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A Productivity Study of Norwegian Construction Industry

by

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ABSTRACT

Slow productivity growth in the building and construction industry is often put forward as the cause of rising building costs. In view of the importance of the building sector in the national economy factual empirical knowledge is hard to come by.

The few studies found are usually carried out on a sectoral level and based on time-series data. However, to come to grips with real causes for slow productivity growth one has to analyse at the micro level of actual decision making. Our study is based on establishment data for 1986. On the basis of this cross section data set relative productive efficiency can be studied. The method of analysis is the deterministic frontier approach. The efficiency distributions show large variations with average structural efficiency about 20 per cent. Thus, there is significant scope for productivity improvement if average performance can catch up with best practice. Tentative explanations of efficiency differences indicate that there is a difference between one storey and multi storey buildings, and that increasing materials and subcontractor shares have negative impacts on efficiency.

1. INTRODUCTION

The slow productivity growth in the building and construction industry is often put forward as the main explanation of rising building costs. However, actual empirical studies are hard to come by, let alone analyses of why productivity growth is slower in this sector than in others (see Dacy (1965), Stokes (1981), Ganesan (1984) for some of the few studies). Since this sector delivers about two thirds of all investment goods and employs about ten per cent of the total labour force in Norway, a slow productivity growth has negative repercussions for the economy at large. Or, if we put it the other way round, revealing causes for slow productivity growth may be significant for policy actions to improve the overall performance of the economy.

Productivity studies of manufacturing are usually carried out on a sectoral level and based on time-series data. However, to come to grips with real causes for slow productivity growth we believe one has to work on the micro level of actual decision making (see Kellogg et al. (1981), Koch and Moavenzadeh (1979), Ganesan (1984)). Our study of productivity and productive efficiency is therefore based on establishment data. The present paper will deal with a cross-section data set analysis, but for the programme area under study at Norwegian Building Research Institute we have cross-section time-series data for an eight year period.

On the basis of cross-section data relative productive efficiency can be studied. Our method of analysis is the frontier production approach. While economists may feel comfortable that there operates an underlying technical relationship behind the production of such products as e.g. cement, aluminium and pulp and paper, a technical and stable production function relation for putting up buildings is not a conceptualization that goes down easily with engineers. When adding problems of data availability to inherent product inhomogeneity it takes some courage to proceed. Dacy (1965) p. 406 offers the following observation: "Economists have tended to shy away from this area of research because the available statistics have been viewed as inappropriate or unreliable". But we claim that measuring relative produc-

tive efficiency for establishments in the building industry is a worthwhile first step in exploring structural features of real interest for the industry itself.

The data set is presented in Section 2 and some structural features are shown in Section 3. The frontier production function results are set out in Section 4 together with the definition of Farrell efficiency measures. The distributions of the latter are portrayed and discussed in Section 5, and relationships between various structural variables and the efficiency measures explored in Section 6. Some thoughts on continuation of the research are offered in the concluding section.

2. THE DATA

The Statistics Norway each year collects production related data for all establishments, except one-man ones. The usual definition of establishment has been adjusted to the mobile character of the operation. There are about 1100 units with at least 5 employees in our data set for establishments with more than 50% of sales from building (sector 5011) for the year 1986.

The variables we employ are:

X = gross output (in 1000 Norwegian crowns, NOK)

B = value added (in 1000 NOK)

N = average number of employees during a year including working owners

NA = average number of production workers

NF = average number of salaried employees

K = stock of real capital at replacement value (in 1000 NOK)

M = material costs (in 1000 NOK)

U = payment to subcontractors (in 1000 NOK)

W = total wage bill including social costs (in 1000 NOK)

Establishments with negative value added (37) have been removed together with units with zero values for N and W. Without using formal screening

criteria both tails of partial productivity distributions of capital and labour and capital - labour ratios where inspected, and a few best practice units (five) with values about twice as high as the next were removed. Note that leasing of real capital (machinery, buildings) is not deducted when calculating value added, but converted to equivalent figures for stock of capital by using standard life length assumptions and rate of interest employed by leasing firms.² Checks proved the data to be quite reliable. In principle the establishments should distribute their gross sale in about 12 product groups. We have aggregated to the five groups:

- multistorey buildings
- residential housing
- construction
- subcontractors
- repair and restoration

After having calculated efficiency measures any connection with product type can be investigated by means of regression analysis.

² Due to the enthusiastic cooperation of the people responsible for the building and construction sector at Norway Statistics a new question about full insurance value of machinery, equipment and buildings were asked units with 10 employees or more for the first time in the 1986 census.

3. STRUCTURAL DESCRIPTION

The distribution of labour productivity measured as value added per employee is shown in Figure 1. The establishments are aggregated three and three to obey the secrecy rules of Statistics Norway in all figures in this section.¹

