-run variable cost function

The approach taken in this section diverges from the studies based on neoclassical theory, because it is founded on an aggregation of micro units in a nonparametric form into short-run industry production functions at different time points. This aggregation is nonparametric in the sense that no parametric presentation of the short-run function is obtained in terms of the classical theory of production. The presentation of the short-run function is numerical; it has all of the classical properties of a production function but is continuous piecewise.

The aggregation process is based on maximising output for a given level of inputs implying that the total production cost for the industry is minimised for any factor price ratio equalised to shadow price ratio at any level of production, assuming that all units of production face the same prices. Thus a dual correspondence is found between the production function and costs, exactly as in the classical theory of production. (Cf. Førsund, Hjalmarsson, (1984)). The approach also points to a parameter-free minimum cost function from which average costs and marginal costs at industry level can be calculated at different levels of industry output and at different input prices.

Also of interest is that when the shadow price ratio corresponds to the observed price ratio, the priority of utilisation of individual plants is given according to the Heckscher diagram corresponding to the prices considered when the industry-level capacity utilisation increases. Thus the micro foundation of marginal and average cost functions is presented in the form of Heckscher diagrams, with unit costs at the chosen prices on the ordinate axis and capacity shares of the individual foundries on the abscissa axis. Along the expansion path, the marginal cost function is derived by expanding one production unit after another in order of the ranking given by the corresponding Heckscher ranking. This transformation is performed by moving from the percentage output unit cost space into the output cost space. An average cost curve is obtained by accumulating costs in the Heckscher diagram and weighting them by capacity shares. In this way the procedure applied yields a simple, common-sense solution to the cost functions corresponding to any selected prices and corresponding fully to the dual problem lying behind the original LP problem. The concept of structure is clarified also from the cost structure viewpoint in a manner consistent with production structure. Important is that a well-defined hypothetical, optimal structure is constructed by imposing the condition of industry-level output maximisation/cost minimisation.

The graphs of average and marginal cost curves along an expansion path provide us with a comprehensive picture of variable cost structure for each output level at the input prices corresponding to the expansion path choosen. As usual, the elasticity of costs with respect to output is defined as the ratio between marginal costs and average costs, and in the continuous case the inverse of this ratio is equal to the elasticity of scale. Cost elasticity differs somewhat from the inverse of the scale elasticities for the piecewise linear structure of our short-run function, but the scale elasticities along an expansion path are calculatable. Obviously the minimum value of the elasticity of cost is one, for elasticity is defined with respect to the best unit and thus has to increase when a new unit enters into the solution, that is, when moving outwards along the expansion path considered.

In principle, the substitution properties of the short-run function along the isoquants are summarised by the substitution elasticity, which is elasticity of the factor proportion with respect to the marginal rate of substitution. No substitution possibilities exist of course between the inputs of various micro units. But the dispersion of technology between different plants shown by their different input coefficients makes substitution at the industry level possible, since a given amount of output can be produced with different combinations of plants, the combination depending on input prices. In this study, however, we are not interested in investigating the changes of short-run substitution possibilities, but rather the long-run changes. Therefore we do not present estimates of elasticities of substitution (see e.g. Førsund & Hjalmarsson 1983). However, a visual impression of short-run substitution possibilities may be obtained by looking at the isoquant graphs of short-run functions. Where the changes in isoquant curvature are large, there the elasticity is high. Changes of elasticities of the scale and substitution through time are also measurements consistent with cost-based measurements of structural change as well as technical change and its biases.

4.4. Measuring total factor productivity and technical change in the short-run production function contex

The link between a series of short-run industry production functions over time goes through the ex ante production functions. The ex ante function can be regarded as a choice of a technique function for the construction or rebuilding of an individual micro unit. The short-run industry production function reflects both the history of ex ante functions over time and the actual choices made from these ex ante functions. Production ex post at any point in time must be compatible with the short-run function.

The long-run development of the foundry industry is analysed on the basis of the shifts in the short-run industry production function during the period. The short-run function indicates the optimal, chosen production possibilities of the industry, and it is altered by investment in new technologies and the scrapping of old capacity at micro level. The graph of the short-run function is thus likely to change, giving rise to the problem of eliminating pure technical change from other changes, for instance due to input price changes.

