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THE MEASUREMENT OF PRODUCTIVITY AND TECHNICAL CHANGE AT INDUSTRY LEVEL: AN APPLICATION OF MICRO-DATA TO INDUSTRY ANALYSIS*

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FOREWORD

The measurement of structural change at industry level is of certain interest both for the firms comprising that industry and from the viewpoint of economic policy making. In an analytical framework the structure of an industry is as rich as the industry production function so that the economic analysis of an industry's structure and structural change in an industry is a task full of problems.

We may say that the conventional production function analysis with perfect and costless malleability of inputs, a method based on econometrics, and the hypothesis of a representative firm as depicting the industry are not very appropriate an approach for structural analysis. This is so because the efficiencies of the micro-units within an industry do not differ from each other in a neutral way in the real world, which would be a necessary and sufficient condition for identifying the production function in econometric approaches.

A richer approach to the analysis of an industry - also based on the production theory - is the Johansonian theory of industry functions. This theory combines micro level production with its characteristics with the industry level one in a consistent way. The industry function expresses the optimal structure of an industry in terms of cost-minimising production at industry level, given the micro-units with their measured characteristics. This method thus provides possibilities for measuring structural change and one of its most important components, technical change, as well as industrial efficiency by means of changes in the short-run production function. The purpose of this paper is to illustrate the method, applied to the Nordic cement industry.

The method applied here is nonparametric and constructive in nature, as opposed to the conventional test-theoretical or parametric approaches applied in most of the empirical literature on production. It was developed by Professor Lennart Hjalmarsson of Gothenburg and Finn Førsund of Oslo and first applied in a wider empirical context in the early 1980s in an analysis of the Swedish cement industry. The study referred to was the first attempt to apply the approach to international comparisons. Much work must, obviously, still be done, especially on the decomposition of relative cost competition.

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1. INTRODUCTION

1.1. Background of the study

Economic research has, in recent years, gradually shifted its attention from total economic growth at the 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 (more or less in the aftermath of increasing energy prices) which has often led to large government subsidies to keep employment at an acceptable level. A discretionary and selective industrial and employment policy also requires more exact knowledge about the structure and structural change within industries.

In spite of the close economic connections and strong interdependence between the Nordic economies there seems to be no thorough inter-Nordic comparisons of industrial productivity levels and technical progress. The purpose of this study is to perform such an inter-Nordic comparison of an industry represented in all the Nordic countries except Iceland, namely the cement industry. This pilot study is the first part of a greater project aiming to analyse structural change in the Nordic-industries.

Traditional studies of productivity growth based on the common practice of estimating a parametric production function (or its dual) typically assumes that the observed data reflect a constant return to scale structure of production and a static equilibrium for the firm. If these assumptions are violated, then estimates of productivity growth include the effects of scale economies and movements toward or away from equilibrium, in addition to shifts in the structure of production. Estimates of productivity growth, and hence attempts to distinguish productivity growth from movements along the production function, depend heavily on the assumptions made regarding the structure of production and the behaviour of the firm.

Most studies of productivity are usually based on the theory of economic index numbers and flexible functional forms of production functions pioneered by Diewert in the midd-1970s. These studies give the theoretical background of measuring total factor productivity by economic index numbers and the related framework, based on the production function concept of a representative firm, to perform comparisons between different time points and different production units. Our approach in this study is different from the neoclassical apparatus mentioned above since it is based on micro data for individual kilns, allowing individual kilns to differ by their techniques. Moreover the analysis is based on nonparametric production functions. Our choice of approach is due to the fact that this industry is characterised by a putty-clay technology, new technology being embodied in new capacity.

1.2. The Purpose of The Study

In this study we will make a comparison of the development of productivity and technical progress of the cement industry in the Nordic countries: Norway, Sweden, Denmark and Finland during the period 1960 to 1980.

There are several reasons for the cement industry being an interesting sector to study:

1. Due to the rising energy prices in the 1970s, the cement industry has drawn a great deal of attention as being fuel intensive see e.g. Srinivasan and Fry (1981); Thus, it is an interesting question to investigate the impact on the industry of the jumps in energy prices.

2. In the Nordic countries this industry expanded rapidly during the 1950s and 1960s due to the rapid increase in construction but in the beginning or middle of the 1970s the boom in construction ended and the demand for cement decreased substantially simultaneously with the large rise in energy prices.

3. Capital equipment for this industry is produced by just a few international companies. The knowledge about available technologies and theircharacteristics are well known among the cement producers.

It is reasonable to assume that all cement companies can choose from the same ex ante or choice of technique function when investments are made. This means that the main reasons for differences in productivity between countries should be differences in the development of relative prices, demand conditions, technical and managerial skill and the effects of public regulations.

4. There are considerable differences between the Nordic countries in the level and development of relative prices for this industry during the investigation period.

5. During the period the industry has largely converted from one technology, wet kilns, to another technology, dry kilns except for Denmark.

6. Due to the market structure of very high concentration the industry has been subject to public price regulation policy.

In this study we concentrate on investigating and comparing only the cement manufacturing process. Other factors affecting the total economy of the industry, such as pricing policy and transportation costs etc. are left outside the analysis. Therefore the empirical approach is partial, and aimed to highlight only the progress of production technology.

Depending on the purpose of the analysis there are several ways to perform an intercountry comparison. In this study we will utilise the short-run industry production function.

The short-run industry production function approach based on micro-data is an especially suitable method for the cement industry since the product is homogeneous, and the different production processes are in principle separable. Moreover the various stages in cement manufacturing processes are distinct.

The long-run development of the cement industry is analysed on the basis of the shifts in the short-run industry production function during the period. The short-run function shows the actual, chosen production possibilities of the industry and it is changed by the investment in new technologies and the scrapping of old capacity. More specifically this production function approach may highlight the following points:

a. Long-run substitution and bias in technical progress.
b. The development of unit costs due to technical progress.
c. Differences in productivity and technical efficiency between the. countries and the time path of these differences.
d. Differences in international competitiveness.
e. The dispersion of different technologies and their competitiveness. in the industry at different relative prices.

2. ANALYTICAL FRAMEWORK AND THE DATA

2.1. The Short-Run Production Function

The study is based on a production function approach originating from Johansen (1972) and further developed for empirical applications in Førsund and Hjalmarsson (1983) and (1984). The corner stone in this approach is the short-run industry (or, as Johansen called it, the short-run macro) production function. A very brief sketch of this approach is as follows. Let us consider an industry producing a homogeneous output and comprising a certain number of firms. When investing in new equipment a firm chooses technology from the ex ante production function which may be assumed to exhibit all traditional neoclassical properties. After the investment has been carried out a new production unit appears. The production possibilities of this unit are described by the ex post production function at the micro level. This is assumed to be a limitational law (fixed proportions production function) and in addition there exists a maximum production capacity for this unit. Aggregating in an efficient way all existing production units, characterised by their ex post production functions yields the short-run industry production function.

Thus, the concept of the short-run industry production function rests on an assumption of a vintage (putty-clay) structure within an industry; i.e., that each unit in the industry, for example a plant or a part of it, is characterised by fixed production coefficients with regard to current inputs, and the presence of fixed factors in the form of capital. Fixed capital only determines the capacity of the individual micro-units and does not appear directly in the short-run function. Furthermore, it is assumed that there are no costs associated with the utilisation of the fixed factors in the short run.

Thus the approach taken in this study is quite different from the studies mentioned in Chapter 1, since it is based on an aggregation of micro production functions in a nonparametric way into short-run industry production functions at different time points. This aggregation process is based on maximising output for a given level of inputs. This also means that the industry's total production costs are minimised for any factor price ratio and any level of production, assuming that all units of production face the same prices. The approach implies also a parameter-free minimum cost function from which average costs and marginal costs may be calculated at different levels of output.