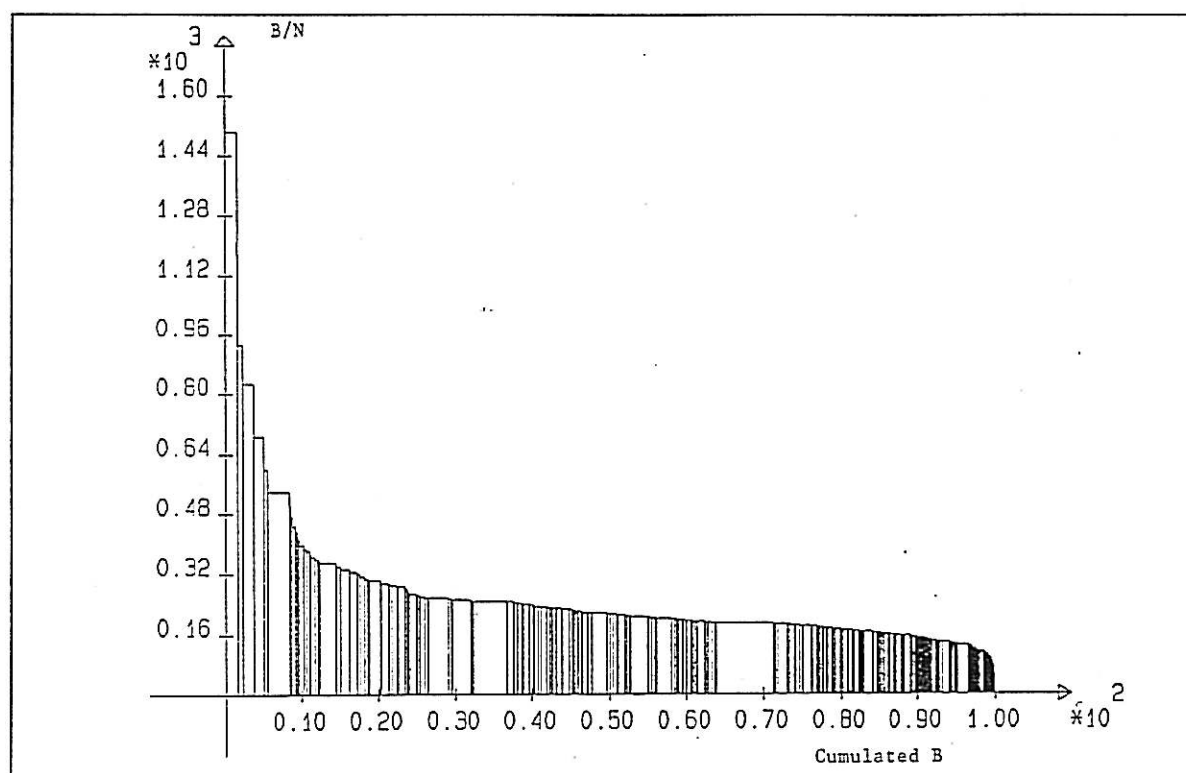


Figure 1:
Labour productivity distribution

The difference between the high productivity units and the low productivity ones is considerable, the productivity of the former being 10 times that of the latter.

The distribution has a marked L-shape with about 10 per cent of value added created in establishments with high productivity levels, and the rest of them having a more even, but declining level of productivity. As to the effect of size, medium-sized units have the highest productivity levels,

¹ Due to the layout of the figures some extreme observations amounting to less than 0.45 per cent of total value added.

and the small units are overrepresented at the lower end of the tail, with the largest units have about average levels of productivity.

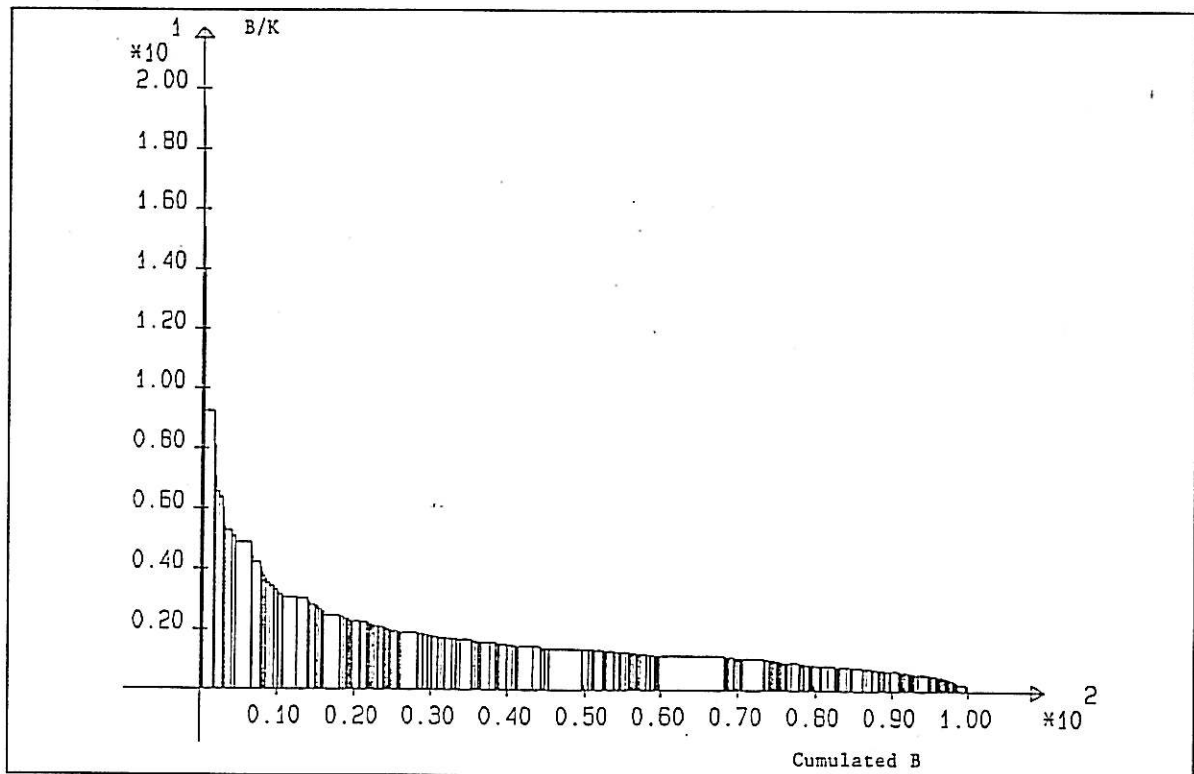


Figure 2:
Capital Productivity Distribution

Inspecting the capital productivity measured as value added per capital unit (1000 NOK insurance value) Figure 2 reveals a shape similar to the corresponding one for labour productivity. The location of units according to size is now considerably more mixed, but the larger units still have about average values.

If size influences the possibilities of mechanisation or substituting capital for labour, this shows up in the capital/-labour ratios portrayed in Figure 3. But the location with respect to size is quite mixed with small units to be found all along the distribution and large units again exhibiting average values.