Technical change at industry level may be characterised from several standpoints. We shall adopt here the measures of technical change introduced by Salter (1960) and further elaborated by Førsund and Hjalmarsson (1983) and (1984), utilising the duality correspondence between production and cost functions. The feature of technical change which is important is the rate of movement of the isoquants of the production function towards the origin. The extent of technical advance from one period to another in the short-run production function is defined and measured by the relative change in minimised variable unit costs at industry level between two points in time, t and t*, t* > t, at a certain output level Q at constant factor prices:

$$(4.4.1)\ T = \frac{C^{t}(\bar{Q},\bar{p})}{\bar{Q}} \Big/ \frac{C^{t^*}(\bar{Q},\bar{p})}{\bar{Q}} = \frac{C^{t}(\bar{Q},\bar{p})}{C^{t^*}(\bar{Q},\bar{p})}$$

It is again interesting to note that the measurements of technical change supplied by (3.1.1) are of the same type as those given by (4.4.1) in terms of economic index numbers of the classical theory of production. Essentially the short-run production function procedure based on cost functions is similar to the measurement approach in classical theory, and it involves asking what changes in the unit cost function at industry level would take place if relative prices and output were constant at industry level.

The classical index number measurements do not dictate at what level of aggregation the measurements have to be carried out. For this reason it is generally presented in a micro level analysis where a well-defined homogeneous output and prices are assumed to be definable. To a degree the analysis at macro level is a question of aggregation. In this section we have applied a parametre-free aggregation; the aggregation problem is solved in a efficient way but numerically, with the price of an assumption of homogenous output and inputs between the micro units, which may be somewhat unrealistic in the context of the foundry industry.

The measurements of technical change are to be performed at some fixed output level and prices, i.e. along the choosen expansion paths between the points corresponding to choosen, fixed and equal output levels in the situations to be compared. The standardisation eliminates substitution type changes and changes in the scale due to input price and output level differences between the two time points. The characteristics of technical advance described by reference to technologies which differ only by shifts in unit cost or production function due to technical differences from one period to another remain. The hypothetical nature of the measurements is revealed if we imagine a situation in which we have observations of industry output levels, say $\bar{Q}^t$, $\bar{Q}^{t-1}$ at industry level input prices p^t, p^{t-1}. In the cost comparision any output/ input price combination may be selected. If we select ($\bar{Q}^t$, p^t) these argument values are observations from the short-run function at the time t, and are the hypothetical but possible values of the short-run function from the time t-1, if the real observations are made at this time ($\bar{Q}^{t-1}$, p^{t-1}). The same idea may be applied to the measurements (3.1.1-2), for but the standardized argument values need not be at all direct observations, any definable values are sufficient to make fully hypothetical comparisions, both in the short-run production function and in the economic index number context.

At fixed output levels of the industry, the composition of the units is choosen and utilised along the expansion paths. Utilisation depends at fixed prices on their input coefficients and thus unit cost rankings. If micro level techniques apply changes over time in an unequal rate, the micro unit decomposition utilised changes. Thus technical change at industry level depends on technique changes at micro level. Thus the rate of micro level change reflects at the same time a change in the structure of the industry. At industry level, of course, altered plant capacities as well as possible scrapping also fall into the category of technical change as a natural part of structural change. In general, there is no reason to delete plants closed during the observation period but in our sample it so happens that one unit ways closed after the observation period.

When the technologies at plant level change, the industry-level short-run function changes. At the same time, the location and shape of the expansion paths change, reflecting locally simply the structural change at the selected prices when industry output level grows. It is natural therefore that industry-level technical change is at the same time a change in the optimal structure of the industry, while the basis of structural change is the uneven progress taking place in micro units.

In our context the structure of an industry seems to be a concept of no particular interest, either whether observed from the production or cost function standpoint, unless there is a certain instability, intertia and clayishness in the capacities of micro units to adjust to price changes and new technology. In a world there firm environments are rapidly changing and expectations are not perfect, structural change is natural to occur, creating at the same time dynamics of industry development. But from our viewpoint it follows that the structure is a as rich as the industry function, so that no unified global measurement of structure nor of technical change seems to exist.

4.5. Empirical short-run functions for the Finnish iron foundry industry

The capacity and substitution regions of the short-run industry functions are presented in figures 4.5.1-2 for the years 1978 and 1985.

The graphs of the functions may well serve for descriptive purposes like a map of a country, and the figures themselves yield valuable information on the industry and its development. In this respect interesting points are shape and location as well as spacing of the isoquants in both regions and their changes over the time.