The maximising approach applied in this study when constructing the short-run function corresponds to the basic definition of a production function, when an industry is regarded as one production unit as opposed to the traditionally estimated "average function" for an industry. According to the basic definition of the production function in the pure theory of production (see e.g. Frisch 1965), the production function in the technical sense provides the maximum amount of output attainable with given amounts of inputs. As noted by Johansen (1972), Sato (1975), and Hildenbrand (1981), 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 clear distinction between alternative concepts of the production function is essential in avoiding confusion in production analysis; on the classification of different production function concepts; cf. Johansen (1972) and Sato (1975).

Moreover, in our approach 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. The conventional average function is based on the notion of a representative firm (plant), i.e. in the latter case it is assumed that all micro units have the same underlying production technology, except for a random error term.

In order to compare the cement industry in the Nordic countries a well defined norm, optimal structure, is needed. Because, the basic approach of this study is to impose cost minimisation when deriving industry production functions in order to present industry structures as 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 the shape and spacing of the isoquants. These depend on the distribution of technical properties of the micro units from which the industry function is built up. Structural change at the industry level is then measured in terms of changes in the optimal industry structures. It follows that there is no universal measure or statistic of structural change as this change is as rich in various dimensions as the structure itself, but there is measures which illustrate partially the progress. Note that the families of cost functions corresponding to short-run function is another, equivalent, way to describe the optimal structure.

The analysis conducted below at industry level has its well defined basis on micro relations. Under these circumstances the macro analysis has well defined microfoundations, a feature which is unusual in industry studies at this stage of the arts in empirical economic literature.

The optimisation problem raised by aggregating the micro-units to industry is a linear programming (LP) problem when the input coefficients are assumed to be constant. However, if one is interested in establishing a reasonable number of isoquants, solving the prolific LP-problems is not a practical procedure. Instead we apply the geometric device developed in Førsund and Hjalmarsson (1983) and further elaborated in Førsund and Hjalmarsson (1984) to locate all the corner points of the isoquants. This yields a complete numerical description of isoquants and provides the whole set of isoquants thus yielding a full characterisation of the production function. Due to the linear structure of the problem the isoquants will be piece wise linear in the two-factor case considered here. In spite of some numerical difficulties, estimates of the usual elasticities of scale and substitution may also be calculated.

The set of ex post production functions of an industry in the input coefficient space is called the capacity distribution. The capacity distribution may be represented by a diagram where each production unit is characterised by its input coefficients and capacity. As in fact, the short-run production function is constructed on the basis of such a capacity distributionin our approach, transforming the short-run function to the input coefficient space yields the capacity region of the short-run function. The transformed short-run production function shows the region of feasible input coefficients of the industry production function as a whole while the capacity distribution shows the dispersion of individual units.

As an alternative to represent the short-run function by the isoquant map in the substitution region or capacity region it may also be useful to portray the complete efficient combinations of the micro units; see Førsund and Hjalmarsson (1984, Chapters 5 and 8). Starting at zero industry production and expanding this to full capacity utilisation the activity regions are formed by adding micro units in accordance with the requirement that at each point in the substitution region maximum industry output is obtained. For the activity regions representation contains the complete set of all possible isoclines, such an activity region representation of the substitution region allows one to follow each individual unit's utilisation as a function of the industry's capacity utilisation. Each unit is moved in parallel shifts in a strip-like fashion from one boundary of the substitution region to the other. We call the graph of this kind of movement of units partial (or marginal) utilisation strips.

By drawing utilisation strips for the kilns for each of the countries, we can bring out their relative distribution. The various technologies employed in industry can generally be analysed in a similar manner as utilisation strips in order to portray technology strips.

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. 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. The 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 on expansion path are calcutable. Obviously the minimum value of the elasticity of cost is one but has to increase when a new unit enters.

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. There are of course no substitution possibilities 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. In this study we are however not interested in investigating the changes of short-run substitution possibilities, but the long run changes. That is why we do not present estimates of elasticities of substitution; (see e.g. Førsund & Hjalmarsson 1983). However, one may get visual impression of short-run substitution possibilities by looking at the isoquant graphs of short-run functions. Changes of elasticities of the scale and substitution throught time are also aspects of structural change as well as technical change and it's biases.

2.2. Technical Change

Technical change may be characterised in several ways. We shall adopt here the measures of technical change and factor bias introduced by Salter (1960) and by Førsund and Hjalmarsson (1979) and (1984), utilising the duality correspondence between production and cost functions.

The first 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 total unit costs between two points in time, t and t*, t*>t, at a certain output level at constant factor prices:

$$T = (C_{t*}/X)/(C_t/X) = AC_{t*}/AC_t$$

Here X is the chosen output level and C_t the minimised costs at time t.

Essentially this procedure is analogous to the index number problem, for it involves asking what changes in unit cost function (or production function) would take place if relative prices were constant. In this way substitution type changes in technique may be eliminated and the charasteristics of technical advance described by reference to techniques which differ only by shifts in unit cost or production function from one period to another. In an industry where technical advance is rapid, there would be large differences in the position of corresponding isoquant levels and in a technically stagnant industry, the isoquants will be stationary.

The second feature of technical advance which is important relates to the biases towards uneven factor saving. Salter's measure of factor bias is defined as the relative change in the cost minimising factor ratio for a given output level at constant factor prices:

$$D_{ij} = (V_{i,t*}/V_{j,t*})/(V_{i,t}/V_{j,t});$$

where $V_{k,t}$ are the inputs at time t, k = i,j, i = j, i,j = 1,...,n

Technical change may be characterised by the biases of factor saving. If D_{ij} is greater (less) than one this means that technical change is factor i-using (saving) relative to factor j. Biases and technical change shift the location of the substitution region in an uneven way and moreover changes the location and shape of isoquants. The change in elasticity of substitution is another dimension of technical change, not treated here; see Salter (1960).

The connection between a series of short-run industry production functions over time goes through the ex ante production functions of the micro units with the fixed factors as variables. The ex ante function is the choice of technique function for the construction 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 at any point of time must be compatible with the short-run function.

The changes in the short-run industry function and related concepts through time will be generated by many more factors than technical progress as represented by changes in the ex ante functions, by which new techniques are supplied. One might therefore expect the changes in the short-run function to be more complicated and less accessible to a representation in terms of limited number of parameters of an analytical production function. Thus the short-run production function and its different properties to a high degree will be illustrated graphically in the empirical sections.

2.3. The Cement Manufacturing Process

The raw material in cement production is lime or chalk mixed with clay containing silica, alumina and iron oxide. To obtain the desired composition additional raw materials are used. Cement manufacturing is one of the most energy intensive industrial processes.

The cement manufacturing process consists of four phases:

1. Crushing and grinding the raw materials.
2. Blending the materials in the correct proportions.
3. Burning the prepared mix in a kiln.
4. Grinding the burned product, clinker, together with gypsum to cement.

In the cement manufacturing process, the output is homogeneous; the production process is relatively uncomplicated and separable from other activities of the plant. In the various Nordic countries, different production techniques have been in use up to this decade.

The three different main types of technologies used in cement production are the wet, dry and semidry processes, according to the nature of the kiln which is the main part of the plant.

2.4. The Data

The data has been collected for five-year intervals from 1960 to 1980 from the individual cement companies. The data includes the energy consumption of each kiln. The energy consumption is fairly closely tied to the nature of the capital equipment, and fits quite well into the putty-clay assumption. The energy sources in burning are coal and oil and in crushing and grinding electricity, which, in our calculations, have been converted to a common physical unit, calories. Note, however, that the energy coefficient varies somewhat with the utilisation of production capacity, i.e. it decreases with rising utilisation.