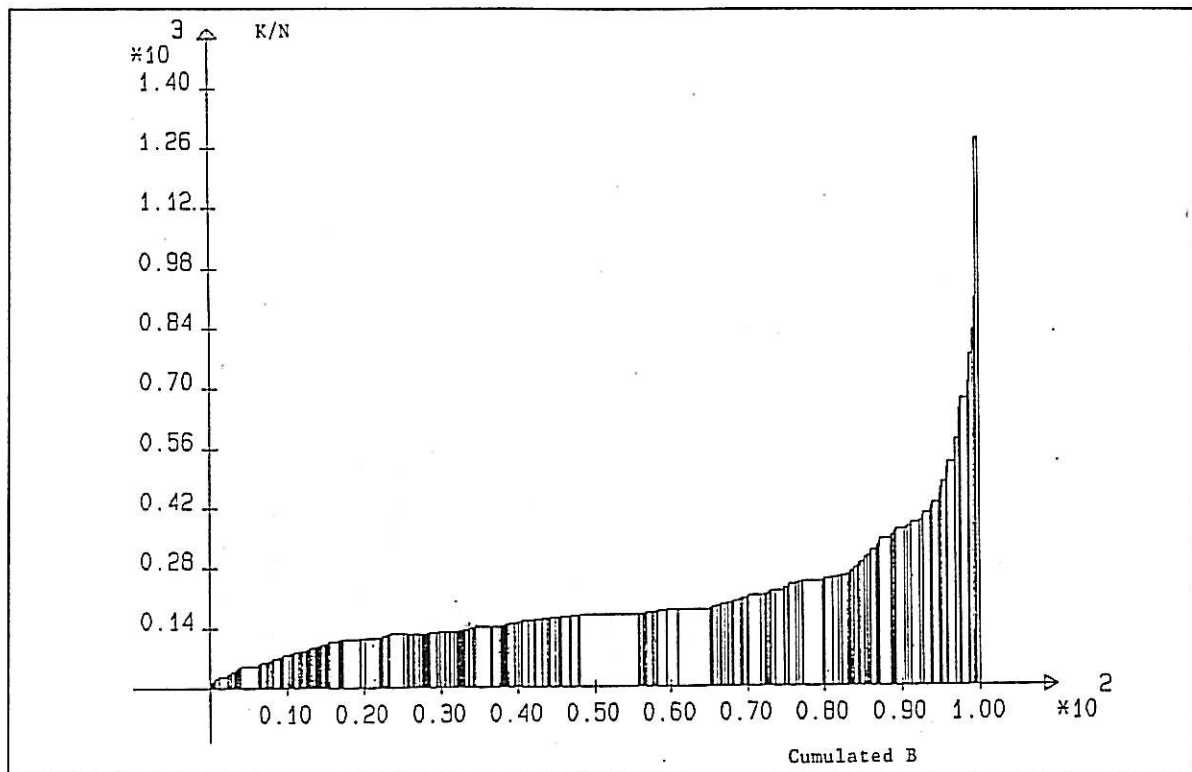


Figure 3:
Capital - Labour ratio

Observing this inhomogeneous structure it is of interest to note that Stokes (1981) concludes that the major contributing factor to slower productivity growth 1968-78 has been the slower growth in capital per worker. Ganesan (1984) points out the typical reactions to the uncertainty in the building sector of holding back investments in fixed assets. Differing expectations and/or attitudes to risk may contribute to the wide distribution in Figure 3.

The units compete in the same labour market except for intraregional immobility so the differences in wages should not be too large.

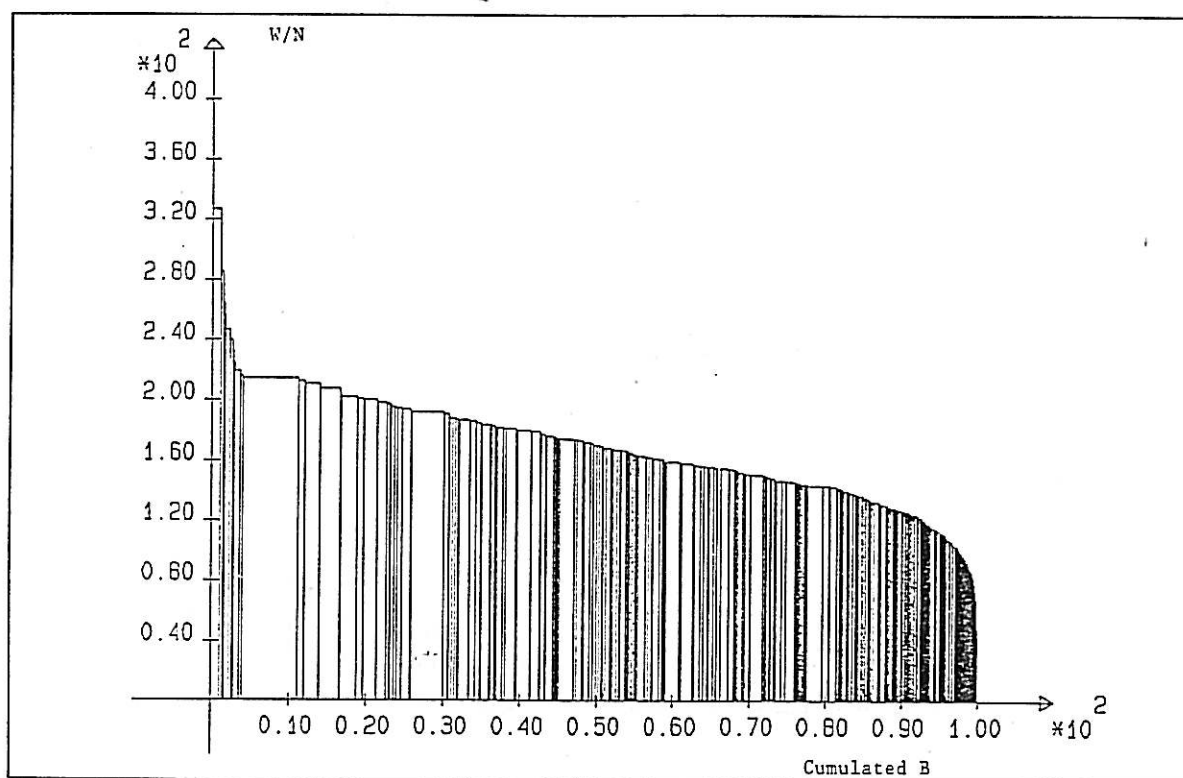


Figure 4:
Yearly wage per employee

Figure 4 shows the wage distribution, and it is considerably more even than the productivity distributions. However, the differences are still significant. A small group of establishments pay much above the average, while small units typically pay the smallest salaries. This may partly be due to the fact that the amounts that the owners draw themselves are not included in the wage data, and partly due to regional wage differentials, the small units tending to be overrepresented in remote regions with low salary levels. The large units pay their staff rather well.

The variable labour cost structure and profitability is shown in Figure 5 by plotting the wage share of value added.

