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No. 18 August 1983

Productive Performance in West German Manufacturing Industry 1970-1980; A Farrell Frontier Characterisation

Douglas Todd

Internal Paper

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ABSTRACT

Some measure of the success with which economic resources are utilised lies at the heart of any meaningful indicator of economic performance. A traditional and obvious point of departure is to say that for a given state of technical knowledge and initial endowments of factor inputs, resource allocation depends on the degree of ability to transform inputs into outputs and the relative returns which these resources can earn.

In this paper, the more recent productive performance of the West German manufacturing sector is appraised from one particular viewpoint whilst remaining firmly within what might be called the conventional framework of relating outputs to the factor inputs labour and capital.[1]

Section I provides an initial brief overview of the West German manufacturing sector over the period 1970-80. In this section, some of the more interesting trends are noted for a more detailed analysis in later sections.

Section II sets out the approach used. Again, this is not very extensive given the relatively well documented nature of the methodology. Section III takes the form of some notes on the data used with a more substantial Section IV containing the major analysis. Some more general observations and concluding comments are brought together in a final Section V.

[1] This study is the first part of a larger comparitive exercise concerned with the static productive efficiency and total factor productivity growth in the EEC countries.

CONTENTS

1. INTRODUCTION

1.1. The West German Manufacturing Sector: An Overview

In many respects, the post-war productive performance of the West German Economy overall can be regarded as a remarkable success story. In the thirty years 1950 to 1980, GDP grew at an annual rate of over 5 per cent. This figure does however mask a considerable slowing down in the trend increase as the Table below illustrates clearly.

GDP growth (%)[2]

1950 - 1980	5.2
1950 - 1960	8.0
1960 - 1970	4.7
1970 - 1980	2.8
1973 - 1980	2.3

Thus the most rapid expansion occurred during the reconstruction period, a standard which makes performance over the last decade appear rather modest. It was during these last ten years that the economy was subjected to the two oil shocks and it is of interest to see what changes have taken place. Breaking this period down a little more reveals the following picture:

Annual Average Growth Rates[3]

	GDP	Manufacturing Output
1960-73	4.5	5.2
1970-80	2.8	2.1
1970-73	3.8	3.4
1973-80	2.3	1.6
1975-80	3.5	3.3
1976-80	3.2	2.6

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[2] Source: OECD National Accounts

[3] Source: Jahresgutachten 1981/82, November 1981.

The West German Economy proved to be quite resilient to the wave of oil price increases. External competitiveness was maintained and a relatively strong exchange rate helped to reduce inflationary pressure. Both GDP and manufacturing output recovered to something closer to the performance achieved prior to 1973. Here it is worth noting the contrast with the United Kingdom where in the face of such price increases, the existence of substantial oil reserves brought about a rise in the real exchange rate. This has tended to depress output and reduce the share of manufacturing.[4] The German manufacturing sector in effect has had little choice but to try and absorb the oil price increases and attempt to maintain competitiveness in its tradeable goods sector. Nevertheless, capacity utilisation in the German manufacturing sector has declined from 96.2 per cent in 1970 to a low of 82.9 per cent in the greatly depressed year of 1975. Thereafter, it has recovered to remain at around 90 per cent over the last four years of the decade.

From 1970, there has been an almost unbroken decline in numbers employed totalling nearly 1.16 millions, that is a fall of 1.45 per cent per annum. The volume of capital measured by the stock of gross fixed assets, on the other hand, has exhibited a steady rise at an annual average rate of 3.06 per cent. The ratio of capital to labour therefore rose at a rapid rate (4.6 per annum) over the ten years, whereas capital productivity fell at a rate of 1 per cent per annum.

Labour productivity growth measured in terms of numbers employed rose at 3.6 per cent per annum. Measured in terms of output per man hour worked, the figure is 4.8 per cent. Unit labour costs given here by the ratio of wages and salaries to volume of net output increased at an annual average rate of 5.1 per cent. Hence, on average, unit cost increases were not very much out of line with increases in labour productivity, taking the period as a whole. There were, however, periods when significant departures occurred; 1970 to 1974 for example, when the growth of unit wage costs exceeded output per man hour by 2 per cent per annum and output per employee by 2.8 per cent per annum.

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[4] See P. Forsyth and J.A. Kay (1979) and Byatt et al (1982).

There has been also a strongly inverse relationship between labour productivity on the one hand and capital productivity on the other. Chart I illustrates the main trends in productivity growth over this period.

Within the manufacturing sector there were some structural changes which are summarised in Table I.

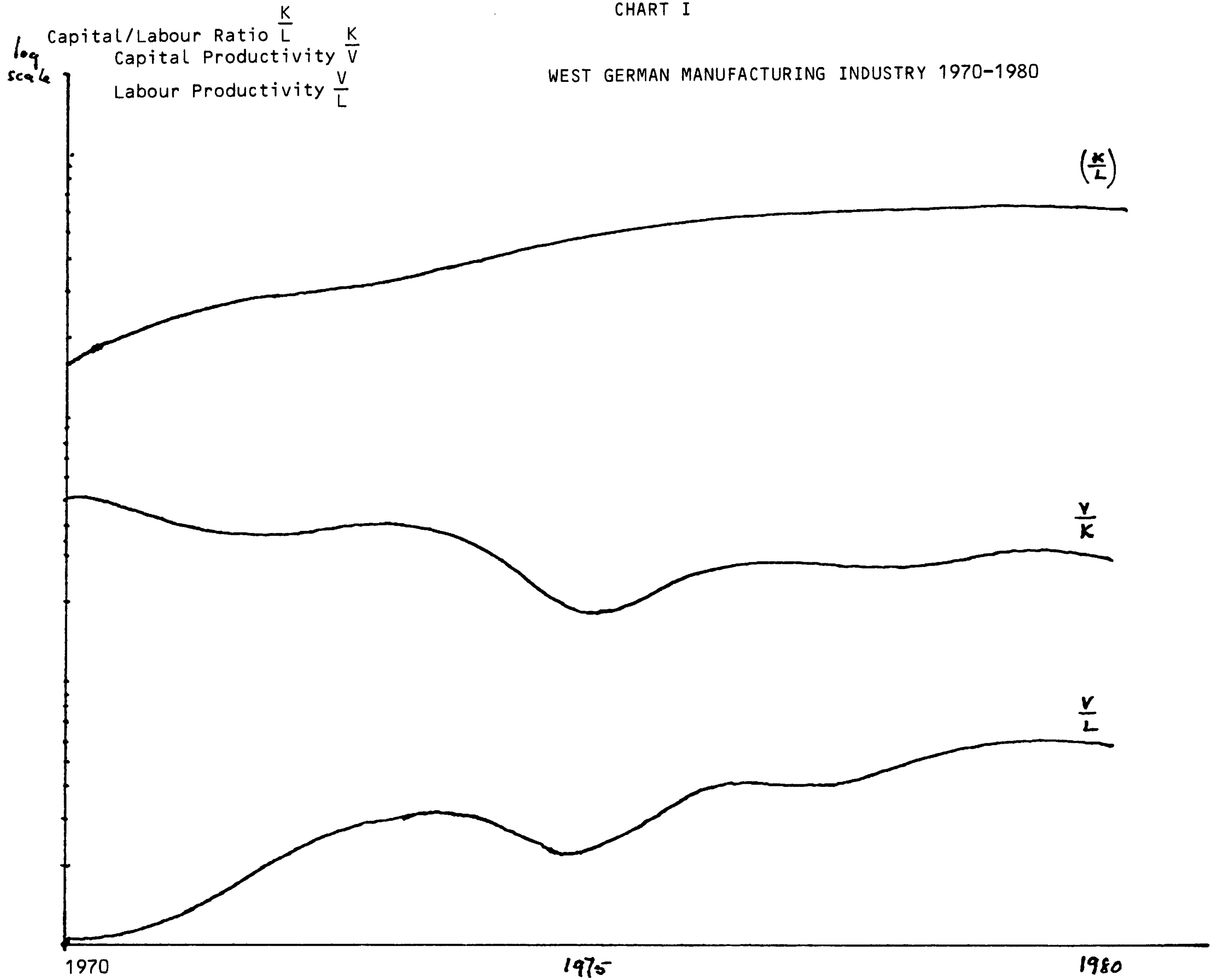
Table I

Sectoral Shares

	1970	1973	1975	1980
Manufacturing Output / GDP	41.2	41.9	40.4	40.3
Basic Manufactures / Total Manufacturing Output	27.5	28.4	26.9	26.9
Capital Goods / Total Manufacturing Output	41.1	40.2	40.5	41.3
Consumer Goods / Total Manufacturing Output	18.9	19.2	18.9	18.6
Chemicals, Vehicles, Electrical and Engineering / Total Manufacturing Output	40.0	40.8	41.1	41.7
Shipbuilding, Textiles, Iron and Steel / Total Manufacturing Output	5.6	5.2	5.4	4.4

CHART I

WEST GERMAN MANUFACTURING INDUSTRY 1970-1980



There was a slight fall in the share of Basic Manufactures due to the relative decline of the heavy steel industry. Most noticeable where output matters, is the continuing growth of what are in post war terms the more traditional sectors vehicles, chemicals and engineering and the decline of older sectors such as shipbuilding and textiles.

