Chapter 5

Production Function Variables

Due to limited time and other resources, model simplicity is desirable and hence, only the most important variables will be included in the model. Those are labour, capital, energy, and technological progress.

Variables that are found insignificant will be excluded of the model -if it make economic sense.

5.1 Output

It is obviously burdensome to construct a gross-output production function, hence, output is measured as ton finished steel. The output for the firm is long products and quarto-plates, however the proportions of total output have stayed nearly constant over time. Moreover, output has not changed character in the observed period except for quality improvements. - Hence, output is homogeneous.

However, the firm has other outputs such as engineering expertise, and sales of by-products. Those outputs are of insignificant importance and are difficult to measure.

5.2 Labour Hours

In the real world labour hours supplied by different people are by no means equivalent. It is expected that hours supplied by skilled workers embodies more inputs than hours supplied by less skilled workers. Education, occupation, experience, sex, etc could distinguish labour types. We can somehow aggregate all of our different labour inputs together into a single measure $q = f(K, Lh^*)$, where $L^* = g(Lh_1, Lh_2, Lh_3, \cdots, Lh_n)$, as were done in section 2.4.

However, labour hours are treated as supplied by one type of labours and an input that is homogeneous once it has been trained. The consequences are: (i) the work force is assumed to have homogenous skills; and (ii) investing in more capital simply means the firm makes use of existing labour.

Equal costs for the labour hours in question, this is the case at Danish Steelworks and in general for the labour market in Scandinavia, the company has no other choice than to make sure all labours have same skills. -This reinforces the assumption of homogeneous work force.

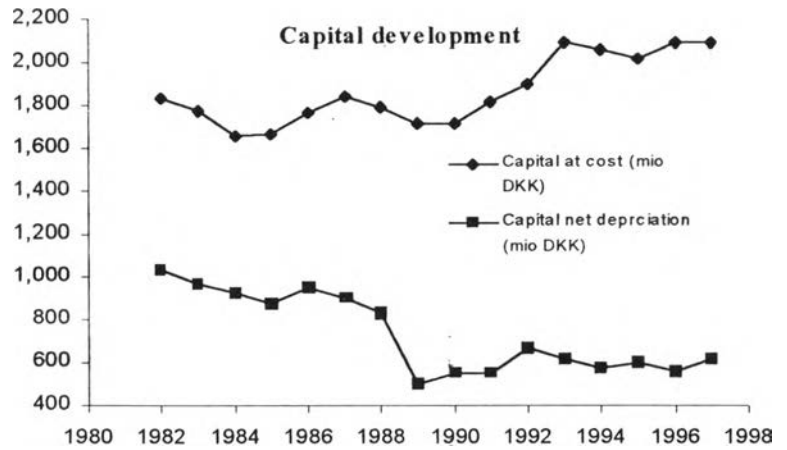
The Danish Steelworks can be simplified to act as a price taker concerning the price of labour, for the reasons mentioned below.
Firstly, the Danish Steelworks is not a sole employer of the labour hours in question in the geographical area. Secondly, the Danish Steelworks has to offer a wage rate and fringe benefits that are on level with the rest of the economy, in order to attract and most important to keep their employees.

Labour hours are estimated on background of information from two sources: (1) the Danish Statistical Database for wage statistic, which give the statutory annual working hours. This is considered as depicting the *true* time the labour work under normal conditions. (2) The financial statements giving the years average number of workers.
It is presumed that the company has an agreement with the union that it can adjust the working hours within a narrow band under "unstable market conditions". Therefore, the measurement of labour hours is not accurate, and contributes only to a lower R^2.
Nevertheless, the measurement errors are believed to be minor.

5.3 Capital

The quarto/heavy plate mills (which count for $^2/_3$ of the production output) is know for using old machinery and the Danish Steelworks is no exception. *Figure 5.1* shows that the company's capital depreciation is faster than the wearing out. The graphs depict an increase in "capital at cost" and a decrease in "capital net depreciation".
The overall trend in the economy as a whole is that productions are getting increasingly capital intensive.
The facts that price of labour has increased sharply while the increase in the price of capital has been lees steep only reinforce the argument that capital should increase in time and with output. Hence, "capital at cost" represents capital in process.

Figure 5.1



Because of the firm's financial reconstruction in the 1980's; and the high degree of self-financing[1], this study presumes that the company up to the late of the observed period has had limited access to capital.

For that reason, with new investments in productivity-increasing-capital follows: technological upgrading must obviously be on older capital in order to solve the problem of bottlenecks. Hence, capital can also be considered homogeneous.

5.4 Technical Progress

"As the firm's knowledge and understanding, of the set of efficient production possibilities, extend and deepens, then the set of efficient input combinations widens and new possibilities emerge. The production function is therefore not static"[2].

"A common way of introducing technical progress is to make technical progress a function of time. This is tantamount to assuming technical progress falls like manna from heaven. It is a weak proxy in that typically, factor inputs have been growing over time and hence, the scale of operation is highly correlated with time. It therefore becomes difficult

[1] Between 33 and 36 percent in the observed period as stated in the financial statements.

[2] David F. Heathfield and Soeren Wibe, An Introduction to Cost and Production Functions, (Houndmills, Basingstoke, Hampshire RG21 2XS and London: Macmillan Education Ltd,. 1987).

empirically to distinguish between technical progress and returns to scale"[3]. This shall be kept in mind when estimating the production function.

5.4.1 Technical Progress: Embodied or Disembodied?

Disembodied technical progress is assumed to be homogeneous such that any one piece of capital is exactly like any other and is equally suited to any task: More capital simply means more of the same. If this is true then technical progress must affect all existing processes. –It makes use of existing labour and existing capital to produce more of the same output[4].