The labour input is not as dependent on the kiln, since it is tied to the plant as a whole, which may comprise several kilns. We have, nevertheless, opted for keeping the kiln as our production unit, and for distributing labour to the kilns in proportion to total production. Labour input is measured in hours. We have also obtained the production capacity for each kiln. The estimation of capacity varies somewhat between countries. Maximum daily capacity is defined in more or less the same way, but there are national differences in the count of annual operating hours.

As regards the Danish data it was not possible to obtain kiln specific energy data. But the Danish kilns are so similar as to the basic wet technology that the variation of energy coefficients is very small. The main features of the development at industry level is summarised in the Tables 1 and 2.

Table 1. The cement industry in Norway, Finland, Sweden and Denmark 1960-80.

Year	Capacity (ktonnes)	Production (ktonnes)	Capacity utilisation (%)	No. of existing kilns	No. of wet kilns	Taken into production (in previous 5 year period)	Taken out of production (in previous 5 year period)
Norway							
1960	1155	1139	99	9	6	-	-
1965	1708	1484	87	9	6	3	3
1970	2759	2526	92	11	7	2	0
1975	2759	2599	94	11	7	0	0
1980	2422	2101	87	9	6	0	2
Sweden							
1960	2962	2797	94	20	17	-	-
1965	3744	3846	103*	23	18	4	1
1970	4967	3968	80	25	19	4	2
1975	4374	3415	78	19	12	2	8
1980	3827	2327	61	9	3	1	11
Denmark							
1960	809	805	100	7	7	-	-
1965	1099	1013	92	8	8	1	0
1970	1493	1414	95	8	8	1	1
1975	2015	1833	91	7	7	2	3
1980	2015	1963	97	7	7	0	0
Finland							
1960	1125	997	89	9	9	-	-
1965	1605	1452	90	11	11	2	0
1970	2005	1781	84	13	10	2	0
1975	2415	1923	80	14	7	1	0
1980	2335+	1569	67	9	2**	1	6 (2**)

*) The number of operating hours this year exceeded the number of hours defining full capacity utilisation.

**) Mothballed.

+) Included monthballed capacity.

Table 2. Development of factor prices in the Nordic cement industries 1960-80 in each country's currency.

Year	Wage rate**)	Energy cost	Development of relative price (labour/energy)	
Norway*)	NOK/hour	NOK/Gcal.	Gcal/hour	Index
1961	7.8	8.3	0.9	1.0
1965	10.6	8.0	1.3	1.4
1970	15.9	7.7	2.1	2.2
1975	48.8	53.1	0.9	1.0
1980	69.4	82.6	0.8	0.9
Sweden	SEK/hour	SEK/Gcal.	Gcal/hour	Index
1960	7.4	9.6	0.8	1.0
1965	11.1	8.3	1.3	1.7
1970	15.3	7.3	2.1	2.7
1975	26.5	31.7	0.8	1.1
1980	55.2	69.7	0.8	1.0
Denmark	DKK/hour	DKK/Gcal.	Gcal/hour	Index
1960	6.2	8.8	0.7	1.0
1965	9.2	8.4	1.1	1.6
1970	16.6	8.3	2.0	2.8
1975	36.5	35.7	1.0	1.4
1980	62.5	50.9	1.2	1.7
Finland	FIM/hour	FIM/Gcal.	Gcal/hour	Index
1960	2.8	4.7	0.6	1.0
1965	4.1	4.7	0.9	1.5
1970	6.6	6.8	1.0	1.6
1975	18.7	26.5	0.7	1.2
1980	29.2	41.2	0.7	1.2

*) For 1961-75 the figures refer to a single establishment; for 1980 to the average for the whole industry.

**) Including social insurance costs.

3. EMPIRICAL ANALYSIS, INTERCOUNTRY COMPARISONS

3.1. Introduction

We shall employ here two main ways of comparing the cement industries in Nordic countries. The first comparison of the cement industries will be to show various countries' characteristics for the same year together in the same figure. The second comparison is obtained by merging the three data sets into one pooled Nordic set and then exhibiting characteristics of this set by means of pooled Nordic production and cost functions where the individual countries can be identified. This is done in the next chapter.

3.2. The Capacity Distribution

We begin the comparisons by looking at the capacity distributions of the four countries. These are shown in the Figures 1.-3, where the capacities of the kilns are scaled such that in each year the size of the square representing the largest kiln has been normalised to the same area. From the figures we notice that there are some clear differences in the developments between the countries during the period.

In 1960 Finnish kilns have the lowest input coefficients of labour, while some Swedish and Norwegian kilns are the most energy efficient ones. Except for one Swedish kiln, the least efficient ones are Norwegian. The differences in kiln size are relatively small, but there is some tendency for the largest kilns to be the most efficient ones when considering both input dimensions, and all Swedish kilns are the next most efficient ones as regards labour productivity, after Denmark.

Figure 1. Capacity distribution of the Nordic-cement industry in 1960. The size of the square of a unit is proportional to its capacity.

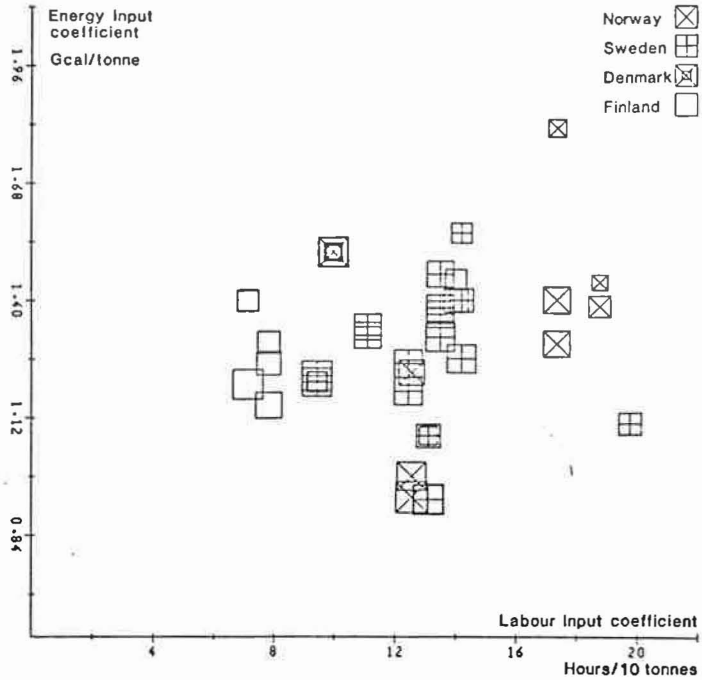


Figure 2. Capacity distribution of the Nordic cement industry in 1970. The size of the square of a unit is proportional to its capacity.