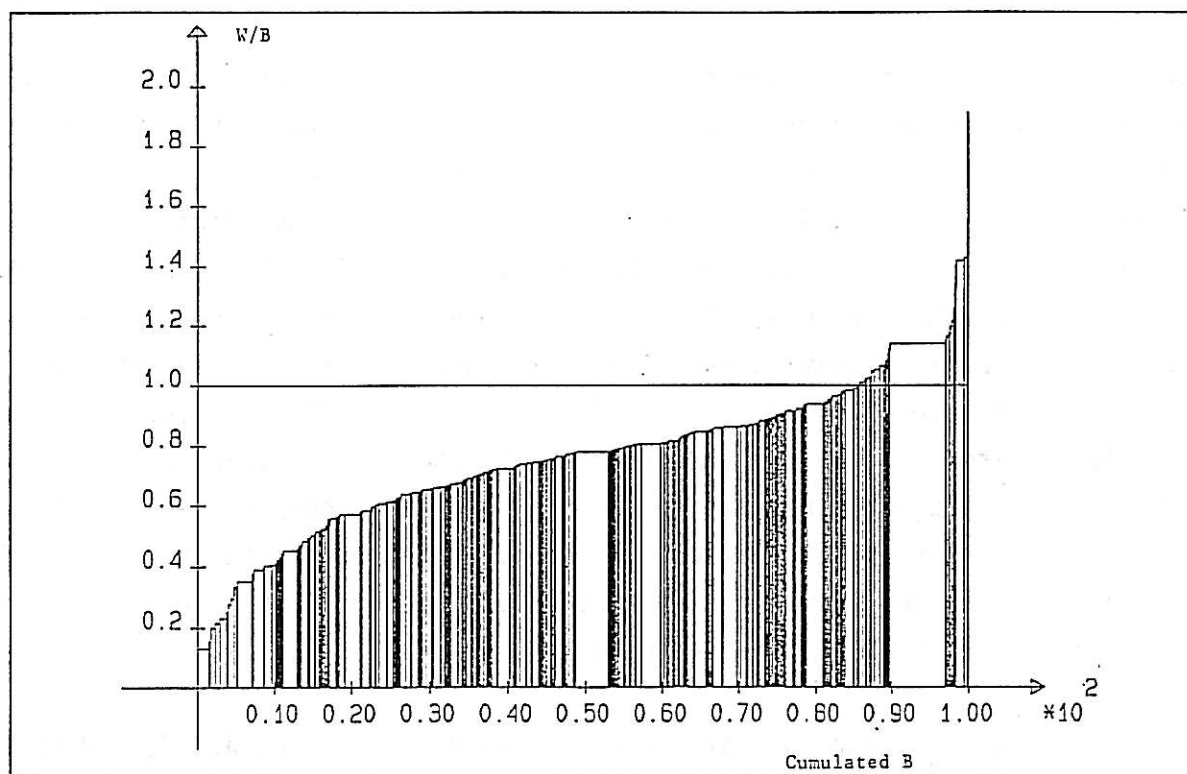


Figure 5:
Wage share distribution

The difference between the horizontal line at level 1.0 and the wage share histogram is the quasi-rent share, which should meet return on capital and remuneration to any working owners. 1986 was a boom year in the building sector in Norway. It is therefore quite remarkable that about 15 per cent of value added is created in units with negative quasi-rent (in addition to the 37 small units with negative value added). About half of value added is created in units with very high to good profitability. There is no special pattern as to location according to size.

4. FRONTIER PRODUCTION FUNCTION

As noted in the introduction the building process does not easily fit the standard concept of an underlying stable technical relationship between input and output. The proper output variable is a project completed, e.g. a building. The organisation of a project from the planning stage to the completion involves a number of different firms and organisations, and can be done in a number of ways. (See e.g. the Hierarchy Model in Kellogg et al. (1981)). We take quite a leap from this reality when abstracting to a relationship between value added, and labour and capital on a yearly basis. For small firms especially, the performance from year to year depend on what kind of projects they are engaged in, and also depends on the quality of the labour force that year on all levels of the organisation. As regards comparisons between firms the inherent inhomogeneity of buildings is often put forward by people of the building sector.

However, when considering that our output measure is value added, and that the units compete in the same factor markets, especially for labour, and that the firms can move from one segment of the market to another fairly easily, one should not put too much into the inhomogeneity issue. We measure efficiency in creating economic value, not square meters, and market conditions are more homogeneous than products (see also Turin (1980)).

The frontier production function we establish for total factor productivity measures is of homothetic form with variable returns to scale and a Cobb-Douglas kernel function. Since we know very little about substitution properties between labour and capital in the building sector, or how we should interpret variable substitution properties on our level of abstraction, we concentrate on scale properties. The latter are of direct interest to industry people.

Concerning the estimation procedure we specify a deterministic frontier, restricting all observations to be on or below the frontier, and obtain the parameters by solving a linear programming problem with the sum of deviations from the frontier as the objective to be minimized (see Førsund and Hjalmarsson, 1979, 1987, Chap.4).

The production function employed is the following in logarithmic form:

$$a \ln B + bB = \ln A + a_1 \ln N + a_2 \ln K$$

Referring to Figure 7 we have an observation at point P. The distance to the frontier represented by the graph can be measured in any directions, the horizontal and vertical being the standard ones. The functional form utilized here makes it simpler to measure distance to the frontier in the horizontal direction.

The complete optimisation problem is then:

$$\text{Max}_{i=1}^N (a \cdot \ln B_i + b \cdot B_i - \ln A - a_1 \cdot \ln N_i - a_2 \cdot \ln K_i)$$

s. t.

$$a \cdot \ln B_i + b \cdot B_i - \ln A - a_1 \cdot \ln N_i - a_2 \cdot \ln K_i \leq 0$$

$i = 1, \dots, N$

$$\sum_{j=1}^2 a_j = 1$$

$$a_1, a_2, a, b \geq 0$$

Table 1. Parameters of the frontier function:

$$a \ln B + bB = \ln A + a_1 \ln N + a_2 \ln K$$

	a	b	$\ln A$	a_1	a_2
First run:	0.0	$0.12 \cdot 10^{-4}$	-1.56	1.0	0.0
Final run:	0.0	$0.35 \cdot 10^{-4}$	-1.48	1.0	0.0

The results for the first run and the final run after sensitivity tests are set out in Table 1. We note that there are limits to the benefits of size. The estimated optimal scale in the first run $((1-a)/b = 80$ mill. NOK) is below the observed 11 largest firms but considerably larger than any other establishment. The optimal scale for the final run is 28,6 mill. NOK. The average value added is 7 mill. NOK.

Concerning the kernel parameters we have a corner solution with labour as the only significant input. The technical explanation for this result is that the unit most efficient in using labour is also the most efficient one as to using capital.

Two serious methodological problems with this deterministic frontier are firstly that we do not have any statistical measures of goodness of fit, and secondly that the parameter results per definition depend crucially on best practice outliers. We will just carry out some rather ad hoc sensitivity tests here by removing outliers and recalculate. This practice dates back to Timmer (1971). However, it is not correct as he states that removing frontier units in any way simulate chance constraints introduced by Charnes and Cooper (1959). There has been some development of this approach, see Thore (1987), Land et al. (1989) but it is still a way to go before empirical applications.

The two units originally on the frontier are the largest one and a small unit. Removing one unit at a time with the highest shadow value in the solution to the programming problem we start with the small unit. It turns out that the largest unit remains as a frontier unit while there is a succession of small units, up to four at a time, that turn up as the other frontier units. The scale properties remain fairly stable while the kernel parameters change away from the corner solution and to both the labour and capital parameters being positive and in the range of 0,8 and 0,2 respectively. However, we are not approaching an average function as erroneously stated by Timmer (1971) as an empirical fact. Removing the largest unit from the original data set the next largest unit appears as a frontier unit (together with another small unit different from the original one). The optimal scale is reduced from 80 to 50 mill. NOK. Removing both the two dominating large units still leaves us with the same corner solution for the kernel parameters, but optimal scale is further reduced to 34 mill.

NOK. Note that this scale is still considerably higher than average; i.e. about 5 times higher.