Embodied technical progress is that technical progress requires some adoption of existing processes. Existing labour is less costly to adapt but capital constructed to perform particular operations simply cannot adopt. Therefore, introduction of new capital accompanies introduction of new production-processes.
The consequences of those assumptions are first; the efficiency of production will depend not only on the current state of knowledge but also upon the rate of investments in new machines. Second, since capital now embody particular techniques it is no longer possible to regard all capital the same. Therefore, non-homogeneous capital must be indexed by vintage[5] -in order to aggregate into a single measure of K. This is the same discussion as for Lh in section 2.4.

Putty-Clay: Vintages of capital can be tightened still further if we assume that capital is constructed so as to require a fixed amount of other inputs and produce a fixed amount of output. Before the capital is installed the company can choose any combination on the frontier (capital is putty). After the capital is installed the company is constrained to use one and only one set of inputs (capital is clay).

The above discussion concerning *embodied vs. disembodied technical progress and putty-clay* is rather simplified. We know that a firm's capital embodies different techniques

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[3] David F. Heathfield and Soeren Wibe, An Introduction to Cost and Production Functions.
[4] Ibid.
[5] Ibid.

hence; it is no longer possible to regard all capital the same, which only defends the introduction of the vintage capital stock concept.

However, because of the existence of bottlenecks in the production, we can not assume that all capital are utilised to the same degree. The increasing human-capital and the "technological upgrading" of the vintage-capital -by small investments- help solve some of the bottleneck problems and therefore improving overall productivity significantly.

These smaller investments in technological upgrading are often not much bigger than the necessary maintenance expenses and therefore, very difficult to measure. Moreover, the upgrading must obviously be on older capital in order to solve the problem of bottlenecks. Hence, capital is homogeneous and therefore technical progress is not related to vintage-capital or any other indexes.

5.4.2 Human Capital

Human capital is as technical progress, interpreted as an efficient parameter. The incentive for the company to invest in human capital is to increase labours productivity. It is very difficult to measure human capital due to its qualitative assets, including educational background, learn-by-doing and experience, and received direct job training. For that reason, it is very difficult to distinguish technical progress and human capital empirically.

To measure human capital we must examine the assets it composes separately:
The wage is the only way to pay for *educational background*. Hence, the wage depicts educational background.
Learn-by-doing and experience can as well only be paid for by the wage.
"There is a great incentive for the firm to share the return to specific human capital investment with the worker in the form of wage premium. If the firm pay a premium, its total wage costs will increase but so would the expected tenure of the worker, thereby reducing the periodic rent"[6].
As the Danish Steelworks Ltd. has been operating since 1940, we can expect a uniform

[6] Robert A. Hart, The Economics of Non-Wage Labour Costs (London: George Allen & Urwin Ltd., 1984).

distribution in tenure. That is, some workers are paid above and others below the average MRP_L but on average labour costs equal MRP_L.

In addition, the wages for the production workers has been more or less identical. This is because the strong union and the company have agreed on "equal work equal pay", hence suggesting the work force to be homogeneous.

By learn-by-doing and smaller investments in existing capital, we are able to achieve productivity improvements. This justifies the introduction of human capital into the technical progress term.

5.4.3 Bias Resulting from Leaving out Intermediate Inputs

Leaving out non-fixed intermediate inputs from the production function has an effect on measurement of the "true" technical progress[7].

As discussed above technical progress is introduced as a function of time in the production function ($A(t)$) and interpreted as output growth leaving other inputs constant. Hence, expressing output: $q=f(L(t), A(t), M(t))$ (M is intermediate inputs).

Taking total derivatives $dq = \frac{\partial q}{\partial x_i} dx_i + \frac{\partial q}{\partial t} dt + \frac{\partial q}{\partial M} dM$, holding all factor-inputs constant ($\partial M/\partial t=0$, $\partial x_i/\partial t=0$) yields: $dq = \frac{\partial q}{\partial t} dt$.

However if M does not appear in fixed proportions of q over time (a "non-fixed intermediate inputs") then $\partial M/\partial t \neq 0 \Rightarrow dq = \frac{\partial q}{\partial t} dt + \frac{\partial q}{\partial M} dM$. Therefore, estimating technical progress introduce the bias term $\frac{\partial q}{\partial M} dM$. However, estimating the firm's demand for any primary factor input is not affected by the bias. For that reason, neither is estimate of elasticity of labour demand.

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[7] Michael Bruneo, Duality, Intermediate Inputs and Value Added, in A Dual Approach to Theory and Applications. Vol. 2 (. Amsterdam: North-Holland Publishing Company, 1978).

5.5 Energy

It has only been possible to get the company's exact energy consumption data for the period after 1991. That is when the company started enclosing the "*environment statement of account*" (the company's environmental "burden" in form of pollution and consumption of natural resources).

The introduction of energy (E) yields an overall fit R^2 of 0.97 (see appendix 3 for computer printout). However, a high correlation between energy (E) and the other factor inputs plus technical progress was found.
The result was that the model estimated capital, labour-hours, and technical progress to be insignificant and leaving energy (E) as the only significant variable

The multicollinearity problem can be solved by:

(i) Transforming the data into ratios. However, those transformed numbers does not make economic sense and we may lose valuable information in the transformation.

(ii) Excluding variables from the model.

For the above reason energy (E) is excluded from the model.

5.6 The Final Production Function Model

On background of the above discussion the Cobb-Douglas production function model to be estimated:

$$q = A(t)\, Lh^{\alpha}\, K^{\beta} \qquad (5.1)$$

Where: $A(t)$ denotes technical progress.
Lh denotes labour hours.
K denotes capital in progress