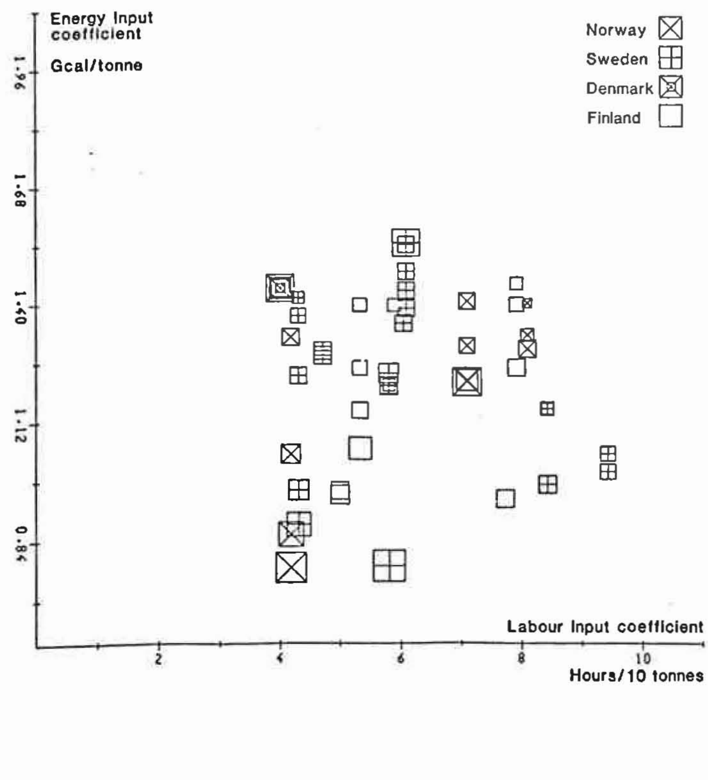
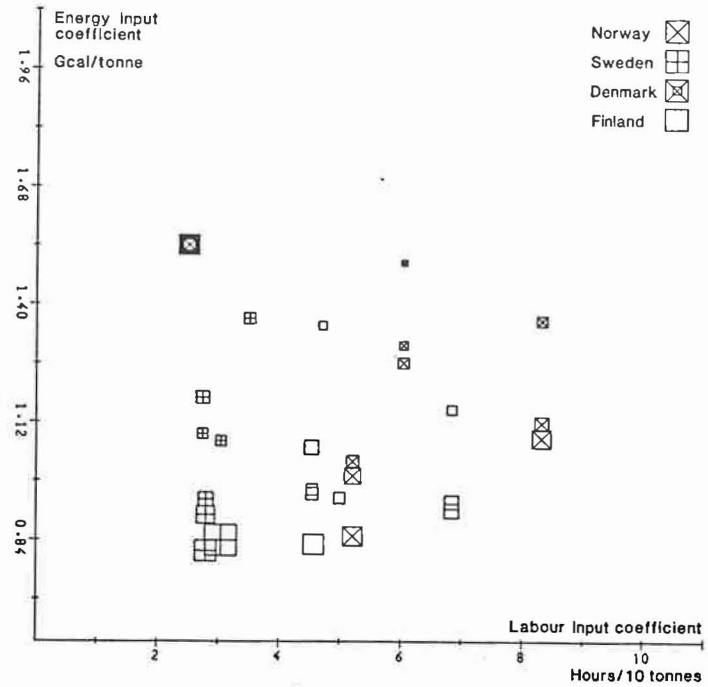


Figure 3. Capacity distribution of the Nordic cement industry in 1980. The size of the square of a unit is proportional to its capacity.



Between 1960 and 1970 there was a change in the relative position between the countries. Now the Danish kilns turn out to be the most efficient ones as regards labour, while a Norwegian kiln is the most energy efficient followed by some Swedish and Norwegian kilns. Most Finnish kilns are in the centre of the distribution. The size distribution is more uneven than in 1960 and there is a more clear tendency for the largest, dry, kilns to be the most efficient ones in both input dimensions, while two large wet kilns are less efficient as regards energy.

In the 1970s there was a further change in the relative positions in the distribution, except for Denmark still being the most labour efficient. In 1980 a Swedish kiln now appears as the most efficient. Especially the Norwegian kilns, with a few exceptions, are lagging

behind together with the three least efficient Finnish kilns. The size distribution is still more skewed and there is a clear tendency for the largest kilns to belong to the set of the most efficient ones.
A general feature of the developments of the capacity distributions is a relatively greater reduction in labour input coefficients. For all countries there was a rather large movement of the distributions towards the energy axes, particularly between 1960 and 1970. This increase in labour efficiency holds both for new and old kilns, technical progress being both embodied and disembodied. Decreasing labour input coefficients partly reflect the increase in size of the kilns (a larger unit does not require more labour than a smaller one).

Since energy input coefficients are largely embodied in the kiln technology, we cannot expect much change for existing kilns. For all countries except Denmark, there are typically marked reductions in energy input coefficients, when old kilns are rebuilt or when new kilns are taken into use. An exception is the largest Swedish wet kiln, which did not keep up with the ex ante expectations about energy use. One explanation might be inherent technical problems in process control when increasing the scale. In Sweden a new large dry kiln was taken into operation in 1979. According to engineering expectations, the energy input coefficients should be very low, but this was not yet fully realised in 1980. An older kiln performed somewhat better. As regards Denmark, the variations over the years do not reflect any technical change but variations in utilisation rates and random operational efficiency.

As regards existing kilns, there are several Norwegian and Swedish (but not Finnish) ones, which show decreasing energy efficiency both between 1960 and 1970 and between 1970 and 1980. The explanation for this might be the reduction in capacity utilisation and conversion of fuel from oil to coal in Denmark and Sweden. As pointed out above, coal means a slight decrease in energy efficiency. Finnish kilns have always used only coal.

There are great differences between the countries between 1970 and 1980 as regards the creation of new capacity. For Sweden about 60 percent of the capacity in 1980 was taken into operation after 1970, while the corresponding figures are 40 for Denmark and Finland and zero for Norway. Since new capacity in general is more efficient than the old one, these differences will show up in differences in technical advance.

3.3. The Short-Run Production Functions and the Capacity Regions

We can compare each country's short-run function, and its corresponding capacity region too, for the same year in the same figure. This is done in Figures 4.-9.

Starting in 1960 we find the regions of substitution and the capacity regions for Finland and Denmark on the one hand and Norway on the other hand on each side of that of Sweden. The Finnish and Danish structure is characterised by low input coefficients for labour and high for energy while the opposite holds for Norway, Sweden being in between. This is consistent with the differences in factor prices so far that Finland (due to coal-prices) has the lowest energy prices at the 1980 exchange rates among the Nordic countries; see Table 2. On the

Figure 4.

The short-run industry production functions of the Nordic cement industries in 1960. (Distance between isoquants 500 ktonnes).

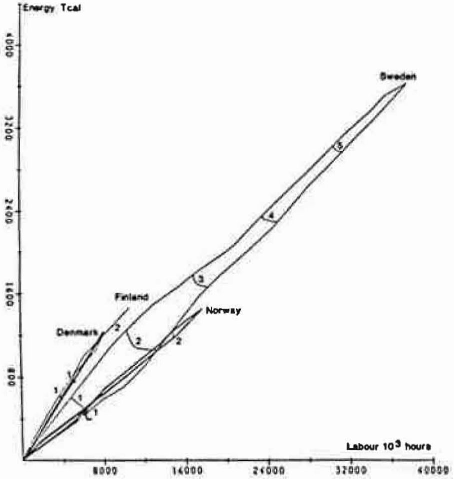


Figure 6.

The short-run industry production functions of the Nordic cement industries in 1970. (Distance between isoquants 500 ktonnes).

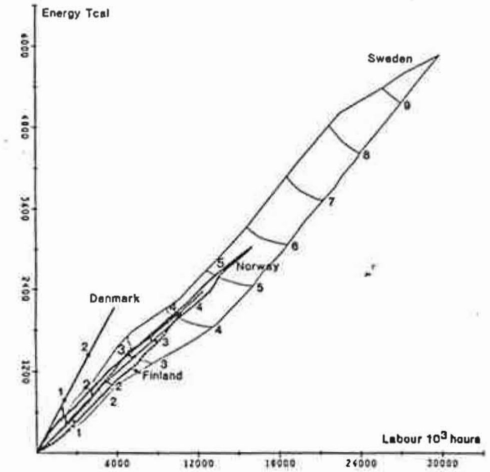


Figure 8.