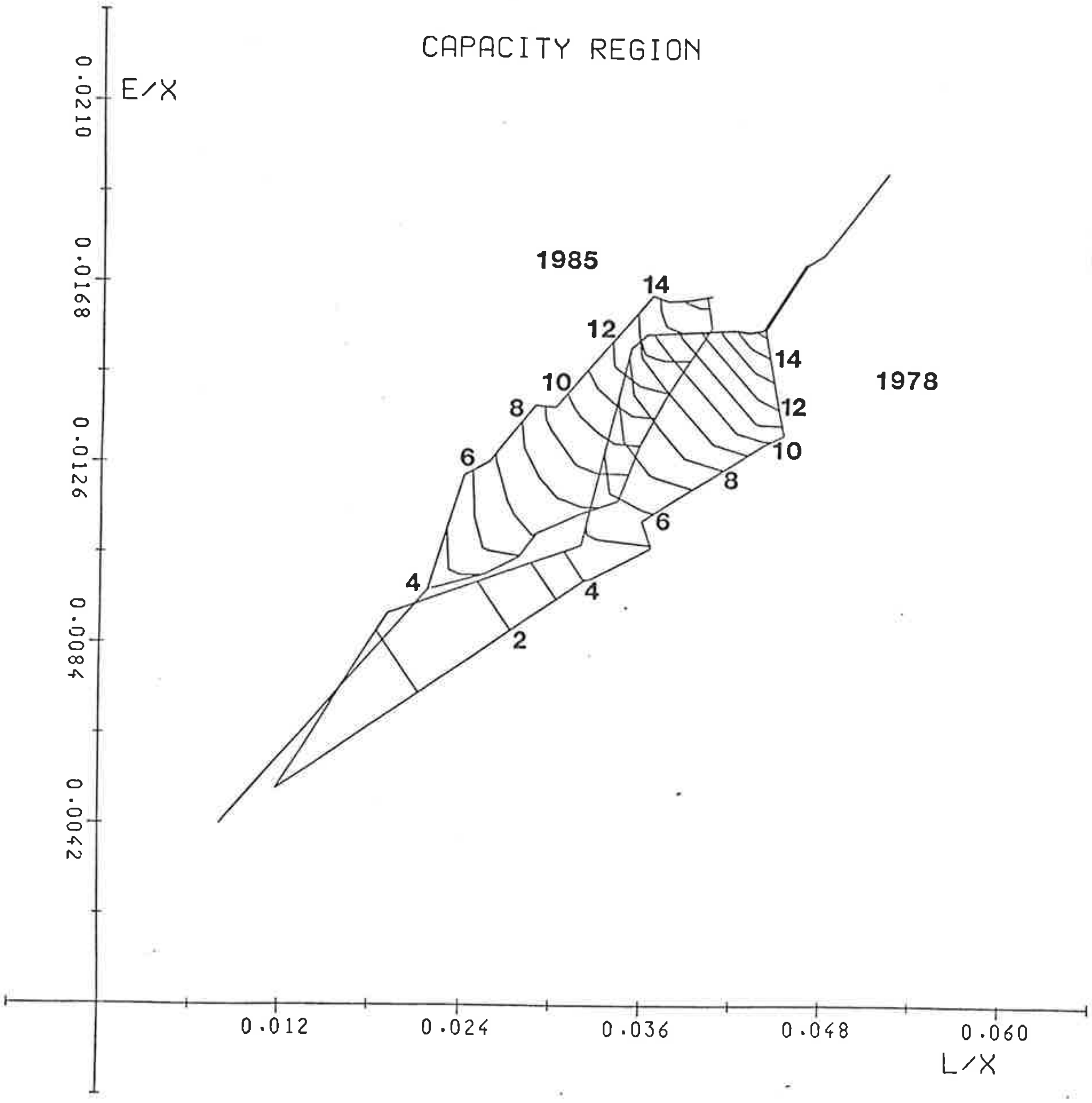
The substitution area exhibits the feasible region at which production takes place at any input price when organised in an optimal way, that is, putting on stream at any input price ratio individual foundries according to their cost effectiveness. The factor input usage of the whole foundry industry can be seen lying along the axes and corresponding to this type of organised production. Also to be stressed is that the whole construction is theoretical, devised to make measurements and possible only when the construction has a well-defined basis and, in this case, clearly defined microfoundations based on the characteristics of the micro units.