Referring back to the distributions in Figures 1-4 we recall that the large units tend to be located in the middle. They are not outliers in any productivity dimension, but are picked as frontier units just due to their size. They cannot be ignored by the minimization routine because they are so far away from the other observations in input - output space, employing about 4-5 times the number of employees, so the potential deviation are large, while the function is fairly flexible over this range.

We have therefore found it appropriate to exclude outliers of this type. The largest unit that entered as a frontier unit when removing the three largest ones has a group of five units of about equal size measured by output.

Then we proceed to test the sensitivity of small units. The pattern described above is then repeated. Since there is a large number of small units with efficiency measures (first run) above 0,95, and the first small frontier unit does not stand out as an atypical outlier, we have found no good reasons not to keep the original small unit as a frontier unit. The unit is no. 12 in the ranking of labour productivity. The case with the dominating three largest firms removed is therefore used as the final run on the basis of which the efficiency measures have been calculated.

Since we have a corner solution of zero for the kernel elasticity of capital, the frontier function and the data set behind the computations of efficiency measures can be portrayed in a two-dimensional output - labour input diagram as in Figure 6.

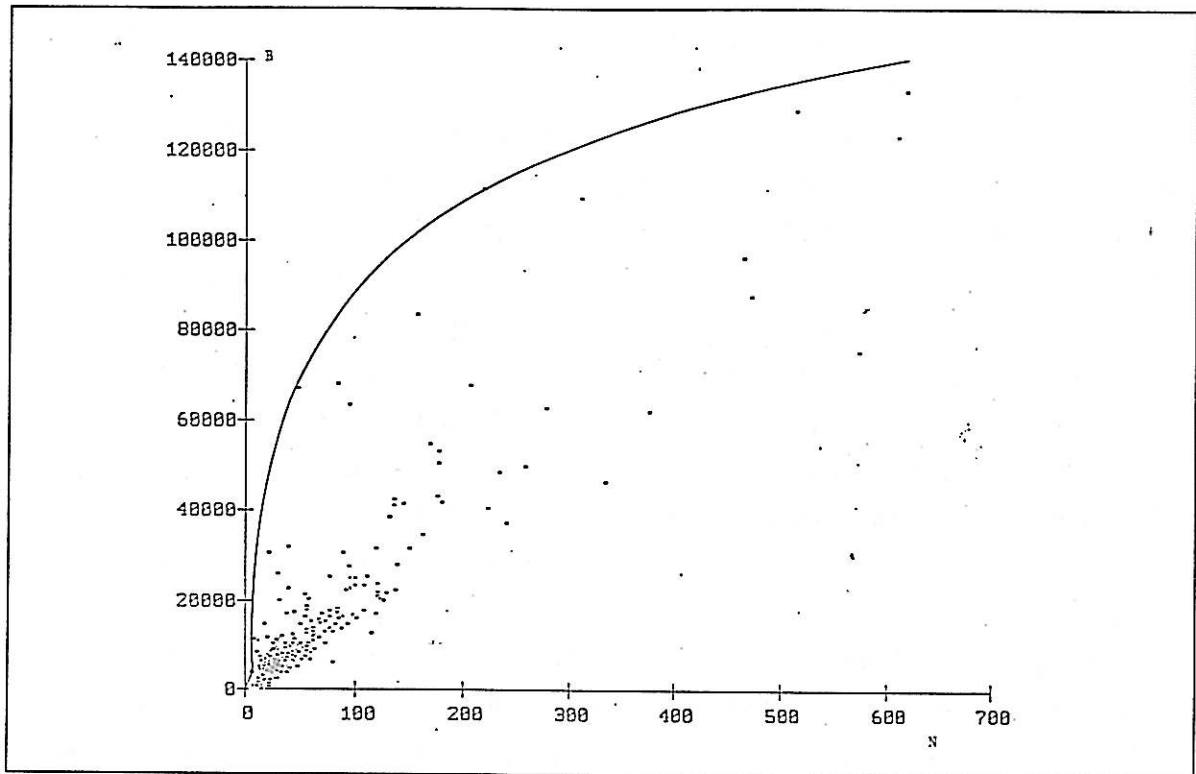


Figure 6:
Best Practice Frontier and data points

The scatter diagram shows a wide distribution both diagonally and across. Although we have not entered any average function in the diagram it is not hard to imagine that the frontier function, serving as an envelope of the data, has quite a different form from the average. The two frontier units are at the opposite ends of size range, with an additional few (4-5) being rather close. The significance of outliers is clearly portrayed.

5. THE EFFICIENCY DISTRIBUTIONS

The efficiency measures we calculate are of the Farrell type of comparing observed performance with potential frontier performance keeping the same factor as observed. (See the seminal article by Farrell (1957), and further developments in Førsund and Hjalmarsson (1987)). The three types of efficiency measures we calculate are shown in connection with Figure 7.