This view is, however, somewhat superficial when the contributions of both labour and capital are taken into account; the picture now becomes somewhat more complex. Further, the kind of interpretation which is placed on these factors depends to some extent on the techniques used and this is the area to which we now turn.

II. The Productive Efficiency Approach

The relevant literature provides an enormous number of examples of comparative performance measures which are based on one or more partial indicators. Easily the most popular are the rate of return on capital and output per unit of labour, with the relevant variables being defined in a variety of ways. However, if social efficiency or some notion of national resource allocation is the object of interest, it makes no real sense to assume that maximising say the return to labour alone is necessarily preferable to any other measure of performance. In 'economic' terms, a low figure for say labour productivity can be generated just as 'efficiently' as a much higher figure. In the production process, all factors are relevant and a meaningful performance measure or assessment of performance should attempt to take these into account.

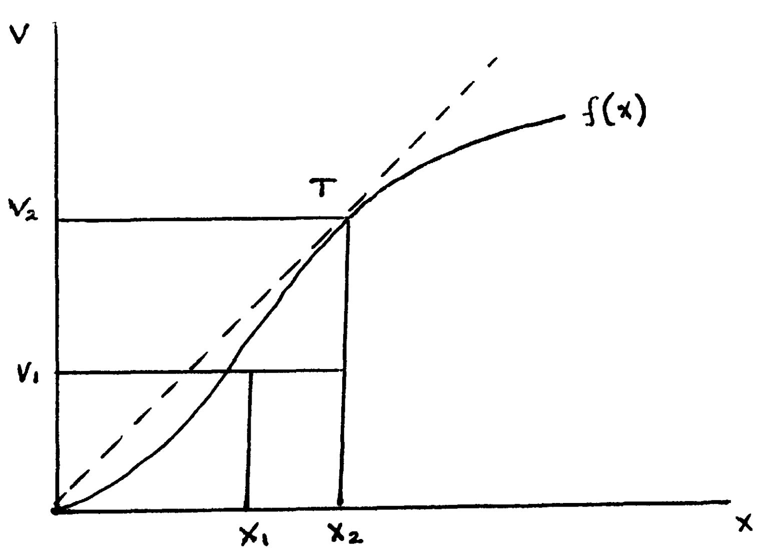
Economists traditionally have attempted to cope with the multi-factor case by specifying and estimating explicit forms of production function in order to identify contributions separately. In the time series case it is usual to make some assumptions about the embodiment or otherwise of technical progress. Alternatively, one might specify one or more total factor productivity measures taking account of technical progess as a residual element.

In this exercise, observations on sectors or manufacturing industry cover ten years only which effectively rules out a fully fledged econometric time series study. However, one candidate for consideration is set in static productive performance terms being an application of the technique suggested first by M.J. Farrell in his seminal article (Farrell 1957). We start first of all with a description of the motives underlying this methodology leading to a discussion of strengths and weaknesses.

II(i) <u>Technical Efficiency</u>

In economic terms, as we have mentioned, a fundamental approach to the productive efficiency problem is to use the notion of a production function which relates flows of factor services to a given output. In its more general form, the production function being essentially a micro concept defines either a maximum output yielded by given inputs, or alternatively the minimum inputs required to achieve a given output. Figure 1 illustrates these two versions for the single output single input case:

Figure 1



If output V is held constant, one measure of productive efficiency is given in Figure 1 by

$$\frac{X1}{V1} \bigg/ \frac{X2}{V1} \quad = \quad \left.\frac{X1}{X2}\right| \quad V \text{ const} \qquad (1)$$

Alternatively, for constant input we have:

$$\frac{X2}{V2} \bigg/ \frac{X2}{V1} \quad = \quad \left.\frac{V1}{V2}\right| \quad X \text{ const.} \qquad (2)$$

We have therefore a production boundary conditional on a given state of technical knowledge and set of production techniques. One cannot do better in a purely technical sense than produce on the boundary or frontier as defined by the function f(X). It should be noted however that the above two measures are not necessarily the same and we will return to this point again later in the discussion.

One well known interpretation is to say that prior to an investment taking place, the production function takes an ex-ante form. The set of latest or best practice techniques yields a frontier or isoquant which is convex from below. Once the investment decision is taken however the production function is in effect frozen and assumes an ex-post character embodying the more recent techniques and remaining unchanged. The boundary now is defined by the maximum utilisation of the chosen capital stock and labour supply. Over time, the ex-ante frontier will tend to move as improvements in the state of technical knowledge take place. In addition to this, as relative factor prices change, the convolution of price changes of both labour skills and capital goods of the latest vintage makes such ex-ante relationships very difficult if not impossible to identify.

From the viewpoint of an individual firm, the best that can be achieved is to be on the boundary or frontier of the best practice technique at the correct set of relative factor prices. The position of other firms can then be compared with such a point on the best practice boundary and this provides one standard against which efficiency differences can be compared. Excluding price or allocative efficiency effects, then simply being on the frontier is the relevant criterion for maximum success in technical terms.

This basic idea was first given empirical significance by Farrell in his paper cited above. The approach is to construct an innermost or 'technically efficient' frontier from a set of observations on factor inputs per unit of output defined for a given set of firms or industries. The frontier thus generated is best-practice only but nonetheless importantly in the sense that those observations which define it <u>reveal</u> that they are capable of producing a unit of net output whilst utilising smaller factor input proportions than are other firms.

Figures 2 and 3 below illustrate the Farrell approach in two factor input space

Figure 2

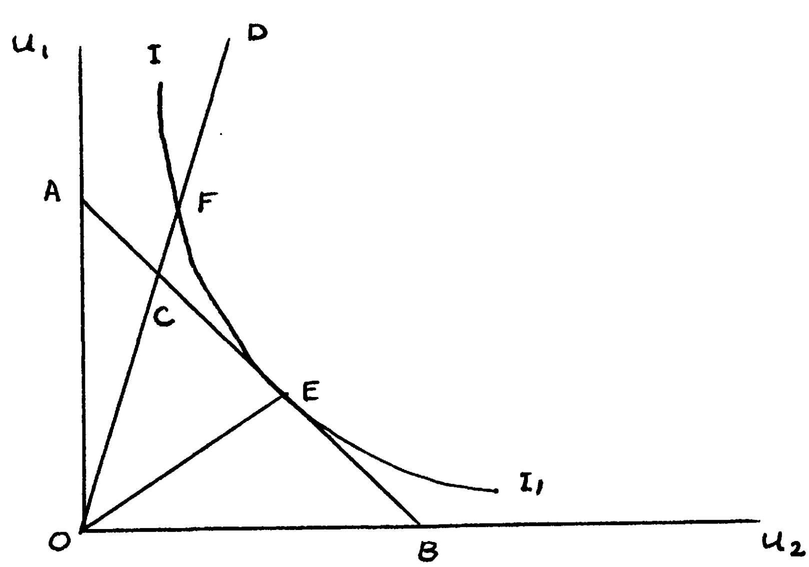
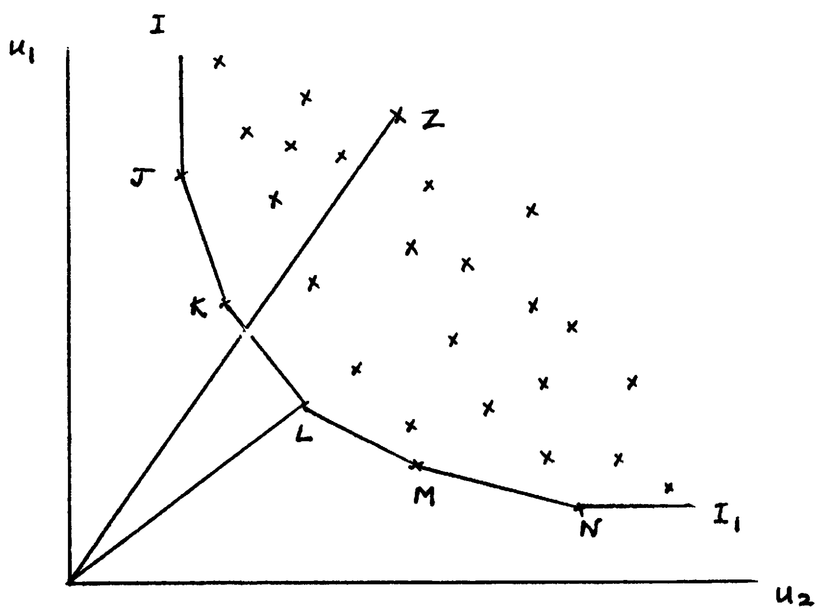