The short-run industry production functions of the Nordic cement industries in 1980. (Distance between isoquants 500 ktonnes).

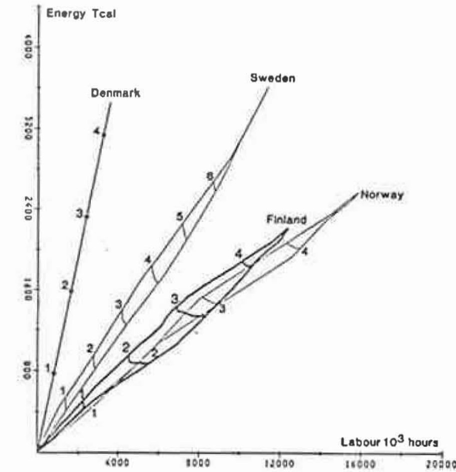


Figure 5.

The capacity regions of the Nordic cement industries in 1960. (The isoquants correspond to those of the short-run function).

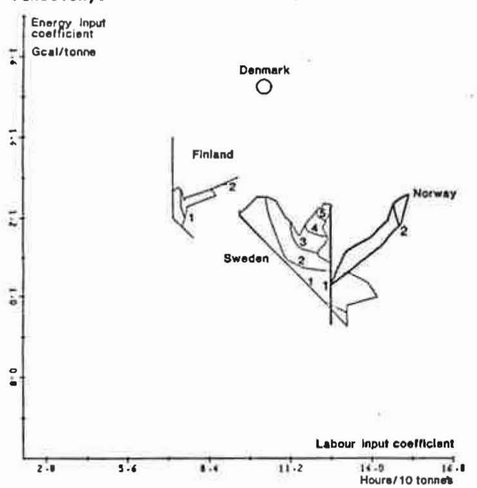


Figure 7.

The capacity regions of the Nordic cement industries in 1970. (The isoquants correspond to those of the short-run function).

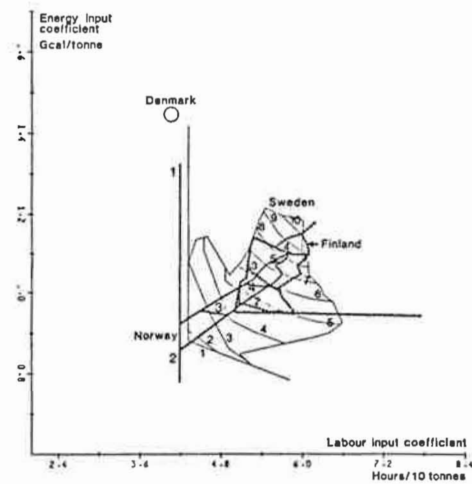
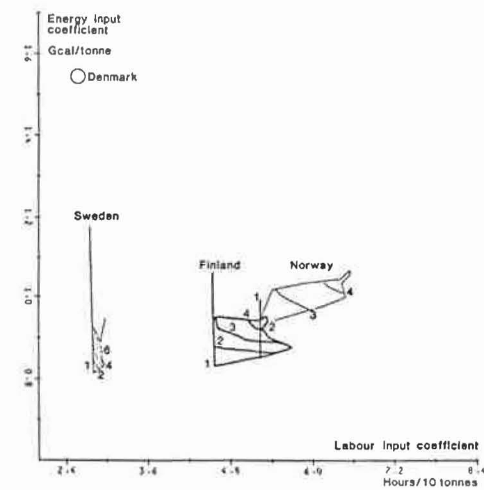


Figure 9.

The capacity regions of the Nordic cement industries in 1980. (The isoquants correspond to those of the short-run function.)



other hand Finland has also the lowest cost of labour and moreover the lowest relative price of labour among the Nordic countries during the period 1960 to 1980; see Table 3. During the 1960s Sweden had the highest relative price of labour which is consistent with its greater energy using structure in comparison with Norway. We shall not, however, stress the link to differences in relative prices in 1960 too far since the observed structure in that year is a result of the past history of relative prices, including capital prices, and the development of the ex ante production function.

If somewhat loosely, productivity is measured by the distance from the origin to the same isoquant levels in the different countries we observe approximately the same productivity level for all countries except Denmark in 1960.

In 1970 the slimmer substitution regions of Norway and Finland are now inside that of Sweden, while Denmark's has moved towards the energy axis, see Figure 6. This almost also holds for the capacity regions. Looking at the difference in relative prices it turns out that the cost of energy has increased for Finland and decreased (due to decreasing oil prices) for Sweden and Norway almost cancelling out the earlier energy price level difference; see Table 2. As a matter of fact, at the current exchange rate, energy costs in Finland are somewhat higher intercountry differences in 1970 except for Norway. The relatively high Norwegian labour-energy ratio is due to discretionary employment policy inducing the Norwegian firm to keep its level of employment constant.

Turning to productivity differences we find that the isoquants of Sweden now are closest to the origin next to Finland and Norway and lastly Denmark.

3.4. Technical Change and Related Biases

To provide a summary of our findings of technical progress and bias the Salter measures for the period 1960 to 1980 along the expension paths corresponding to 1980 Norwegian prices are summarised in Table 3. (In original study these measures are calculated and reported at five years periods)

Table 3. Salter measures of technical progress and bias from 1960 to 1980 in the Nordic countries.

	Output level (ktonnes)					
Technical Progress	Frontier	500	1000	1500	2000	2500
Norway	0.42	0.42	0.35			
Sweden	0.29	0.29	0.27	0.25	0.24	0.24
Denmark	0.74	0.74				
Finland	0.60	0.61	0.52			
Bias						
Norway	2.19	2.03	2.09			
Sweden	3.11	3.04	2.83	3.15	3.27	3.14
Denmark	4.04	4.04				
Finland	1.43	1.24	1.30			

There is an overall pattern of coincidence between the degree of bias and technical progress, Denmark being the exception. High rates of technical progress are associated with strong labour saving bias in the case of Sweden and a low rate of progress associated with a small bias in the case of Finland, Norway being in between. The very high labour saving bias in Denmark between 1965 and 1970 also coincided with the highest rate of technical progress for any subperiod. During this period the relative price of labour almost doubled in Denmark; see Table 2.

The rate of technical change seems to be highest in Sweden, then Norway and Finland. In the last two countries it seemed to be highest at the higher levels of industry capasity thus reflecting the fact that at best part of the capacity there is not so much room for progress than in older kilns.

Comparing the development between different periods all countries except Denmark show a strong rate of technical progress of almost the same magnitude between 1960 and 1965, a period characterised by rapidly increasing relative price of labour and a strong labour saving bias. After that the uniformity between the countries disappears. Between 1965 and 1970 the rate of technical progress is still high in Norway and higher than for any country and five year period. In Finland it is negligible and in Sweden at about the same rate as in the beginning of the 1960s. Denmark experiences the most rapid technical progress in this period. In 1970 the relative prices of labour peaked in all countries but at a much higher level in Norway than in the other countries. For the period 1970 to 1975 technical change in Norway went into a severe technical regress while it increased again in Finland. Sweden showed some slowdown but was still at about the same rate as Finland. During the last five year period technical progress was still negative in Norway and decreased to almost a negligible level in Finland, and to a standtill in Denmark, but increased again in Sweden.