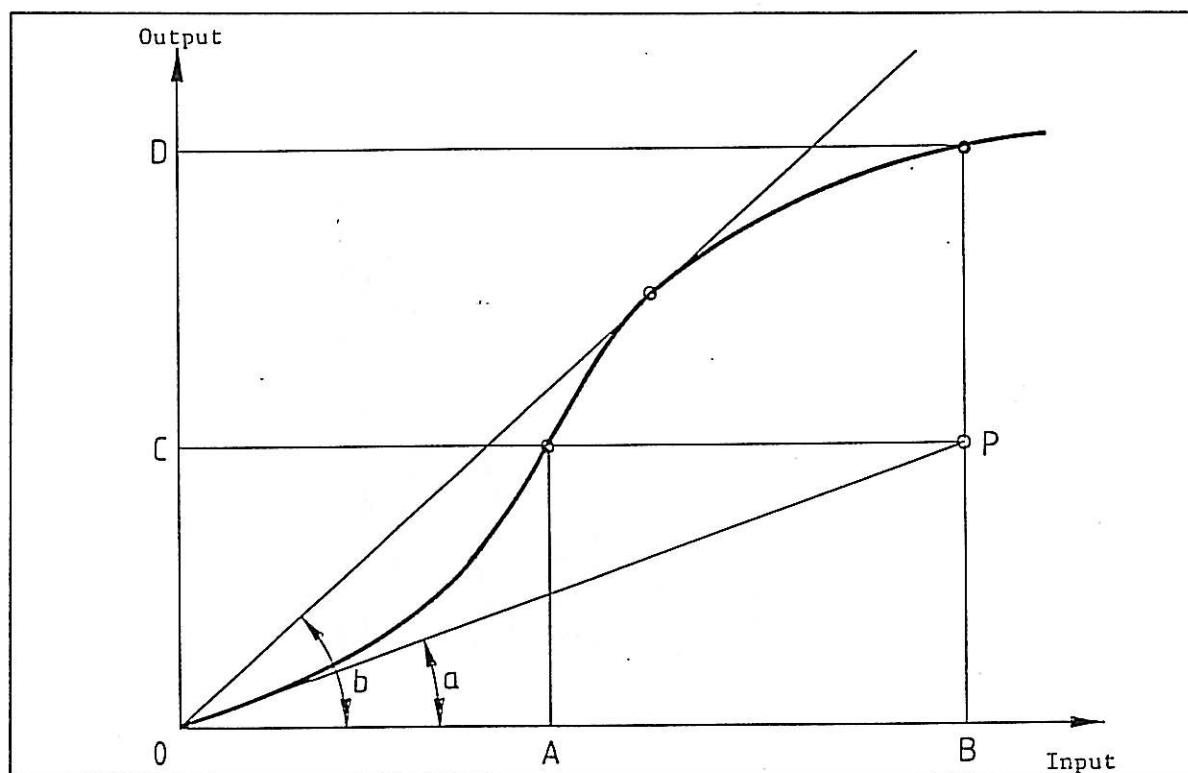


Figure 7:
Definition of efficiency measures for unit P

$$E_1 = OA / OB$$

$$E_2 = OC / OD$$

$$E_3 = a / b$$

$$S_1 = E_1$$

$$S_2 = E_2 \text{ For average unit, P}$$

$$S_3 = E_3$$

$$S_4 = \text{Average moved to (A,C) and then } E_3$$

$$S_5 = \text{Average moved to (B,D) and then } E_3$$

The input saving measure, E_1 , is obtained when holding output at the observed level for a unit and measuring the inputs needed at the frontier

compared to the observed for the observed factor ratio. The output saving measure, E_2 , results when observed inputs are utilized on the frontier and observed and potential output compared. The scale efficiency measure, E_3 , is calculated as minimal input coefficients at optimal scale relative to observed input coefficients (see Førsund and Hjalmarsson, 1987, Chap.3). The distributions for the three measures of efficiency are shown in Figures 8-10.

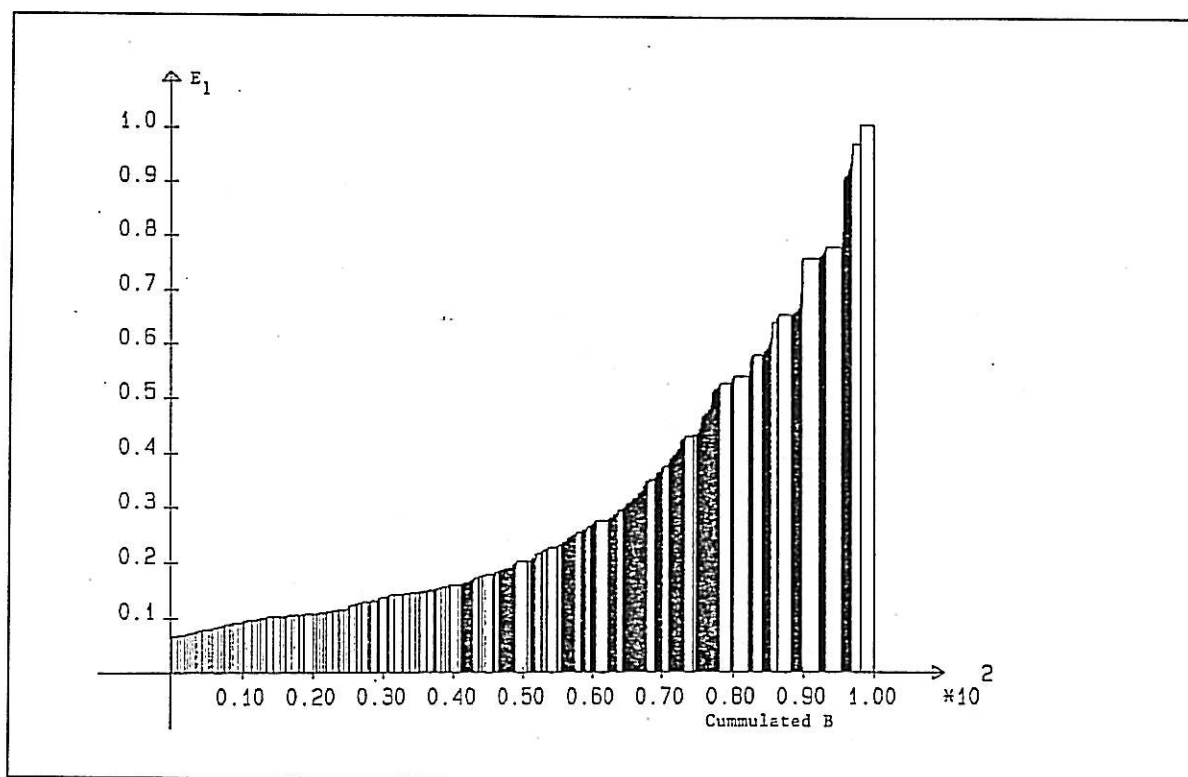


Figure 8:
Input saving efficiency measure

The distribution for E_1 is markedly skewed with the least efficient units having efficiency values below 0,7. The interpretation is then that these units could have produced the observed value added by using less than 7 per cent of observed labour and capital. The efficiency measure does not exceed 0,2 before we are through least efficient units representing almost 50% per cent of value added. The most efficient units with measures above 0,8 represent only 5 per cent of value added. As regards size and efficiency we have observed that the largest unit and then the smallest units are the most efficient. The medium sized units are the least efficient ones. As to the first run distribution and sensitivity analysis the results for the

Largest units are unstable when removing one at a time until we settle at the final run. Removing small units do not change the distribution much.