Figure 2 is the usual isoquant diagram where the preferred point of production is F; here the production unit is producing maximum output at the correct relative price given by the tangency of AB to the frontier $I - I_1$. Production unit D however is inefficient on two criteria. Firstly it is operating away from the production frontier and the ratio OE/OD is Farrell's indicator of this technical inefficiency. Secondly, the ray OD cuts the frontier at an implied relative price ratio which is different from that at F. That is to say, input U_2 is relatively more expensive than would be the case at F. Such price or allocative inefficiency, Farrell denoted by OC/OE. Overall efficiency is thus $OE_{/OD} \cdot OC_{/OE} = OC_{/OD}$[5]

Concentrating on technical or productive performance, the empirical analogue of the above is represented in Figure 3.

Figure 3



[5] The Farrell construction bears some close similarity to the welfare 'distance' measure used in Section 9 of the early paper by Debreu (1951).

Each point represents the observed unit factor requirements of a firm or industry. Observation Z has technical efficiency $OW_{/OZ}$ relative to the convex frontier $I - I^1$ constructed from the innermost set of observations. All points such as J, K etc have maximum revealed efficiency of unity, e.g, OL/OL = 1. Observation Z is thus assessed relative to a hypothetical observation W along the ray OZ and which is assumed to lie in the efficient production set as defined by $I - I_1$. Hence comparisons are set in terms of maintained factor proportions such that if say industry Z could produce using input ratio $^{U1}/U2$ at lower cost, it would move inwards along the factor ray OZ.

Whilst the ideas which lie behind the above are extremely simple and certainly appealing, the implied assumptions necessary to generate meaningful results can be demanding.

First of all, one can see intuitively that efficiency comparisons made on the above basis assume first degree homogeneity in the underlying production technology. In the absence of such a restriction, standardising along the unit input ray such as OZ in Figure 3 would not be possible in these same terms.

Taking this a little further, if the production function is

$$V = f(x_1, x_2, x_3 \; . \; . \; . \; . \; x_n)$$

following Frisch (1965, Chapter 5) we can write

$$f(\lambda x_1, \lambda x_2, \; . \; . \; . \; . \; . \; \lambda x_n) = f(\lambda x) = f(X)\lambda^e \qquad (3)$$

where Frisch defines e as the average size of the elasticity of scale or passus coefficient over the interval $(\lambda i; 1)$. Interest in this particular formulation arises from the fact that as demonstrated by Forsund and Hjalmarsson (1974), the two measures of productive or technical efficiency illustrated in Figure 1 and relationships (1) and (2) can be related in a simple way.

Given (3), any actual output xi can be defined in terms of the technical frontier as λxi. Hence, comparisons can be made by means of the scaling factor λ. From Figure 1 and expression (1) we can then write

$$E_1 = \frac{\lambda X}{X} = \lambda$$

and

$$E_2 = \frac{f(\lambda X)}{f(x)}$$

from (3)

$$\lambda^e = \frac{f(\lambda X)}{f(X)}$$

or

$$e = \frac{\log \frac{f(\lambda x)}{f(X)}}{\log \lambda}$$

so that

$$e = \frac{\log E_2}{\log E_1}$$

We now see that if and only if the elasticity of scale is equal to unity, will the two alternative measures of technical efficiency be identical, i.e, $E_1 = E_2$. In other words, since from (3), the elasticity of scale is the degree of homogeneity, it is only production technologies of degree one homogeneity which have this property. Referring back to Figure 1, output per unit of input is maximised at the point of tangency T where the ray OT has the desired property.

It is now clear that the convex hull approach suggested and as employed by Farrell imposes this particular restriction and the fact must be borne in mind in application (6).

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[6]The literature in this area has grown enormously in the last eight years or so. Many approaches and analyses of efficiency measures for both homogeneous & inhomogeneous functions have been suggested and developed; see for example Faré and Knox Lovell (1978), Raymond Kopp, (1981), the excellent article by Forsund and Hjalmarsson (1974) and Forsund et al. (1980).

II(ii) Further limitations

Extensive discussions on the characteristics and limitations of the Farrell frontier method are available in the references cited already. However, it is helpful to mention briefly some of the more important elements since these bear heavily upon the interpreation of any empirical results derived from use of this particular methodology.

First of all, unlike the more conventional production function approach, the Farrell technique applied strictly is a non-parametric technique. It is therefore difficult, if not impossible, to apply the usual classical methods of statistical inference. Secondly, the constructed convex hull is a support set generated from marginal data only. It is the innermost 'outliers' which define the frontier rather than the whole sample and in this classical inferential context, the technique makes inefficient use of all information. Finally, there is always the problem of different qualities of factor inputs employed. A production unit could be judged efficient in a purely static technical sense and yet be operating with older machines and a labour force which lacks more up to date training skills. These are points which are all taken up again at various stages of the analysis.

Despite these restrictions, the Farrell approach remains a very simple technique in that set of more recent approaches to frontier function estimation[7]. In this respect, one is closer to the textbook concept as opposed to the average function which is used more often in econometric work.

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[7]See for example Meller (1975) and Todd (1971, 1977)

III. The Data

The analysis is based on observations on net output volume, potential net output, numbers employed, average hours worked, wages and salaries per employee and the volume of fixed assets for 32 sectors of West German manufacturing industry over the period 1970-1980[9]. The observations on output and capital are expressed in terms of base year 1970.

Whilst 32 industry groups are worthy of investigation in their own right, for the purposes of the analysis here this does nevertheless represent a high degree of aggregation. The basic theoretical underpinnings as we know, are expressed quite explicitly in terms of single production units with homogeneous product markets. Faced with this, it is tempting to argue that comparisons are likely to be meaningless, or at best somewhat misleading. There are two replies to this, which although not entirely satisfactory, suggest nevertheless that the investigation is worth continuing.

The first quite simply, is that questions are and indeed can be expected on such matters as whether manufacturing as a whole is performing well; whether say the chemicals sector is better or worse than engineering or whatever. In an everyday situation it is not sufficient to argue that before any inferences can be made, one needs to disaggregate and yet disaggregate further.

[9] The Data source is DIW "Produktionsvolumen etc" - Rolf Krengel et al, Berlin, October 1981. The OECD "Historical Statistics 1960-1981-1983, suggest that industrial production in 1970 was slightly more above trend than was the year 1980. Thus whilst neither end year can be described as 'normal', the discrepancy is not great.

Answers are needed at different levels, e.g, plants within firms, firms within product groups, industries within the economy and so on.

A second and more formal reply is to regard an industry's ratios of labour and capital per unit of net output as weighted averages of those ratios of its constituent firms.

Thus for the jth industry we can write

$$V_j = (wL)ij + (rK)ij$$

Denoting an arbitrary input output ratio as u, that is

$$\frac{K}{V} = u \quad \text{then:-}$$

$$uj = \frac{\sum j u \, nij}{\sum i \; Vij} = \sum i \; uij \; \frac{Vij}{\sum i \; Vij}$$

The factor/output ratio uj are therefore weighted averages with weights Vij.

This obscures, of course, any variations within broad industry groups and thus focuses attention on variations between such groups. If the former is known or thought to be the more important, then if possible this will demand further disaggregation.