It is also valuable to study the capacity region, which is the transformed isoquant map of the short-run function. This shows the region of feasible input coefficients of the industry production function as a whole. Thus, this region must necessarily be narrower than the area of the capacity distribution of the individual units. The boundary towards the origin of the feasible region is called the efficiency frontier.

The movement and transformation of the capacity region is shown in figure 4.5.1. Turning to the shape of the regions, it can be noted that if the individual plants have about the same ranking in both input coefficient dimensions, a narrow capacity or substitution region is obtained, while if the production units are scattered in a north-west/south-east direction, the regions are wide.

In 1978 there was only some scattering in the rankings of individual foundry input coefficients in both dimensions, so that the capacity and substitution regions are relative narrow up to about the 40 % level of capacity. After that percentage figure in the solution, such foundries are put on stream which have a wider variability of input coefficient rankings in both dimensions so that the regions wider. The spike at the top of the substitution, or capacity, regions is a result of the last two "marginal foundries" shown in the Salter and Heckscher diagrams. They reveal distinct differences in the rankings of the energy-labour input coefficient dimensions. A substitution area approaching a straight line is thus formed, where the capacity utilisation of the less efficient plant gradually grows and finally the last small marginal unit is utilised up to its full capacity to obtain a full-capacity utilisation level for the entire foundry industry. The opposite happens at the fullest capacity in 1985. The two superior units, having a unique ranking according to both input coefficients, enter one by one, first into the solution, and only after achieving their full capacity utilisation, the remainder are utilised. After this the regions gradually assume their typical shapes. That is why the linear spike first appears in the area of feasibility. In general the capacity and substitution regions seem to be slightly narrower in 1985 than in 1978, indicating that the units are becoming similar, which of

Figure 4.5.1. Capacity regions of the Finnish iron foundry industry in 1978 and 1985. The distance between the isoquants is 5 ktn.



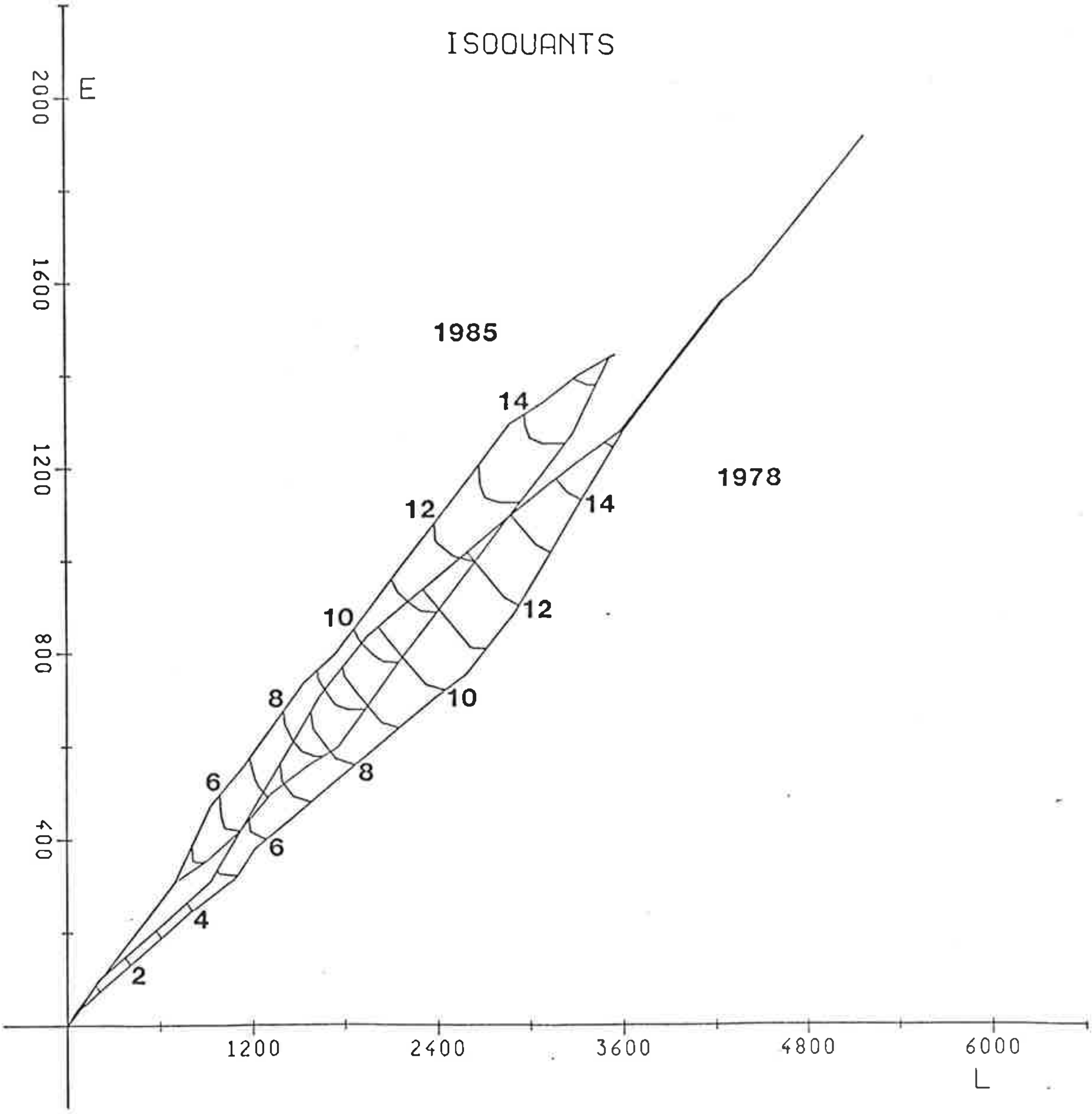
course is also apparent from the capacity distribution and the Salter/ Heckscher diagrams as well.