3.5. Further Comparisons of Productivity and Internal Efficiency

In the previous section productivity levels were somewhat loosely compared. By analysing the productivity figures portrayed in the Salter diagrams (not shown here) relative comparisons of productivity levels can be performed in a more precise way. Table 4. shows the relative difference in best practice labour and energy productivity and the corresponding values at median capacity. When interpreting Table 4. the development of the capacity regions shown in Figures 5, 7 and 9 should be consulted.

Table 4. Index of productivity levels for labour and energy at best practice and median capacity levels. Finland = 100 each year.

		Labour		Energy	
Year	Country	Best practice	Median	Best practice	Median
1960	Norway	57	45	124	100
	Sweden	76	60	124	104
	Denmark	72	79	76	86
	Finland	100	100	100	100
1970	Norway	120	75	121	94
	Sweden	116	92	120	95
	Denmark	124	133	65	80
	Finland	100	100	100	100
1980	Norway	78	76	98	86
	Sweden	165	150	102	111
	Denmark	181	182	54	60
	Finland	100	100	100	100

Table 4. shows the <u>physical</u> relative productivity differences. However, it is also of interest to compare actual competitiveness for observed domestic prices and current exchange rates. The cost functions shown in Figures 10, 11, 12 and 13 may be utilised in such comparisons.

Figure 10.

The marginal and average cost functions of the Norwegian cement industry 1960, 1970 and 1980 in Norwegian 1980 prices.

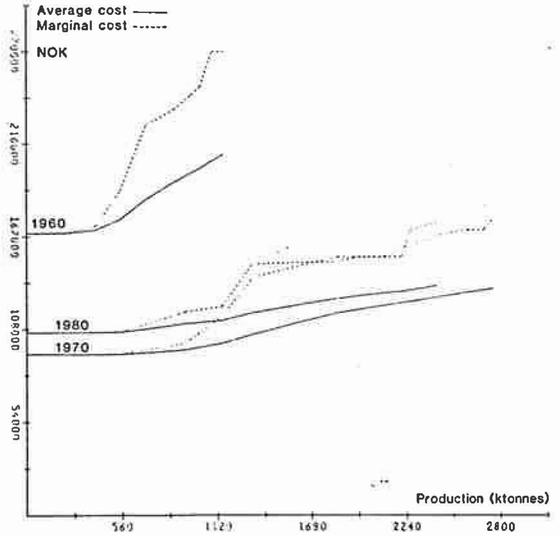


Figure 11.

The marginal and average cost functions of the Swedish cement industry 1960, 1970 and 1980 at 1980 prices.

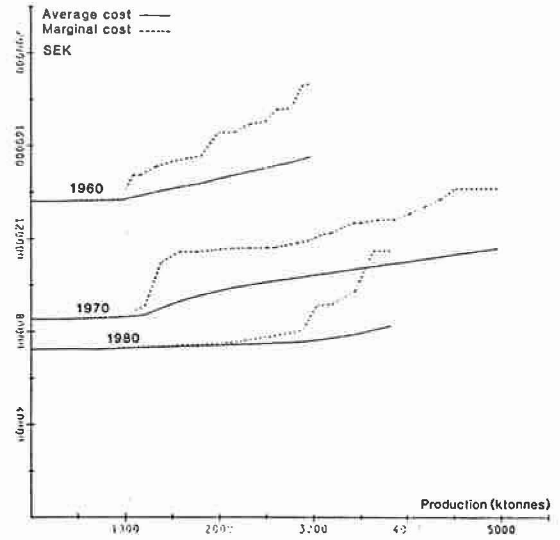


Figure 12.

The cost functions of the Danish cement industry 1960, 1970 and 1980 at 1980 prices.

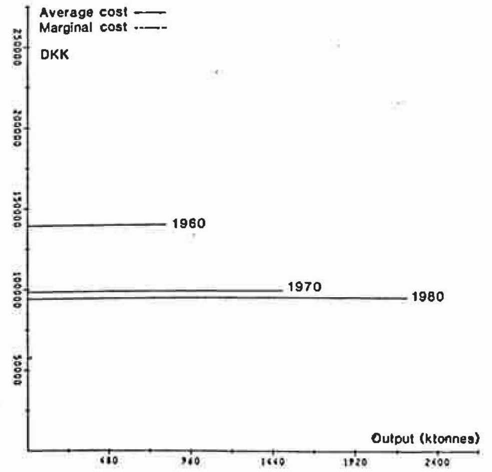
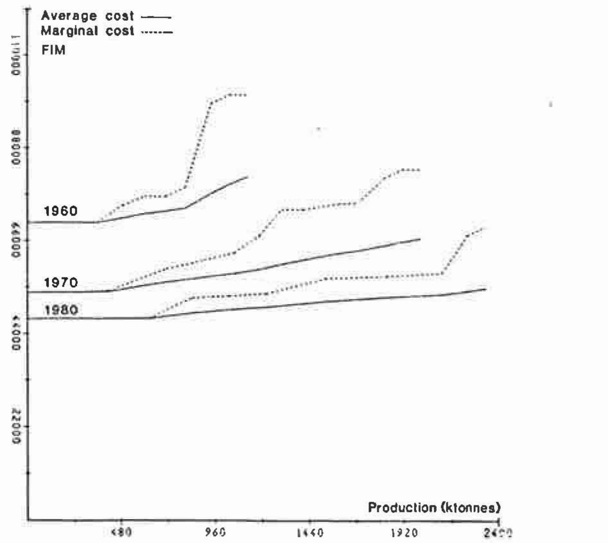


Figure 13.

The marginal and average cost functions of the Finnish cement industry 1960, 1970 and 1980 at 1980 prices.



Relative competitiveness measured by unit variable costs of production are shown in Table 5.

Table 5. Competitiveness of the Nordic cement industries. Variable costs of Norway, Sweden and Denmark compared with those of Finland at 1980 prices and exchange rates

Country	Relative variable factor costs	
	best practice capacity	least efficient capacity
Norway	1.5	1.8
Sweden	1.2	1.5
Denmark	1.9	1.9

The calculations are based on 1980 prices and exchange rates. The development from 1960 may be studied by combining the information of exchange rates in Table 2 and the cost curves in Figures 10, 11, 12 and 13. We see that both for best practice and worst practice kilns the Finnish ones are the most competitive as regards variable production costs, the Danish costs for their best practice capacity and the Norwegian costs for their worst practice capacity being almost double those for Finland.

The cost figures can be further utilized to calculate various measures characterising the structure of the cement production in all countries except Denmark (due to lack of individual kiln data). Comparing actual observed costs with minimised costs obtained when producing the observed output according to the short-run function yields a measure of overall efficiency for the industry in the spirit of Farrell (1957). However, this measure does not show whether this efficiency figure is obtained due to efficient capacity utilisation or due to the extent of the range of inefficiency. A measure of the latter is obtained by comparing the minimised costs and the maximal costs at the observed output. The maximal costs (without waste of inputs) are found by starting at the full capacity point and moving towards the origin along the expansion path until the observed output level is reached (calculated from the full capacity point as the origin). The cost figures are calculated in 1980 prices in local currencies, i.e. the measures are based on figures 10, 11 and 13. The costs are imputed at average prices reported in Table 2.

Although Norway is a high cost producer compared with Sweden and Finland, Table 6 reveals that the structural efficiency measures are quite high, i.e. the internal organisation of production in Norway is efficient. For 1960 the overall efficiency measure is about one, but this reflects the almost full capacity utilisation that year as seen from the figures on these in Table 1 reproduced in the last column of Table 6. The difference between the possible performance and the best one, scope of improvement column, is only about one per cent. The relative efficiency measure, actual utilisation of the scope of improvement, shows a realisation of 81 per cent. Even when the scope of improvement increases for 1970 and 1980 due to lower rate of capacity utilisation the overall efficiency measure is quite close to one, and the level of realisation of potential improvement is about 70 to 80 per cent.