Whereas the DIW published series provides for each industry a single estimated figure for fixed assets employed [10], there are several alternative definitions for the labour input. Numbers employed is probably the most widely recognised definition of labour input, and figures for output per employee are quoted extensively in most countries. Although output per head is of interest in its own right there are other possibilities. Hours

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10 Vernon Smith (1961) however, seems to favour a stock concept.

worked per employee is somewhat closer to a flow of services concept and which seems more appropriate in a production function context. This however does not take into account differences in quality or work intensity. Here it is possible that real earnings per employee has some attractions insofar as payments to labour are expected to reflect, in part, different skills and perhaps, differences between male and female work intensity.

Because there is no unique preference for one specification over another in the results which are quoted, some examples from all three are sometimes given. In fact, however, the average hours and real earnings variants turned out to be very close indeed in the vast majority of cases.

On the question of which deflator for earnings per employee, again the choice is not entirely obvious. From the viewpoint of the employee, the purchasing power of his money reward is what matters and hence a general consumer price index is appropriate. The firm or industry however may view things differently and assess factor returns in terms of its own product price. That is to say the 'own product' real wage is the relevant specification. Fortunately, this problem is easily resolved because for the West German economy over the period 1970-1980, the consumer price and ex-works manufacturing output price indices tracked each other closely so that choice of deflator is not a serious problem.

In presenting and discussing results in experiments of this sort, inevitably one runs into a problem of selection. It is clear that one cannot set out everything and this makes the issue of exactly what to concentrate on something of a problem.

The decade 1970-1980 as we know is an awkward one for economic analysis. The first oil shock of 1973 led to a sharp recession in the manufacturing sector in 1975. The year 1976 was one of very rapid recovery followed by an easing down in the next two years. 1979, however, was another year of relative boom in output which preceeded the second oil price hike. Hence, there is something in the notion that almost every year is a special event. Simple averaging obscures significant changes whereas too much concern with individual years diverts attention from the trend. Further, given the sharp divergences it is almost impossible to choose a suitable base year for all purposes.

The simplest but by no means wholly satisfactory approach adopted here is to focus attention on the two end years 1970 and 1980.(See foot-note 9). At various points however, explicit reference is made to an individual intermediate year where this is thought to illuminate the discussion.

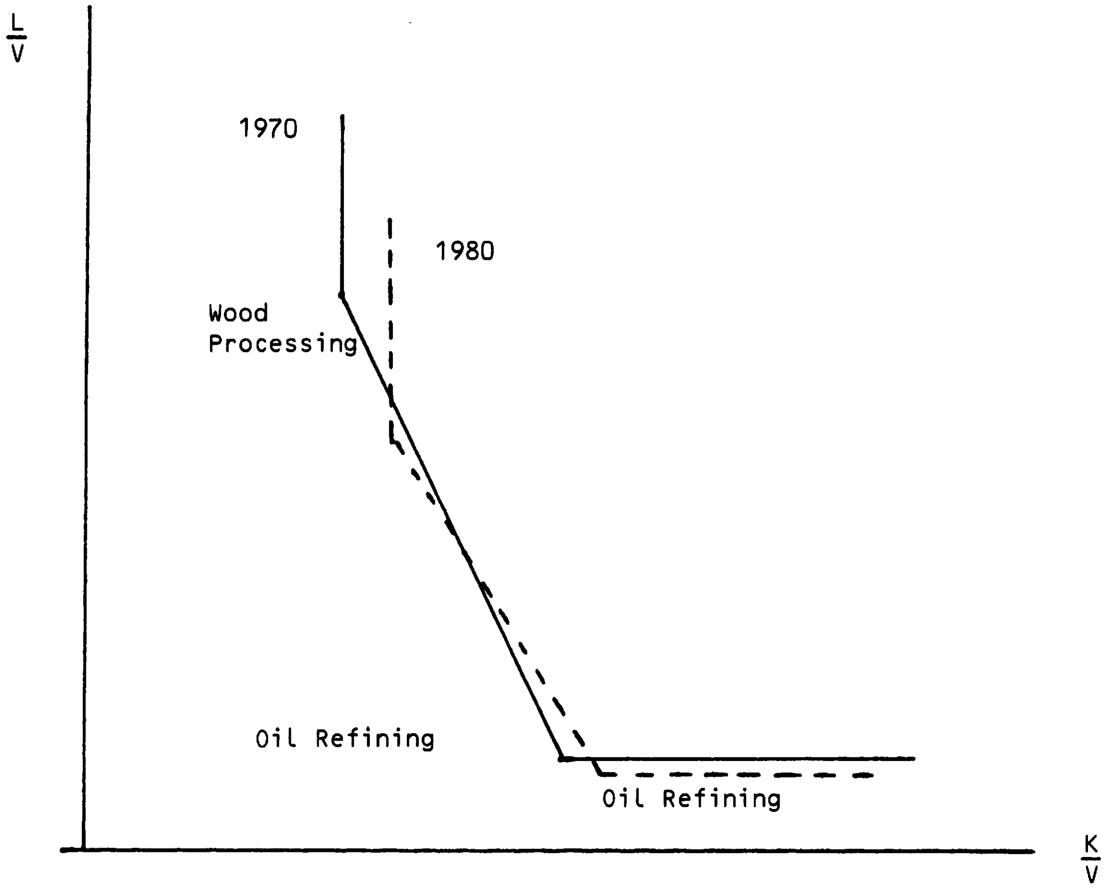
IV. Productive Efficiency

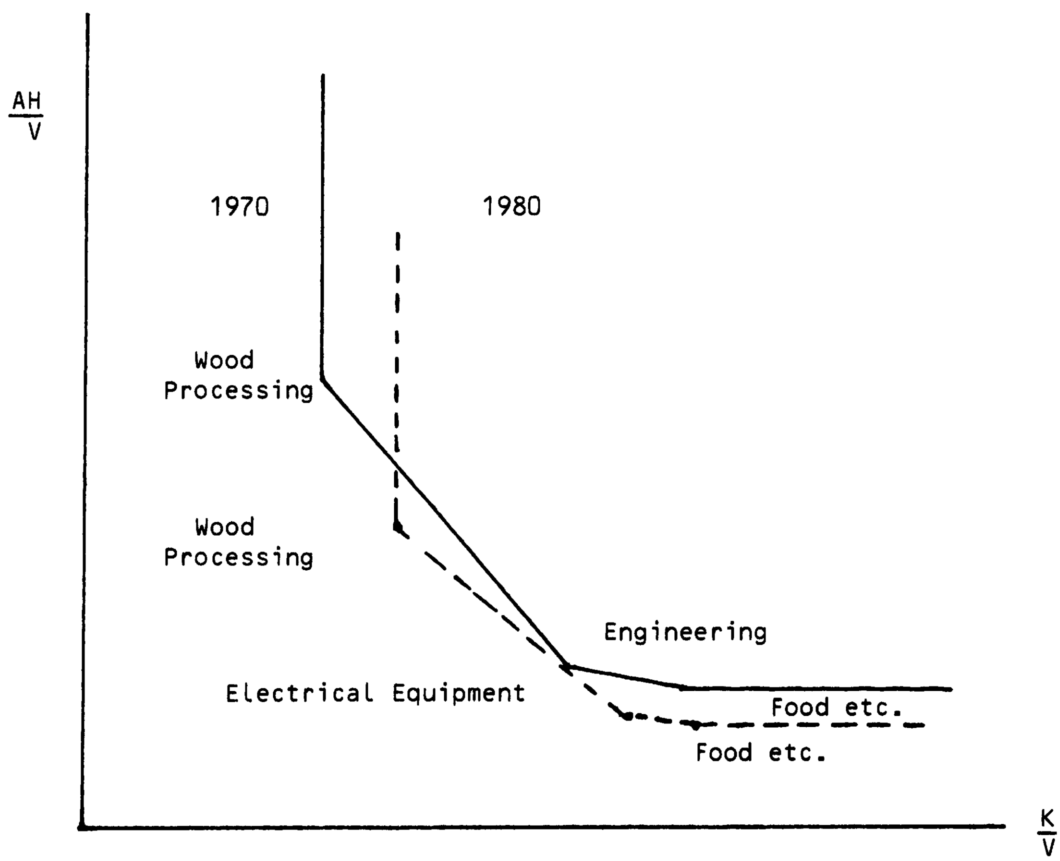
The discussion here describes the set of experiments using the Farrell frontier methodology. The approach initially is to estimate a set of two factor Farrell frontiers for each of the years in the sample. Detailed figures are given in Annex Table I.

Charts II and III provide an illustration of technical frontiers for actual output and also for the comparison between actual and capacity output - 1970 and 1980; where the labour input is expressed in terms of numbers employed and hours per man respectively.