In 1978 variations in the labour input coefficients at low output levels of the industry are smaller than those for energy. At higher output levels of the industry the situation is nearly reversed, and the shape of the capacity region varies greatly. In 1985 the situation is nearly the opposite so that at high capacity levels the labour input coefficient at industry level varies more than the corresponding energy coefficient.

Some differences in the form and spacing of the isoquants also emerge inside the same function graphs. In 1978 the isoquants are nearly linear in shape at low industry capacity levels but become more kinked near both boundries of the regions at higher industry capacity levels. In a capacity region presentation, the distances between the isoquants decrease, reflecting increasing costs when industry-level capacity utilisation is extended, i.e. the scale properties of the industry is rapidly decreasing in general. Locally this is not so clear, for after the best capacity is utilised, the marginally, nearly similar, centre area capacity enters into the solutions. In this area the spacing of isoquants is about equal for a some time, illustrating that the marginal cost of this capacity only increases by a slight, nearly linear degree. Real marginal units create high marginal costs at high industry output level causing the spacing of isoquants to become again denser.

In 1985 isoquant spacing was stabler compared to that of 1978. In general the units following the best ones are marginally more similar, and this character produces a modest, smooth increase in industry-level marginal cost.

Figure 4.5.2. Graphs of the short-run production function of the Finnish iron foundry industry in 1978 and 1985. The distance between the isoquants is 5 ktn.