The measures for Sweden reveal a lower level of overall efficiency and especially a lower level of realisation of potential improvement, and both measures are decreasing from 1970 to 1980. The scope for improvement and the capacity utilisation rates are markedly lower than for Norway, the latter being on the level of 46-52 per cent. The low level

Table 6. Structural efficiency of the Nordic cement industries.

		Overall efficiency	Scope of improvement	Relative efficiency		Capacity utilisation
		$\frac{C_{min}(X_0)}{C(X_0)}$	$\frac{C_{min}(X_0)}{C_{max}(X_0)}$	$\frac{C_{max}(X_0)-C(X_0)}{C_{max}(X_0)-C_{min}(X_0)}$	$\frac{C_{min}(75\%)}{C_{max}(75\%)}$	
	1960	1.00	0.99	0.81	0.86	0.99
Norway	1970	0.98	0.95	0.69	0.84	0.92
	1980	0.99	0.94	0.78	0.88	0.87
	1960	0.98*)	0.98*)	- *)	0.92	0.94
Sweden	1970	0.94	0.89	0.52	0.87	0.80
	1980	0.91	0.85	0.46	0.89	0.61
	1960	0.97	0.95	0.34	0.88	0.89
Finland	1970	0.96	0.93	0.49	0.88	0.84
	1980	0.98	0.89	0.79	0.92	0.67

*) Figures not comparable due to production greater than capacity at several less efficient kilns leading to actual costs being greater than maximal costs.

C = total variable costs

C_{min} = minimised variable costs

C_{max} = maximal variable costs (no waste)

X_0 = observed output

75 % = output level corresponding to 75 per cent capacity utilisation

of relative efficiency in 1980 is due to a new efficient large kiln being run at a low level of capacity utilisation.

The overall efficiency measures for Finland are almost as high as for Norway, being in the interval 0.96-0.98. But especially for 1960 we see the importance of calculating also relative efficiency measures. The higher scope of improvement in Finland than Norway implies a considerably lower level of realisation of potential cost improvement; only 34 per cent is realised. This situation gradually improves, so in 1980 the picture for Finland is quite the opposite to that of Sweden. Overall efficiency is at its highest, and relative efficiency at 79 per cent. This is partly explained by two less efficient monthballed kilns not being used, but included in potential capacity.

Since the rate of capacity utilisation varies over the years and countries the scope of improvement at 75 per cent capacity utilisation is also shown in Table 6. The levels are fairly equal and stable between countries in the interval 0.84 to 0.92; i.e. maximal potential cost improvements in the range of 16 to 8 per cent. The levels increase from 1970 to 1980 for all countries indicating a more equal technical structure.

When evaluating structural efficiency measures in Table 6. it must be kept in mind that they focus exclusively on productive efficiency. Transportation costs have not been taken into consideration.

4. POOLED DATA ANALYSIS

4.1. Nordic Cost Functions

Pooling the data sets permits a study of the competitiveness of the Nordic countries′ cement production due to technical differences in utilising current inputs.

In this section we limit our presentation to the development of the Nordic average and marginal cost functions in 1960, 1970 and 1980 for the same pooled data set. The cost functions are derived on the basis of the observed factor price ratio in Norway in 1980 but due to the similarity in relative factor prices the results are not very sensitive to this choice. The result is presented in Figure 15 The Heckscher diagrams and the position of individual country kilns are shown in Figures 14.

As we move outwards along the average cost curves on expansion path, the utilisation of the individual countries kilns are labelled N for Norway, S for Sweden, D for Denmark and F for Finland. Along the chosen path the features of the cost curves change towards a more flatter shape during the 1960s, in spite of an increased skewness in the size distribution of capacity on the period, while this tendency is reversed again in the 1970s due to some less efficient Norwegian kilns. We observe that in 1960 the most cost effective kilns are Finnish, then some Swedish, then the Danish and then some Norwegian, etc., while in 1970 some of the Norwegian kilns are the most cost effective. In 1980 the main bulk of Swedish capacity comes first, while Danish and Norwegian kilns constitute the last third of capacity. These Norwegian and Danish kilns push the graph of the marginal cost curve upwards.

Figure 14.

Heckscher diagrams of the Nordic cement industry at Norwegian 1980 prices. The bottom part of the histogram denotes the share of wage costs and the upper part the share of energy costs.

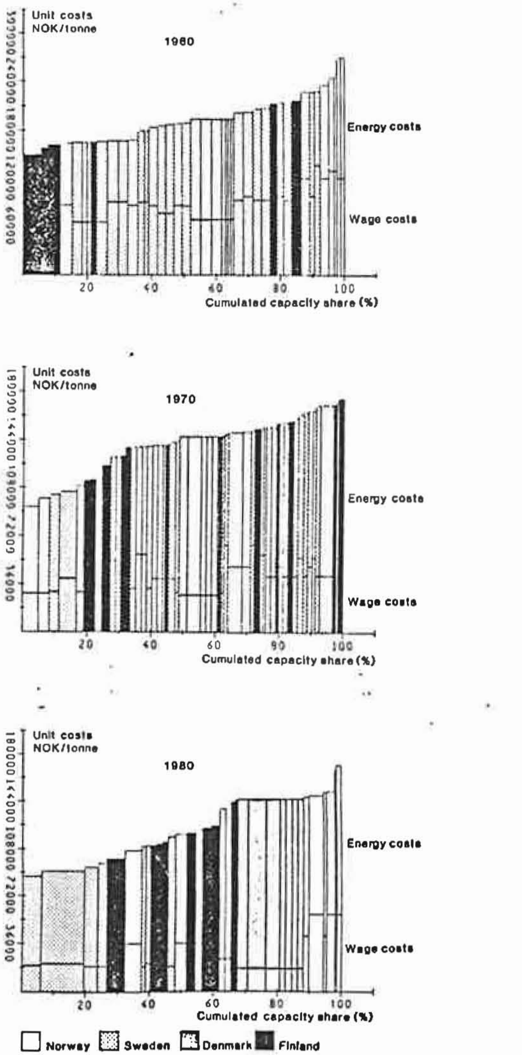
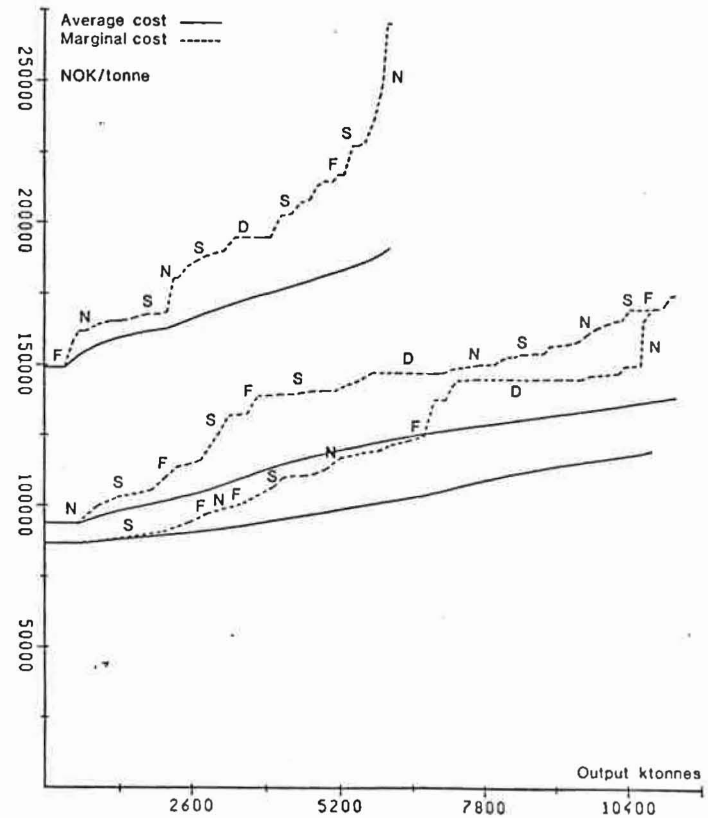


Figure 15.