The first point to note in Chart II is that there is not a great deal of difference between the two sets of points. There is some suggestion that the technical frontier has shifted inwards slightly towards the origin over the decade. The frontier for 1975, the most depressed year in the sample and omitted, in order to avoid overcomplicating the graphs, lies well inside the two boundaries given here. The second point is that almost identical industries lie on the frontiers. Indeed for each individual year, what might be called the technical leaders in these static terms change hardly at all. In summary, these are

CHART II WEST GERMAN MANUFACTURING





Oil Refining
Wood Processing
Food, Drink and Tobacco
Engineering
Electrical Equipment

where each of these, of course, has a revealed efficiency index of unity. Thus oil refining because it has a relatively high capital labour ratio is in these terms no more or less efficient than wood processing which is relatively labour intensive. This is the simple essence of the multi-factor approach. A labour productivity comparison taken in isolation would, of course, produce a different ranking, and more is said about this later.

One further point of interest is that over time, the technical frontier tends to shift downwards and to the right which is an indication of increasing capital intensity. This general drift is illustrated in Chart IV which is drawn on a double logarithmic scale. The advantage here is that equi-proportionate efficiency differences are equi-distant on the graph. Four illustrative labour/capital ratios are shown on the 1980 static dispersion and it can be seen that the 1980 ratio has shifted downwards.

Chart III is a simple representation of how the gap between actual and capacity output compared at best efficiency as revealed, has opened up over the period. The two frontiers for the most depressed year 1975 (again not shown), produce a much wider divergence as one might expect.

Because each industry is assessed relative to the frontier generated in any given year, individual comparisons of industries across years are neither obvious nor easy to make. What is of some interest, however, is the technical efficiency distribution relative to any given frontier

CHART III

WEST GERMAN MANUFACTURING

Actual and Capacity Output Farrell Frontiers

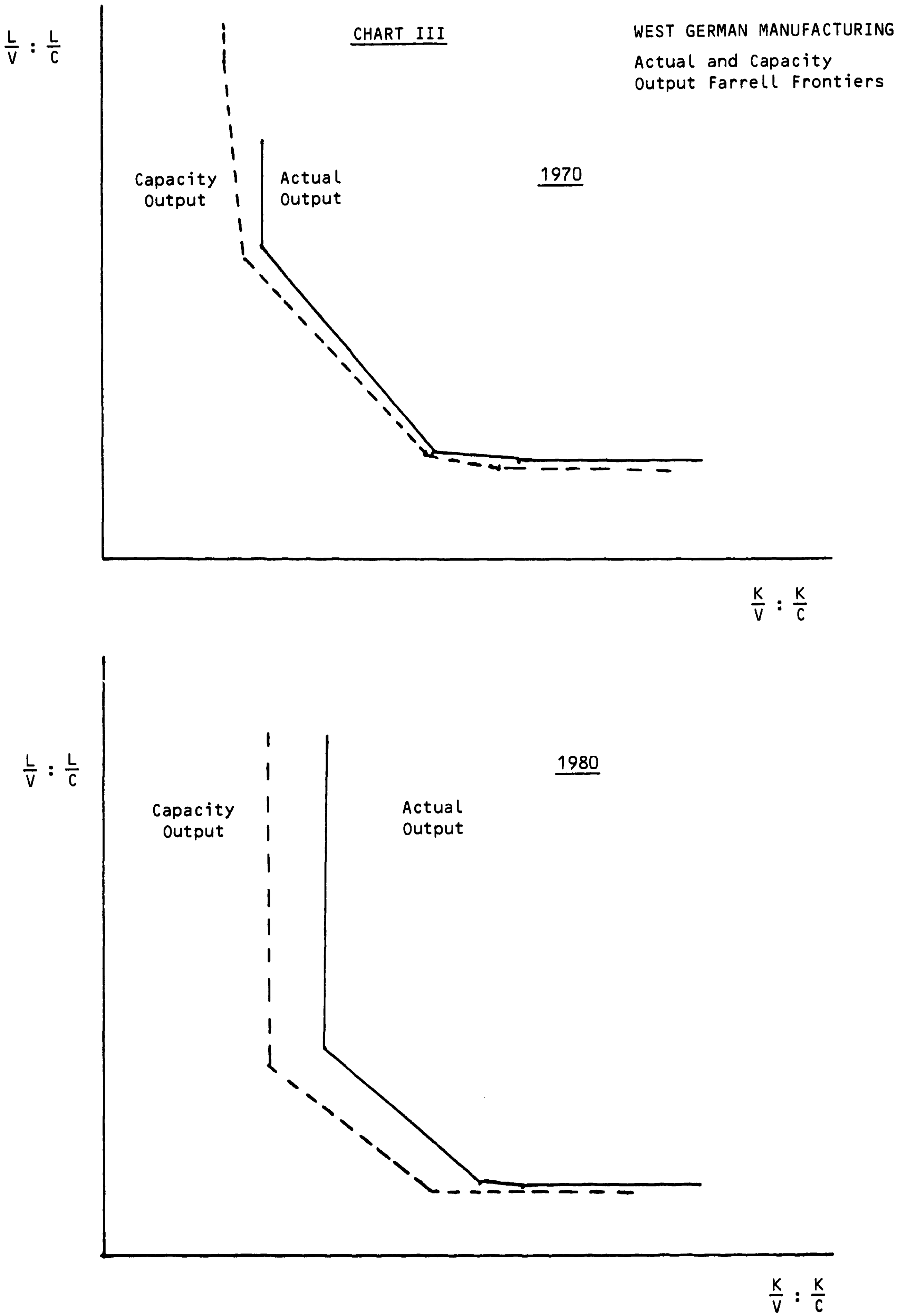
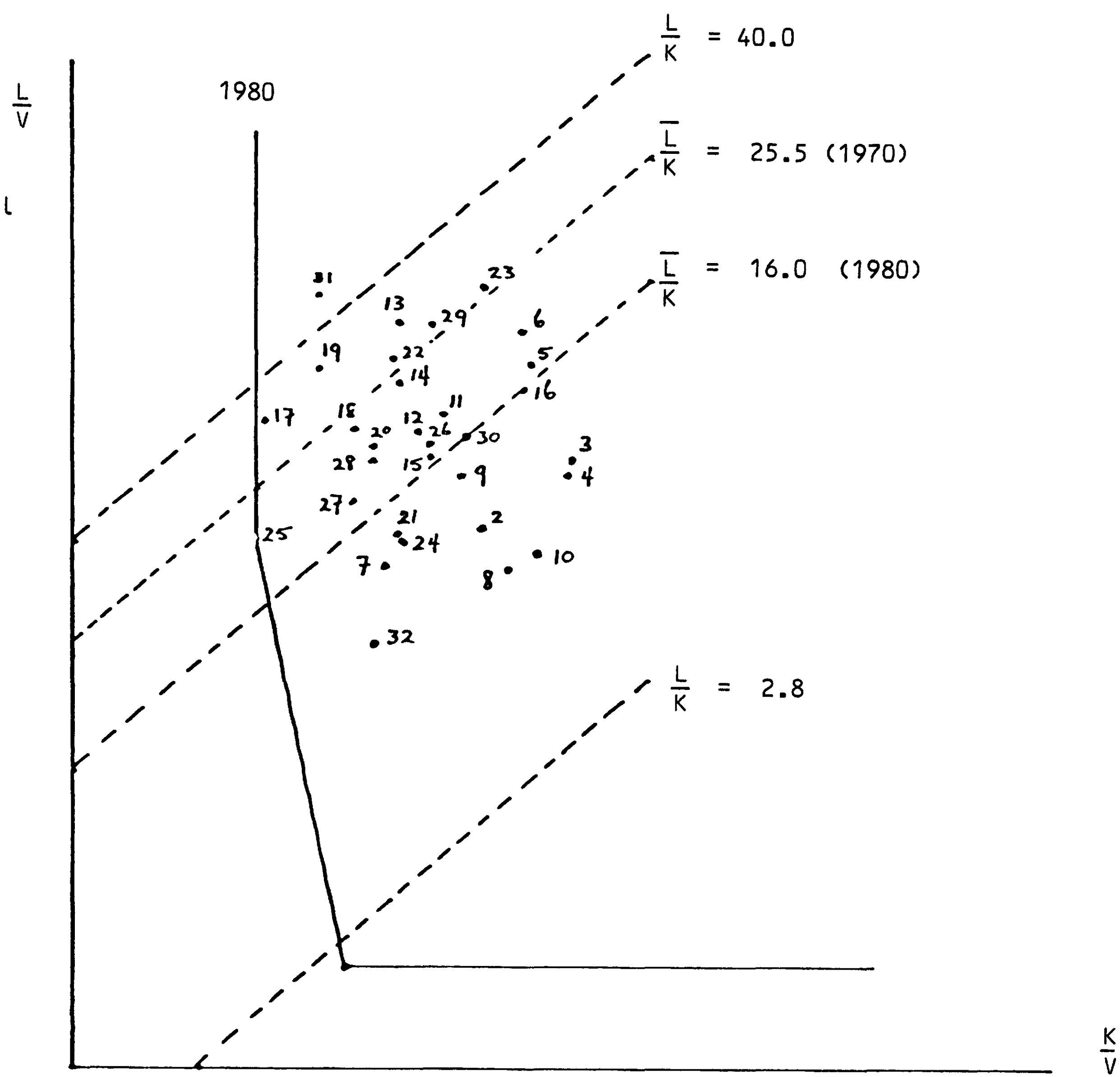