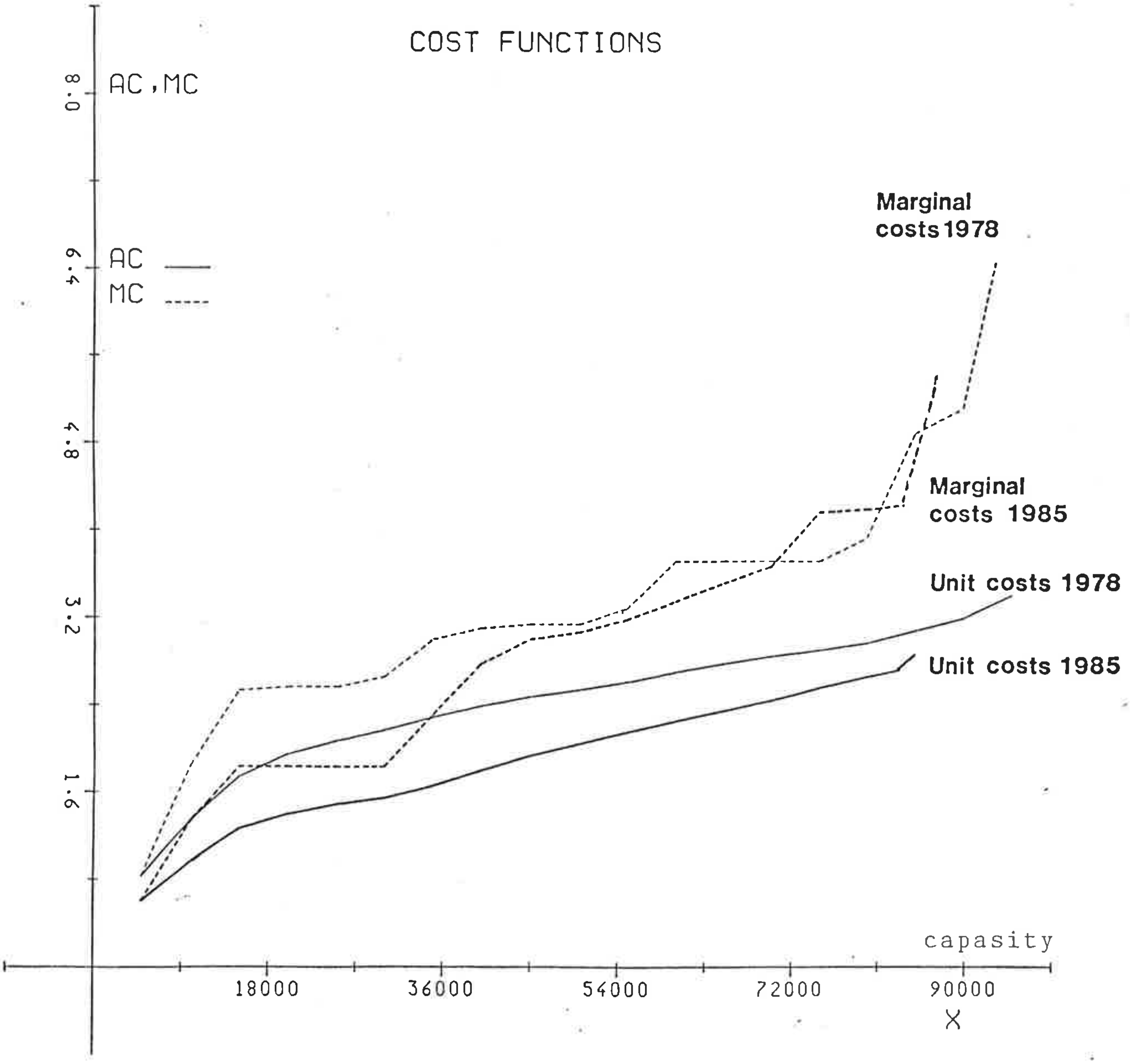
Some differences also appear in the curvature of the isoquants as well as the function graphs and between the graphs of different time points. In 1978 isoquants at the best capacity are virtually linear but display more curvature at higher output levels of the industry. The isoquant shows how inputs or input coefficients at industry level vary at a fixed industry-output level with fluctuations in relative input prices. A picture of substitution properties is also provided. The high rate of change in curvature indicates high substitution possibilities. There is of course no direct substitution between the inputs in separate foundries, but individual plants have different input coefficients characterising their technologies, however, and at specific input prices the cost advantages of the unit may vary, so that at different input prices different ranking are possible and may be applied to the solution in different order. Thus at certain isoquant levels the unit composition of the industry varies for different prices. This dispersion of techniques between individual foundries makes substitution at industry level possible since a given volume of output can be produced with different combinations of plants. The dispersion in plant composition at a given output level when input prices change is an interesting structural feature, explaining why substitution properties on different parts of the isoquant map may vary substantially.

In 1978 isoquant curvature in the substitution, or more clearly, capacity region is seen to change in numerous areas where labour was relatively cheap compared to energy. When energy is expensive, there is little chance to substitute energy for labour, but substitution opportunities grow when the price of energy becomes relatively less expensive. This indicates that near the upper boundary there is an approximately definite composition of plants utilised in order of decreasing ranking of labour coefficients represented by Salter diagrams, while at the lower boundary the utilisation rate depends on the ranking of energy coefficients.

More or less the same characteristics seem apply to 1985 with respect to substitution possibilities, but the kinks are apparently somewhat tighter. At a comparatibly high industry capacity levels when the price of energy is high compared to that of labour, substitution possibilities with respect to labour seem to be narrower, and when the price of labour is low, energy substitution possibilities may be weak with a relatively greater scope to adjust with labour.