The marginal and average cost functions of the pooled Nordic cement industry, 1960, 1970 and 1980 at Norwegian 1980 prices. N, S, F, and D denote main groups of kilns from Norway, Sweden, Finland and Denmark respectively.



In addition to the information obtained by the marginal cost curve the Heckscher diagram reveals a declining share of labour costs during the period 1960 to 1970. There is also a clear tendency towards low unit costs for large units. This tendency is accentuated in 1980.

4.2. Capacity Utilisation by Country

In order to get a complete picture and in order to check to which degree the utilisation of each country's kilns are dependant on the expansion path chosen, we shall investigate here how the countries' kilns are utilised in the entire utilisation region by forming activity regions for individual kilns in each country. Since the activity region presentation allows one to follow each individual kiln's utilisation as a function of the industry's capacity utilisation, it illustrates the technical competitiveness of the individual kilns in a Nordic framework. From the computer output it is possible to recognise each individual kiln and follow its position at every isoquant level. The figures of this section portray the partial (or marginal) utilisation strips, i.e. the graphs of the movements of individual kilns at the margin of their profitability measured by their variable costs as the capacity utilisation rate of Nordic cement industry increases. Kilns being utilised from the right-hand boundary are not used in the area to the left of their partial utilisation strips while they are fully utilised to the right and vice versa for kilns being utilised from the left-hand boundary.

Figures 16-17 illustrate this for Finland in 1960, and Norway in 1970; For a more detailed explosition, consult the original publication.

We see that in 1960, a large proportion of the Finnish kilns have entered the area at the energy input axis near the origin. That is, they are labour efficient. However, utilisation strips for Finnish kilns are found throughout most of the substitution region. A small amount of the Finnish capacity is less efficient in both dimensions and is utilised accross the utilisation region to the level of about 80 per cent of total Nordic capacity.

In 1970, some Norwegian kilns are included almost from the beginning. They are in the area towards the energy axis. That is, they are particularly efficient with regard to labour. (These are dry kilns). The bulk of Norwegian kilns, however, are utilised in the second half of total production capacity and also at the very high level of production. This means that in 1970 those Norwegian kilns acted as marginal kilns at the relative prices used.

Notice, that this kind of calculation is at the same time an overall sensitivity analysis of the cost function to prices. The analysis shows that ranking of the countries kilns will depend to some extent upon the expansion path used calculating the cost function. So the ranking of kilns depend on relative prices.

4.3. Technology Utilisation Patterns

In this section we illustrate the utilisation of the two basic technologies of cement production. Partial utilisation patterns of semi-dry and dry technology within the Nordic short-run production functions are displayed for the years 1960, and 1980 in Figures 18-19

Figure 16.

The short-run industry production function of the Nordic cement industry in 1960. Partial utilisation strips of Finnish kilns.

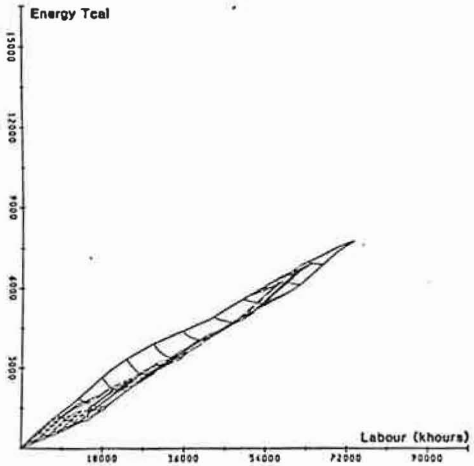


Figure 17.

The short-run industry production function of the Nordic cement industry in 1970. Partial utilisation strips of Norwegian kilns.

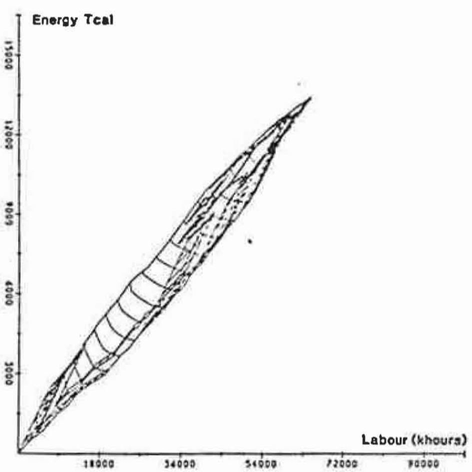


Figure 18.

The short-run industry production function of the Nordic cement industry in 1960. Partial utilisation strips of semi-dry and dry kilns.

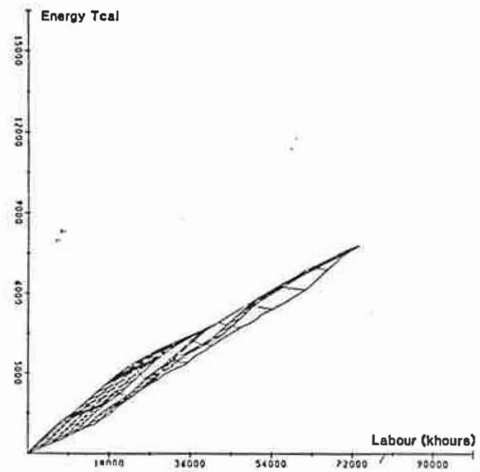
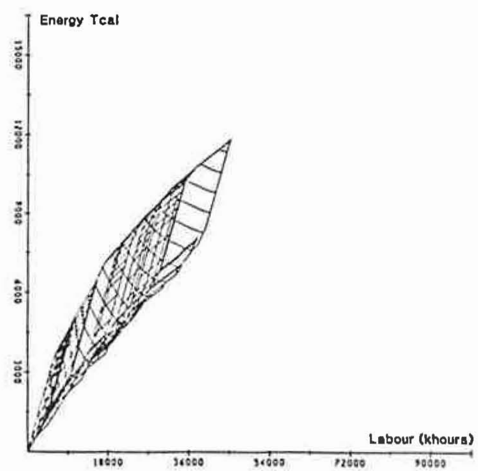


Figure 19.

The short-run industry production function of the Nordic cement industry in 1980. Partial utilisation strips of semi-dry and dry kilns.



The overall impression from the Figure 18 is that semi-dry and dry kilns are used throughout the substitution region. In 1960 the strips of parallelograms move in a longitudinal direction. At high energy prices they enter early along the lower boundary ending at much higher isoquant levels at the upper boundary. That is, ranking of the kilns according to increasing energy input coefficients gives quite another order than ranking the kilns according to increasing labour input coefficients.

In 1980 the pattern has changed. Now several kilns in the middle range of the substitution region move in a latitudinal way across the substitution region. The marginal utilisation of these kilns are more scale dependent. This means that they have about the same ranking number in both the energy and the labour dimension. In 1980 the whole dry capacity is fully utilised at lower industry capacity utilisation as opposed to previous years. Dry capacity is more efficient relative to the wet one compared with earlier years.

The analysis show that the kiln technology is relatively dependent on factor price ratios. This feature is also in certain sense of common interest e.g. when speaking about the appropriate technology in developing countries.

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