CHART IV

EFFICIENCY DISPERSION
and the Labour/Capital
Ratio



The figures on the Chart refer to industry number, e.g, 1 = Oil
Refineries etc; see Table 1 in the Annex.

and how this might have moved through time. Chart V shows that the cumulative frequency distribution of efficiency indices moved relatively little when the two end years are compared. In other words, relative to own frontier there is little other than a slight suggestion that the movement is north eastwards, the final point of which is where all industries would lie on the technical frontier.

The question arises as to how one might interpret such information. In static snapshots such as those given here, one view is that it is desirable that industries and firms be close to the frontier. If this is so, one may feel that the resource allocation system is operating reasonably well. A relatively small dispersion would then be judged more satisfactory than one which is larger. On the other hand, the market economy is a witness of constant change. Capital equipment is replaced and labour skills adapt. Both the economy and individual industry frontiers are shifting. This vintage factor input interpretation suggests therefore a rather different picture. If firms are following something close to an optimal replacement policy, those best practice firms which adapt quickly to increases in market demand will push the productive frontier inwards. Firms and industries in weaker and technically less progressive sectors will not be able to respond in the same fashion. This will, if anything, increase the dispersion from the revealed efficiency boundary[11].

The technique as used here can therefore lead to an apparently pessimistic view of the allocative process. A wide dispersion of skew distribution when viewed as a cross-section of information need not be an indication that industrial structure

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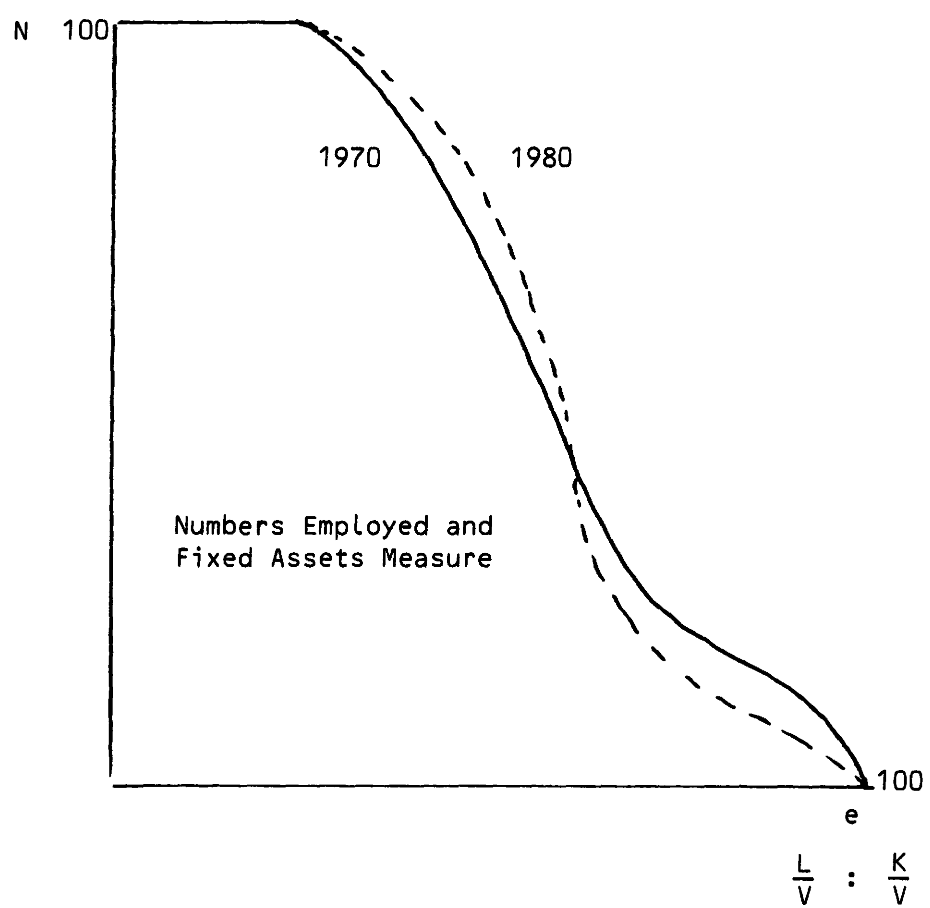
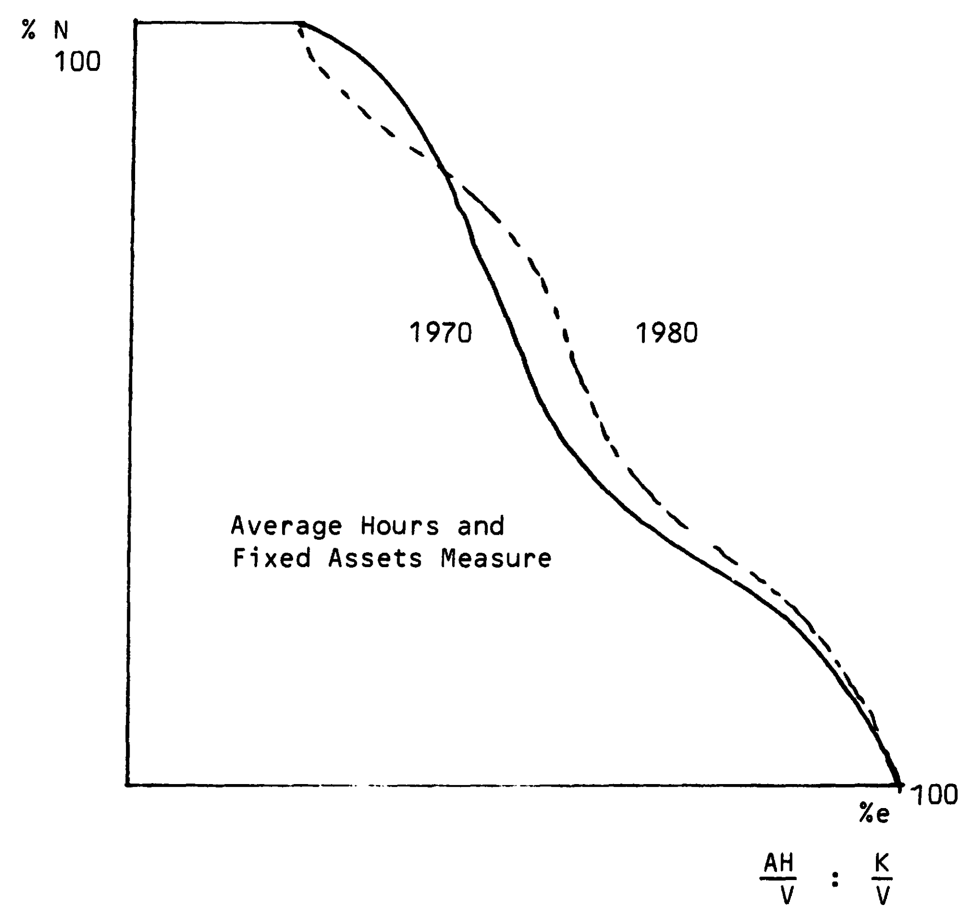
11 On the other hand, if the earnings measure of the labour input is used, it could be argued that in the weaker sectors, competitive forces will tend to drive real wages down relative to those in stronger markets. This will help to maintain efficiency and thus act in the opposite way.