These principles are valid, of course, near the boundaries. In relative price terms this means a zero price of energy along the upper boundary and a zero labour price along the lower boundary when sweeping the quasi-rent line through the capacity distribution. Relative prices change along the isoquants. Thus, the construction of isoquants is a fairly complicated procedure to be explained simply. For details, refer to e.g. Førsund & Hjalmarsson (1984), Førsund, Hjalmarsson, Eitrheim, Karko, Summa (1985), Summa (1986). However, even in the interior of the substitution region micro units are combined into efficient combinations to yield at industry level maximal output with lowest unit cost. Graphically, substitution (as well as the capacity region) is made up of parallelograms, where each parallelogram is an efficient combination of micro units. The procedure is illustrative from the structural point of view, for at every point on the isoquants efficient plant combinations are exactly known and allow a comprehensive sensitivity analysis of plant combinations for relative price changes represented and equalised by shadow price changes as well as by industry level output changes.

Figure 4.5.3 Marginal and average cost curves for the Finnish iron foundry industry in 1978 and 1985 at constant 1985 input prices.



The graphs of the marginal and average cost curves represented in figure 4.5.3. are computed at 1985 prices for the years 1978 and 1985 for reasons connected with the rate of technical change measurements given below. They are, in general, Paasche oriented measurements; cf. Karko (1987).

Over time the shape of the marginal, and thus average cost curves, of the foundry industry have somewhat evened. Especially the majority of capacity cut unit costs except for the smallest unit, which greatly deteriorated compared to the situation in 1978. The best-performing foundry has lowered costs only slightly while succeeding in maintaining its relative ranking. The second in 1985 has much raised its ranking along with absolute unit costs. In general, the slope of the average cost curve for the foundry industry has tapered off, in accordance with Heckscher information of course. This development indicates that in the main part of average capacity, technical differences have decreased.

In the future, the development may show a decline in the cost graphs of the industry, but concurrently differences between the foundries may widen, reflecting the dispersion of the clayness in individual foundries in adapting to new technologies. This may lead to some marginal units being closed.

Finally we turn to the measurement of technical change. In practice, the measurement of technical change, or total factor productivity, is performed along the expansion paths corresponding the same, given input prices in the graphs of the short-run functions to be compared at selected output levels. The following calculation is performed at 1985 prices.

In estimating technical change, it may be possible to utilise numerical, local measurements like (3.1.1) or (3.1.2) to estimate the rate of change from the standpoint of total factor productivity or to obtain consistent measurement (4.1.2) from the standpoint of production cost savings. In this paper, we adopt the cost-based measurement (4.4.1) computed at 1985 prices instead of a total factor productivity measurement (4.1.1.). The rate of technical change at certain industry output levels is given in table 4.5.1.

Table 4.6.1. Rate of technical change in the Finnish iron foundry industry between the years 1978 and 1985 in average yearly percentages.

Output level	ktonnes			
FRONTIER	20	40	60	80
4.8	4.7	3.7	2.9	1.5

It is worth noting that using some other prices, the measurements can differ slightly, for the substitution regions are generally narrow.

The rate of technical change is relatively more rapid at the best part of capacity, mirrored in the development of the best unit shown in Table 3.3.1. A point to be noted is that the figures are not fully compatible, because the micro level calculations in section 3.3 are performed at the observed capacity levels of the individual foundries, but the industry level calculations are performed in this section assume that the micro units are running at full capacity and that the input coefficients are independent of capacity utilisation. In general, the rate slows at higher industry capacity levels.

It is difficult to compare the rate of technical change to other studies, for only a few examples are available of the industries to which the method is applied: Cf. Førsund & Hjalmarsson (1984), Førsund, Hjalmarsson, Eitrheim, Karko, Summa (1985), Summa (1986). It should also be borne in mind that the observation period is relatively short. ETLA's Economic Prospects 4/1987 reported that the average annual growth rate of total engineering industries was in 1978-86 about 5 %, or 1.4 percentage points over the long-run average. The corresponding rate in basic metal industries was about 5.2 %, the rate being 0.7 percentage units over the long-run average. In metal and engineering industries the rate was highest among the industries studied.