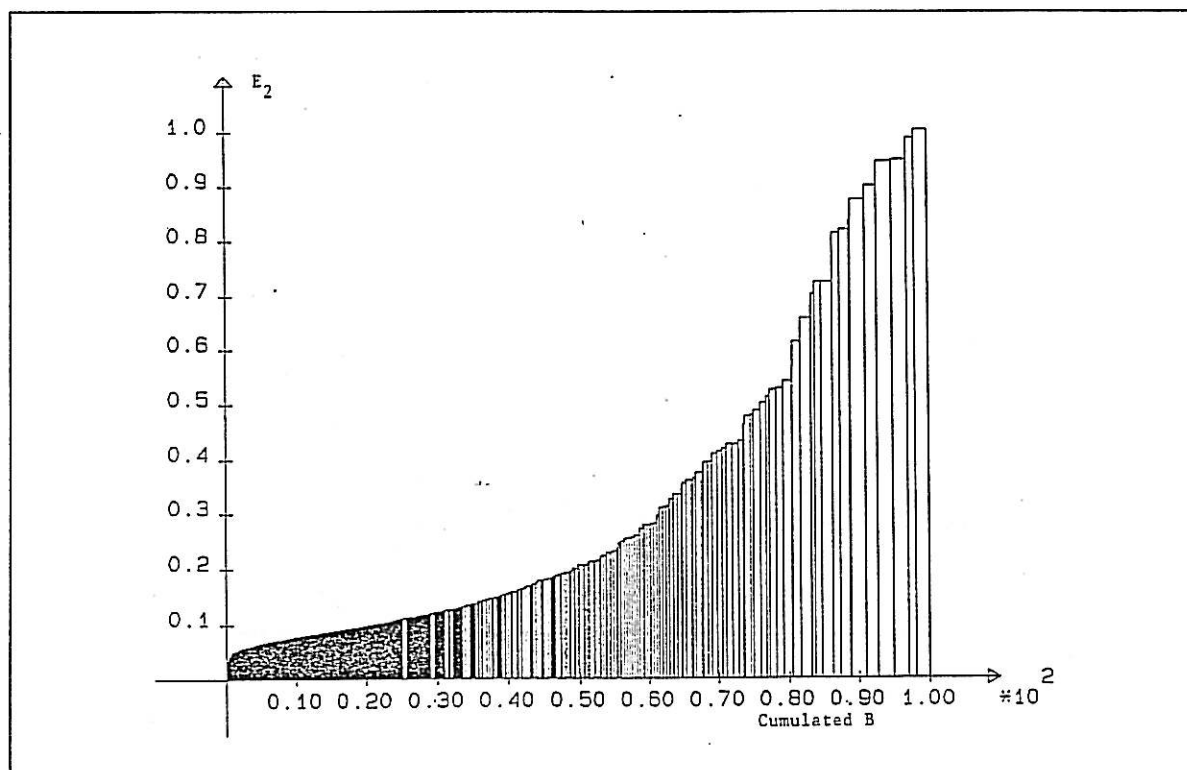


Figure 9:
Output increasing efficiency measure

The distribution for the output-increasing measure E_2 shows the same large differences between least efficient and most efficient units as for the input saving measure E_1 , but the location according to size now exhibits quite a different pattern. The smallest units are now the least efficient ones on the levels below 0,05 up to 0,2 representing about 50 per cent of value added. The number 0,05 means that the unit in question produces only 5 per cent of potential value added at the frontier employing the observed amounts of inputs. The larger the units the more efficient they become right up to the largest on the frontier (with a few exceptions). It should be noted that the share of efficient units have increased markedly. Units with efficiency measures above 0,8 have now about 13 per cent of value added. The sensitivity runs have now very stable efficiency distributions. It holds per definition that $E_1 > E_2$ as long as a unit is smaller than optimal scale. This is in the final run calculated to 28 mill. NOK. For the larger units about 3 per cent of the total it holds that $E_2 > E_1$.

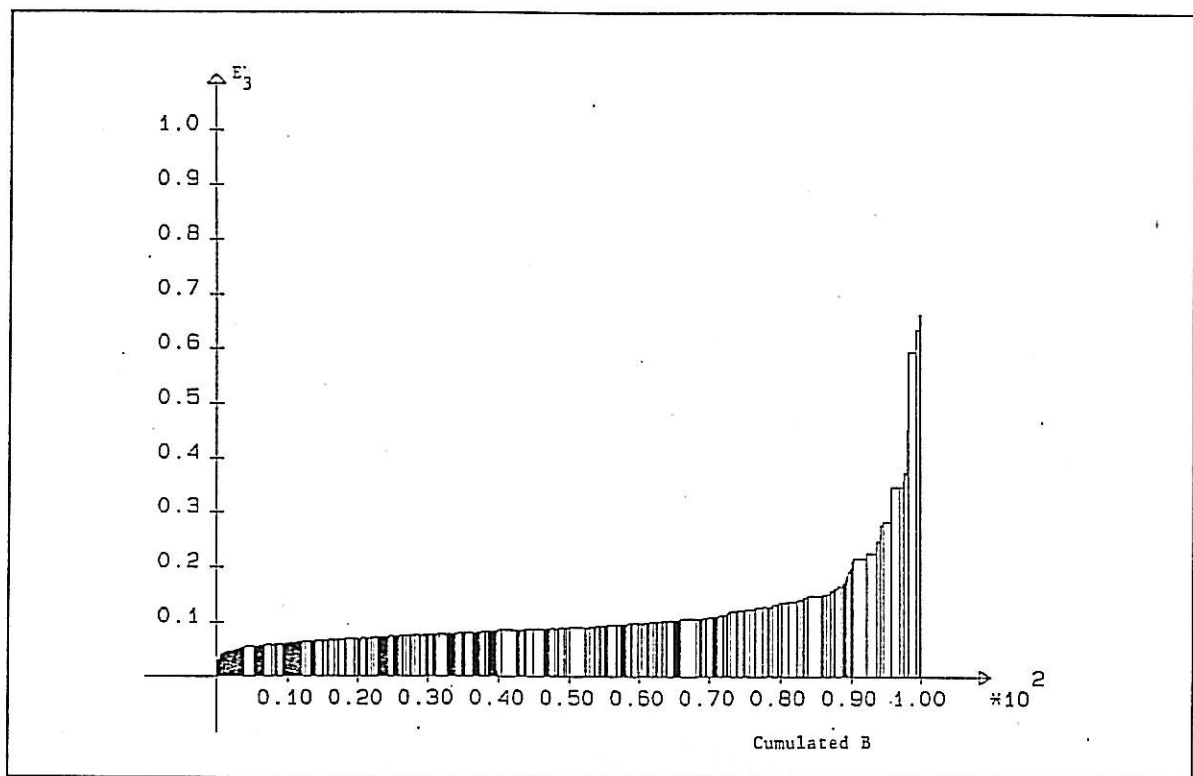


Figure 10:
Scale efficiency measure

The distribution for the scale efficiency measure, E_3 , in Figure 10, has a range of 0,003 to 0,66. All units operate with input coefficients substantially above the potential minimum at optimal scale of the frontier functions. Of the two frontier units one is too small and the other is too large to realize minimal coefficients. For the other units failure to realize minimal coefficients is a mix of either being too small or too large and being technically inefficient.

A lesson to be drawn from the efficiency distributions is that efficiency can be improved if the small units concentrate on getting more value added out of their inputs while the larger units concentrate on trimming their use of inputs.

The differences in efficiency between establishments are so large that one may wonder how these units can compete in the same market. Note, however, that we analyze just one year. The number of bankruptcies in this sector is notoriously high. The observed wage share distribution portrayed in Figure 5 shows the great spread in profitability for existing units. It takes time to adjust capital stock and change product or market. A contributing factor

may also be the fact that the products are not bought off the shelf, but involves two-party negotiations with possibilities of strategic behaviour and incomplete information. A more technical explanation for the skewness of the distribution is pointed out in Caves and Barton (1988). The industry studies referred to (Førsund and Hjalmarsson (1987)) comprise from 7 to 50 units, while we now have 1077. Given feasible upper and lower limits of performance we have a positive probability of getting included in our data more extreme observations as the number of observations increase.