CHART V

Cumulative Distribution of Productive Efficiency 1970 and 1980

(Numbers employed and Average Hours worked)





is 'inefficient'. Hjalmarrson[12] (1973) has suggested that the real problem is one of knowing how to optimise the process of structural change. In the absence of knowledge on plant vintages, replacement policies and labour skills, it is impossible to be more precise about the issues involved.

Looking at the frontiers individually, all variants on the labour input indicate a declining variance of the efficiency indices around the mean over the sample period. Table 2 below gives the profile for a few of the years in question. One interpretation of this trend might be that gradual slowing down in the growth performance

Table 2

Standard Deviation - Farrell Technical Efficiency %

	Nos. Employed	Average Hours	Real Average Compensation
1970	19.56	24.04	23.68
1973	18.82	24.10	22.49
1976	18.19	22.66	21.10
1978	17.0	22.24	21.03
1980	17.2	22.10	20.08

overall in the West German Manufacturing Sector is consistent with a narrowing of differences in productive efficiency between individual industries. 'Best practice' technologies have not been introduced and grown fast enough to maintain the impetus so characteristic of the earlier post-war decades. Again, the static comparisons show little change in either the positioning or the constituent members of the convex frontiers 1970 to 1980.

Further light on this observation is provided by a series of rank correlations of indices for the 32 sectors between individual years. First of all, the Spearman coefficient of rank correlation

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[12] L. Hjalmarrson "On Optimal Structural Change", Swedish Journal of Economics 1973.

for the three variants was computed for the end year 1980. These are given below.

Rank Correlations - 1980

e_L e_H	e_L e_W	e_H e_W
0.814	0.868	0.988

Where e_L, e_H and e_W refer to the index based on numbers employed, hours and earnings variants. As one might expect intuitively, the correspondence by rank is greatest between the two flow specifications of the labour input.

Next, year by year rankings were computed using the average hours variant. Surprisingly we find that on the basis of the Farrell approach, the industry rankings change very little indeed through the sample period and some examples are given below.

1980/1970	1975/1970	1976/1970
0.951	0.946	0.953

We noted earlier that the best performers in static terms remain virtually unchanged and now we see that this applies to virtually the whole sample. Thus those improvements which have occurred would seem to be through a movement in the sector overall, with rather less emphasis on relative movements within the sector. The weakest sectors, for example, namely Shipbuilding, Iron and Steel Foundries, Non-Ferrous Metals and Cellulose, paper and board, maintain their positions in the rankings also.

(i) Extensions of the Static Interpretation

A number of the more important weaknesses of the Farrell characterisation of productive efficiency have been mentioned already. The non-parametric nature of the technique is a particular limitation.

One way of accommodating this is to specify say a Cobb-Douglas technology

$$V = F\,(x)\,e^{-\mu}$$

where log F (•) $= \sum \alpha i \log xi$; the error term μ has the property which implies $V \leq F(X)$. This conforms with the basic requirements of a deterministic production frontier in that all deviations fall on one side of the convex hull. (In this formulation one need not of course constrain the $\sum \alpha i = 1$, the linear homogeneity assumption.) A very simple intuitive procedure therefore is to estimate a functional form

$$\log V = \log \alpha + \sum \beta i \quad \log X i \quad + \quad E$$

with the intercept term $\log \alpha$ scaled so that all but one of the E_i lie beneath the regression plane. The one supporting point will therefore be maximally 'efficient'. This procedure has been shown to provide a consistent estimate of the intercept α . (See W.H. Green 1980).

Simple Cobb-Douglas equations were fitted to data for the two end years 1970 and 1980; the parameter estimates are given below in Table 3 [13]

[13] Some experiments using Kmenta's Taylor's series expansion of the standard CES form which leads to a trans-log formulation suggested again that an elasticity of substitution of around unity is what the data yields. (See Kmenta 1967). One remains uneasy however given the persistently odd discrepancy between time-series and cross-section estimates. Frequently in applied work the former yields elasticities of substitution which are well below and significantly different from unity. The cross-section evidence tends to support the Cobb-Douglas technology hypothesis.

Table 3

	Capital	Nos. Employed	Deflated Employee Compensation	Hours Worked
1970	0.6003	0.3978		
	(6.397)	(3.801)		
	0.5333		0.4623	
	(4.789)		(3.684)	
	0.5853			0.4102
	(5.954)			(3.742)
1980	0.7367	0.2951		
	(7.473)	(2.800)		
	0.6364		0.3981	
	(5.658)		(3.319)	
	0.7253			0.3074
	(7.141)			(2.816)

Shifting the intercept upwards as described enables one to calculate indices of divergence from the regression surface in much the same way as is done in the Farrell method. This was done in each case and rank orders were compared with the Farrell results for each year. The resulting Spearman coefficients are given below in Table 4 using 1980 as an example.

Figures in brackets are the usual 't' statistics

Table 4

Rank Correlation Coefficients

	Farrell (e_F) Nos. Employed	Deflated Employee Compensation	Hours Worked
Cobb-Douglas (e_{CD})			
Nos. Employed	0.920		
Deflated Employee Compensation		0.967	
Hours Worked			0.961

Thus in no case was the rank correlation coefficient below 92 per cent (the same pattern emerged in the 1970 comparisons with the lowest coefficient being 0.926).

For the numbers employed relationships, the two unadjusted intercepts turned out to be negative and of doubtful significance. (In all other cases the constant terms were insignificant also). For 1970 and 1980 we have a natural logarithm - 1.3375 and - 1.3073 respectively, which implies an annual average rate of growth of productive efficiency of around 0.3 per cent. Given the obvious degree of uncertainty surrounding these estimates one might not wish to attach much importance to them. On the other hand, the Farrell frontiers given in the Charts were seen to have moved very little over the period and the rankings obtained from the elementary Cobb-Douglas forms were very close indeed to those obtained via the non-parametric approach.

IV (ii) Some Comparisons

It is useful to compare the static productive efficiency measures here with the more popular single factor productivity indicators; output and capital per head for example.

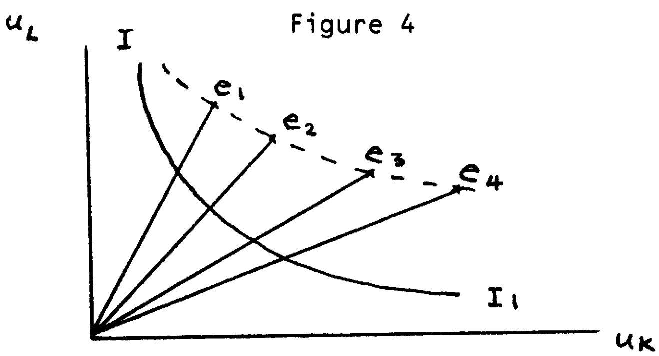
Coefficients of rank correlation relating to the end year 1980 are given in Table 5 below for Farrell frontier indices in association with the various definitions of the labour input

Table 5

eF		eF		eF	
$\frac{L}{V}$	$\frac{K}{V}$	$\frac{\bar{H}}{V}$	$\frac{K}{V}$	$\frac{\bar{W}}{V}$	$\frac{K}{V}$
0.355	0.930	0.678	0.794	0.669	0.868

In every instance there is a closer association between overall productive efficiency and capital per unit of output than with labour per unit of output. The same procedure followed with respect to the adjusted Cobb-Douglas implied indices yielded an essentially similar picture. The Spearman coefficients being 0.38 with respect to labour per unit of output and 0.88 with respect to the normalised capital variable. Given this, the suggestion is that the observations in the normalised input space are grouped in a form broadly similar to that in the illustration provided by Figure 4.

Figure 4



In this extreme case, observations with low capital per unit of output would have high efficiency and here the ranking would be exactly the opposite with e4, the least efficient being ranked the highest in terms of labour productivity.

An alternative way of looking at this feature is to say that proportionately the biggest gains to productive efficiency are likely to be achieved via increases in capital productivity. Simple log linear multiple regression relationships for the two years 1970 and 1980 yielded the following results[14]

Table 6

Dependent Variable	Independent Variable * log u_L	log u_K	$\bar{R}^2$
log e_F 1970	- 0.198	- 0.764	0.982
log e_F 1980	- 0.174	- 0.804	0.975
log e_{CD} 1970	- 0.323	- 0.687	0.844
log e_{CD} 1980	- 0.259	- 0.811	0.954

* All coefficients were significant at the one per cent level.