5. RESUME

The iron foundry industry is a small but significant part of the metal and engineering industry in Finland. The branch has confronted a relative decline in output demand since the beginning of the 1980′s, coming hand-in-hand with severe overcapacity and the weak economic performance of the branch. The technologies of the industry are mature and in general capacity is old. In the near time horizon market conditions will remain virtually unchanged, and the demand for castings will decline relative to the demand for metal and engineering industry products. The need to restructure the industry remains evident.

This paper endeavours to monitor the iron foundry industry from the structural viewpoint and estimate some measurements of the technical progress both at micro level, in individual plants, and at macro level, to make interferences for the whole industry. From the methodological viewpoint, the research is carried out by using some new methods for industry studies in order to avoid the conventional assumptions lying behind the (neo)classical approaches that are widely applied in the literature. As a result, the theories based on the concept of the representative firm are rejected and differences between the firms are exploited to the maximum possible extent. A clear distinction between plant level and industry level is also made within this framework.

At micro level progress is outlined with descriptive index methods that do not resort to assumptions or the behaviour of the firm and that largely fit the illustration of development of the sample units with the aid of conventional Salter, Heckscher and related representations.

At macro level the concept of a nonparametric short-run industry production function is intensively applied, for it provides a well-defined numerical map of the structure of an industry with clearly demarcated roots in the micro units characterising the industry. Within this until recently not widely applied framework, a structure and structural change can be illuminated from several standpoints employing production or isoquant maps, scale and substitution properties as well as the corresponding unit and marginal cost points of view. By investigating changes in these characteristics of the industry, several economic and technical conclusions can be drawn on the progress occuring in the industry.

At micro level a remarkable cross-sectional dispersion is discovered between the factor input coefficients of the individual foundries in addition to some differences between the rankings of the individual foundries according to their separate individual factor coefficients. These observations reinforce the information that the techniques applied in individual foundries, though in general based on similar principles, possess individual layouts, depending on the age and product mix of the foundry in question.

Changes take place in input coefficient distributions over time, and the rankings of the individual foundries also alter somewhat. Noteworthy differences appear in the developments between labour and energy coefficient distributions, so that efforts to increase the efficiency of the process have succeeded in the different founderies to different degrees.

In general, the labour coefficients have changed in the time dimension more than the energy coefficient, revealing that technical change has been labour saving and energy consuming in relative terms. Progress of this sort is typical of manufacturing and process industries. The rate in foundries may depend on the special nature of technology applied in a individual foundry, but in general energy consumption is tightly embodied in the machinery and layout, and it is more likely to be independent of capacity utilisation than of demand for labour. It seems not possible to take advantage of energy consumption without sizeable investments in the long run, at least. However, the investment rate has been modest. Major investment peaks appeared only in the middle years of the observation period in some units. In the observation period many foundries did not invest practically at all.

The rate of total factor productivity has vastly changed in individual foundries over time. There is also a remarkable difference between the foundries. On average the rate has declined for some foundries. However, one most remember that the output measurement in terms of pure tonnes produced carried out in this paper may perhaps not be a fair measurement, for the output mix over time and the output mix between the foundries has been extensively transformed during the study period. Generally there seems to be a weak tendency that those founderies which have invested have also increased their productivity, but the panel also displays evidence of the opposite. In some founderies remarkable advantages have been achieved virtually without investment, but these results stem from the restructuring of the individual foundries. It is evident that over the longer term these opportunities will dry up.

The analysis at industry level discloses that in general the isoquant maps of the iron foundry industry have moved towards the origin with a shift to the energy axes from the year 1978 to the year 1985. At the same time their shape and local characteristics have also changed. These changes have been relatively small, however, so that the structure of the foundery industry have evolved only in a restricted sense. The rate of progress at industry level has been modest in general, or only about 1.5 % per year; at best capacity the rate has been more rapid, however, or about 4 % per year. The bias of the advantage has been in general towards labour saving, which conforms with the general lines of micro level progress.

The slope of the industry-level cost curve has not much altered, but it has declined. The slope reveals that the unit costs of the industry between capacity levels between points 2 and 8 grow at a fairly rapid rate and that the rate has accelerated somewhat during the period. The flexibility of the industry with respect to output demand at constant factor prices has contracted. The narrow shape of the feasible region of the short-run functions reflects that the flexibility of the industry at a constant output level with respect to factor prices is restricted, so that changes in relative factor prices or product demand can cause difficulties to the industry. In this situation individual foundries with a more flexible modern technology may gain relative advantages with respect to other units.

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0033A/26.09.1988