It may be convenient to describe structural efficiency for the sector by a single number. One way of condensing the information contained in figures 8-10 is to calculate the efficiency measures for the average unit, see Figure 6. Since the measures now refer to the structure, we rename the E-measures to S-measures.

Table 2. Structural Efficiency Measures

S1	S2	S3	S4	S5
0,20	0,11	0,09	0,44	0,81

The structural efficiency measures are set out in Table 2. On average, use of inputs could be reduced with about $100 - 20 = 80$ per cent, production should be increased by $(1/S2 - 1)100 = 801$ per cent and input coefficients reduced by $100 - 9 = 91$ per cent at optimal scale on the frontier. The two last measures may be termed pure scale efficiency measures. Technical inefficiency is corrected for by first moving the average unit to the frontier either horizontally; $S4 = S3/S1$, or vertically; $S5 = S3/S2$. We see from the value of the last measure, S5, that the average unit is closer to optimal scale size as regards inputs than output, i.e. productivity improvement should be more easily accomplished by producing more with observed amounts of inputs.

6. EXPLAINING THE EFFICIENCY DISTRIBUTIONS

The information on the building firms in our data set not used so far, allows us to try to correlate efficiency ratings and structural information on three main groups of variables with possible influence on efficiency; main product type, type of establishment and technical characteristics of the production process, such as materials share of gross value of production, workers shares, and hours per worker per year.

The variables tried are listed below:

- v_1 = single family one storey dwellings
- v_2 = multistorey buildings
- v_3 = construction
- v_4 = repairs, rehabilitation
- v_5 = single unit contractor
- v_6 = subcontractor
- v_7 = subunit
- v_8 = main unit
- v_9 = materials share of gross value of production
- v_{10} = subcontractor share of gross value of production
- v_{11} = hours per worker per year
- v_{12} = workers share of total number of employees
- v_{13} = yearly salary

The first variables in the two groups of qualitative variables serve as reference groups in the regressions. Both E_1 and E_2 are tried as dependent variables in the simple linear regressions. The results are set out in table 3.

Table 3. Linear regressions with efficiency results as dependent variables

Variable	E_1		E_2	
	regr.coef.	T-value	regr.coef.	T-value
v_1, v_5	71.88	11.28	19.08	5.61
v_2	-12.67	-8.27	1.41	1.73
v_3	1.76	0.63	0.99	0.67
v_4	3.01	1.46	-0.59	-0.53
v_6	-2.73	-1.08	-0.89	-0.66
v_7	-9.08	-2.80	3.78	2.18
v_8	-10.10	-3.54	7.71	5.07
v_9	-12.04	-2.97	-12.46	-5.76
v_{10}	-30.17	-6.02	-1.21	-0.45
v_{11}	0.02	7.83	-0.002	-1.44
v_{12}	-28.08	-5.36	-13.15	-4.71
v_{13}	-0.17	-8.80	0.08	8.02
R^2	0.33		0.17	

Our structural variables explain the variation in the input saving measure E_1 much better than the output increasing measure E_2 . Note that the frontier is constructed by minimizing with respect to E_1 . The results for the two measures are somewhat different.

Concentrating on the E_1 -regression we find that the difference according to product groups is significant between one storey dwellings and multistorey buildings with the latter group having lower efficiency values. The number -12,67 means that the efficiency number is reduced with this percentage point when moving from one storey dwellings to multistorey buildings. Construction and Repairs are not significant.

As to type of establishment, being a single unit contractor is most effi-

cient. Both subunits and main units have significantly lower efficiency levels in the order of 9 to 10 percentage points.

The variables characterizing the production process are all significant at the 5 per cent level and all but the hours worked per worker reduce the efficiency. Note the unit of measurement for the share variables. The number -30,17 for share of subcontractor means that for every percentage point the share of subcontractors increase the efficiency level decreases with 0,30 percentage points.

The use of materials and subcontractors measured as shares of gross output is significantly influencing input-saving efficiency, E_1 . For every percentage point the share of materials and subcontractors increase, efficiency is reduced by 0,12 and 0,30 percentage point respectively. A difference between two units of 10 percentage points in share of materials (the actual range being 20; 0,2 to 0,4) results on average in a difference in E_1 of 1,2 percentage points.

As should be expected increased labour intensity measured as number of hours per production worker per year increase efficiency. (Remember that we measure labour by average number of employee). The effect is two percentage points plus for 100 hours more per worker. But looking at the effect of share of workers in labour force, then efficiency decrease with increase in share in the order of magnitude of 0,3 percentage point for one percentage point share increase. White-collar dominated units performe on average better that blue-collar dominated ones.

A standard hypothesis is that wage rate varies positively with efficiency. But our result for E_1 shows the opposite. Increasing the yearly salary with 1000 NOK reduces efficiency with 0,17 percentage points. We know that white-collar employees receive higher salaries than blue-collar employees, and that increased share of white-collar employees increase efficiency. The negative impact of higher wages may be the result of establishments with a high share of white-collar employees and being efficient are paying the lowest salaries. The result for output-increasing efficiency, E_2 , is opposite. From Figure 9 we know that large units are uniformly the most efficient compared to the more mixed picture for E_1 (Figure 8). We have noted that large units pay better wages in general to all types of emplo-

yees. This may explain the different results for E_1 and E_2 .

The results for efficiency measure E_2 are either insignificant (for six of 13 of the variables) or of opposite sign for the qualitative variables. For the process characteristics the results are similar in sign with the notable exception of wage rate now being significantly positive as mentioned above, but with smaller impacts except for share of materials.

7. CONCLUDING REMARKS

The efficiency in producing value added from labour and capital varies quite a lot between building firms measured as deviations from a best practice production frontier. The differences are much greater than found when analysing manufacturing (see Førsund and Hjalmarsson, 1987). Taken at face value the rationalization potential in the building industry is substantial. When utilising additional information about the establishments we find indications that a split into two broad product groups of one storey dwellings and multistorey buildings should be done to improve product homogeneity. One should also consider carefully the role of shares of materials and subcontractors of gross output. It might be worthwhile to experiment with gross output as output variable and including materials and subcontractors as input variables (see Caves and Barton (1988)).

We plan to proceed with the research project by getting the cooperation of some of the firms in identifying reasons for efficiency differences. Questionnaires asking about quality of labour, type of contract, use of EDP, number of competitors, local or national market, reasons for cost overruns, etc., have been sent to selected firms among the worst practice ones, the average and the best practice establishments.

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