While one would not wish to attach too much weight to the precise figures here, the coefficient on UK is a good deal larger than that on u_L and has risen somewhat over the decade. This is a reflection of the fact that the capital/labour ratio has risen as we have seen. The 1980 Cobb-Douglas based productive efficiency estimates for example, suggest that at constant efficiency, a unit percentage charge in capital requires a reduction in labour of 3.13 per cent; this elasticity is to the ratio of the coefficient (elasticity) on capital to that on labour. For 1970 the figure is 2.12.

Referring back to Table 3 we see again that the coefficients on capital are much larger than those on labour and the 1980 figure has increased. This all suggests therefore that technical progress is West German Manufacturing over this period and on average is more likely to have been non-neutral and capital augmenting. The production function has shifted in a more capital intensive manner.

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[14] Strictly speaking, the linear regression model is inappropriate given that the dependent variable cannot exceed unity in value. Thus a 'Tobit' model is more appropriate.

If the market is operating reasonably well as an allocator of resources available, it would be comforting to know that those industries which improve or maintain productive performance see this reflected in their position in the market. In order to look at this, changes in market share between 1970 and 1980 were compared with changes in static productive efficiency assessed relative to the revealed 'best practice' frontiers.

Out of the 32 sectors examined, 15 increased or had unchanged market share over the period. Of these, 12 showed an increase in productive performance, one of which remained on the frontier in both years. Thirteen industries experienced both a decline in market share and productive performance which leaves a remaining seven sectors where the direction of change differs.

The picture overall is summarised below.

<u>Industries showing increases in or maintained market share and productive performance</u>

Non-Ferrous Metals
Chemicals
Timber and Sawmills
Cellulose Paper and Board
Electrical Equipment
Office and Data Processing Machinery
Glass Industries
Wood Processing
Paper and Board
Printing
Plastics
Food, Drink and Tobacco

Industries showing both a decline in market share and in productive performance

Stone, Clay and Sand
Iron and Steel Industries
Iron and Steel Founderies
Rubber and Asbestos
Steel Forging
Steel Construction
Engineering
Shipbuilding
Precision Engineering
Musical Instruments, Toys and Games
Fine Ceramics
Leather Goods
Clothing Industries

Industries which do not 'conform'

	change in Market share	change in Efficiency
Oil Refining	-	0
Non-Ferrous Metals Foundries	+	-
Steel Drawing and Cold Rolling Mills	-	+
Vehicle Building and Repairs	+	-
Aircraft and Aerospace	+	-
Metal Products	-	+
Textiles	-	+

In fairly general terms and referring back to the earlier observations made in Section IV, the consistently declining Sectors include more basic Sectors of the iron and steel industries together with Shipbuilding. Included also are the two engineering sectors which appear to be weakening in terms of comparative advantage. Both of these, whilst having increases in output per employee of 1.86% in each case, experienced also a reduction in output per unit of capital of 2.6% for engineering and 3.34% for precision engineering.

Of the so-called 'non-conforming' sectors, Textiles, oil refining, metal products and steel drawing have declined but done so in a manner which is consistent with efficient use of inputs. The case of textiles is especially interesting insofar as gradual withdrawal of government support and encouragement of rationalisation, including scrapping of older vintage capital seems to have produced a desired result. Clearly industries can decline but remain successful in resource use. Subsidised sectors such as Aircraft and Aerospace exhibit the opposite tendency.

V. Concluding Comments

The approach used in the major part of this exercise has a number of limitations. Being non-parametric it lies outside what might be called the more conventional statistical framework. It should be regarded as the title suggests, as one possible characterisation of productive performance; there are others.

Looking at the disaggregated picture, the results seem to be broadly consistent with the macro observation that manufacturing growth has slowed down[15]. The leading and declining sectors in Farrell efficiency terms have changed little over the past decade. The general impression therefore is one of relatively little movement between the various sectors with improvements in output per head being offset to some extent by declining capital productivity. The productive efficiency frontier moves inwards rather little and drfts in a more capital intensive direction.

The set of comparative indices of productive efficiency for any year display considerable variability as the tables indicate. The static dispersions suggest substantial differences, being a reflection also of big differences between inputs per unit of output across the industry set. In a number of respects one would not wish to become over-committed to cardinal differences

[15] See for example Klaus Hennings' Chapter 16 in Boltho (1982).

of this scale. The simple intercept adjusted Cobb-Douglas derived indices rank very closely with the Farrell set, hence an ordinal view of comparitive performance seems to be a safer interpretation.

The comparisons are based on snapshots or static views of the industry set which obscures a more dynamic analysis. It is hoped that the latter will emerge from work which is continuing in this area.

	1980		
	$\frac{L}{V}$	$\frac{K}{V}$	e_F
1. Oil Refineries	2.50	0.90	1.00
2. Stone, Clay, Sand etc.	14.51	1.54	0.51
3. Iron and Steel Industries	19.42	2.49	0.33
4. Non Ferrous Metals	18.76	2.26	0.36
5. Iron and Steel Foundries	28.74	1.89	0.37
6. Non-Ferrous Metals Foundries	32.44	1.79	0.37
7. Steel Drawing & Cold Rolling Mills	12.47	1.03	0.72
8. Chemical Industry	12.37	1.74	0.47
9. Sawmills and Timber	18.08	1.41	0.52
10. Cellulose, Paper & Board	13.29	1.96	0.42
11. Rubber and Asbestos	23.27	1.32	0.51
12. Steel Forging	21.63	1.20	0.56
13. Steel Construction	32.84	1.11	0.56
14. Engineering	25.69	1.11	0.56
15. Vehicle Building & Repairs	19.47	1.26	0.56
16. Shipbuilding	26.25	1.87	0.38
17. Aircraft and Aerospace	21.81	0.65	0.95
18. Electrical Equipment	21.51	0.93	0.67
19. Precision Engineering	27.34	0.84	0.74
20. Metal Products	19.97	0.98	0.66
21. Office & Data Processing Machinery	14.19	1.10	0.67
22. Musical Instruments, Toys, Games	28.19	1.07	0.58
23. Fine Ceramics	38.47	1.58	0.39
24. Glass Industries	14.29	1.11	0.66
25. Wood Processing	14.16	0.62	1.00
26. Paper and Board	20.74	1.24	0.55
27. Printing	16.20	0.93	0.73
28. Plastics Manufacturing	19.02	1.03	0.65
29. Leather & Leather Products	32.84	1.25	0.49
30. Textiles	22.04	1.51	0.47
31. Clothing Industry	37.35	0.79	0.78
32. Food, Drink and Tobacco	9.04	1.03	0.77

		1970	
	$\frac{L}{V}$	$\frac{K}{V}$	e_F
1. Oil Refineries	3.1	0.86	1.00
2. Stone, Clay, Sand etc.	20.93	1.33	0.52
3. Iron and Steel Industries	24.71	2.14	0.35
4. Non-Ferrous Metals	29.78	2.16	0.33
5. Iron and Steel Foundries	33.24	1.41	0.44
6. Non-Ferrous Metals Foundries	37.71	1.65	0.38
7. Steel Drawing & Cold Rolling Mills	16.80	0.95	0.71
8. Chemical Industry	18.26	1.83	0.42
9. Sawmills and Timber	27.96	1.30	0.49
10. Cellulose, Paper & Board	26.33	2.21	0.33
11. Rubber and Asbestos	32.75	1.07	0.53
12. Steel Forging	27.14	1.01	0.59
13. Steel Construction	37.61	0.83	0.63
14. Engineering	30.92	0.86	0.62
15. Vehicle Building & Repairs	22.68	1.11	0.58
16. Shipbuilding	35.45	1.46	0.42
17. Aircraft and Aerospace	34.37	0.54	0.98
18. Electrical Equipment	34.63	0.86	0.62
19. Precision Engineering	32.89	0.60	0.87
20. Metal Products	28.47	0.81	0.65
21. Office & Data Processing Machinery	31.49	1.00	0.56
22. Musical Instruments, Toys, Games	31.60	0.65	0.82
23. Fine Ceramics	45.56	1.29	0.41
24. Glass Industries	28.01	1.12	0.54
25. Wood Processing	19.13	0.53	1.00
26. Paper and Board	31.61	1.04	0.55
27. Printing	23.32	0.81	0.71
28. Plastics Manufacturing	29.04	0.93	0.60
29. Leather & Leather Products	36.30	0.89	0.59
30. Textiles	38.57	1.59	0.39
31. Clothing Industry	47.58	0.57	0.93
32. Food, Drink and Tobacco	14.06	1.03	0.70

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