A Vintage Model for the Swedish Iron and Steel Industry

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Contents

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1 INTRODUCTION

The ISAC (Industrial Structure And Capital Growth) is a multisectoral macro model of the Swedish economy designed to simulate both short-term responses and long-term adjustment to sudden price changes.[1] The impact of past investments, depreciations and choices of technique on future production and substitution possibilities is therefore of particular interest. The industrial sector in the ISAC consists of 15 subsectors. A vintage model has been set up for each subsector in order to analyze the dynamics of growth.

So far, paucity of data has so far set narrow bounds on the possibilities for empirical work on the industrial production structures. However, special efforts have been made with respect to one subsector — the iron and steel industry.

The iron and steel industry was chosen because it is very energy intensive and thus a major energy consumer. As a result, this subsector is a very important part of the energy studies now in progress

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[1] The ISAC model was developed on the basis of earlier macro models used at IUI. The first model of this kind developed at the Institute was designed for medium-term forecasting; see Jakobsson, Normann and Dahlberg (1977). This model was developed further for the next IUI economic survey in 1979 by including i.a. investment functions and price formation equations; see Jansson, Nordström and Ysander (1979).

Since then the model has undergone major restructuring. It now incorporates adjustment mechanisms for wage rates, prices, industrial capital, local government actions, etc. and some of the development of industrial productivity is endogenously explained; see Jansson, Nordström and Ysander (1981).

using the ISAC. It is also a highly capital intensive industry, which makes a vintage approach particularly attractive since it is very unlikely that the technique already installed could be adjusted to rapid price changes.

Another reason for using a vintage model rather than a less complicated putty-putty approach, with one homogeneous production structure, is that the new techniques introduced during the estimation period are distinctly different from the average existing production structure in this subsector.

One problem associated with using vintage models in empirical studies involves specifying the econometric equations so as to match the available data. If observations on individual production units are available, quite general models can be used which allow, e.g., for substitution between factors of production both ex ante and ex post, as in Fuss (1977, 1978).

When only aggregate data are available, it is difficult to test such a general approach empirically. More stringent assumptions have to be imposed. Earlier studies tended to assume fixed factor proportions both ex ante and ex post — the so-called clay-clay type of vintage model. This approach is used in studies by Attiyeh (1967), Smallwood (1972) and Isard (1973). But the effects of changes in relative prices on the input factor mix cannot be studied using a clay-clay model. This, however, is one of the main interests in this paper, as well as in many other studies.

The other main group of vintage models, the putty-clay version, allows for price substitution ex ante and assumes fixed factor proportions ex post.

This approach is used here and was earlier adopted by Bischoff (1971), King (1972), Ando _et al_. (1974), Mizon (1974), Sumner (1974), Görzig (1976), Hawkins (1978), Bentzel (1977) and Malcomson and Prior (1979).

With the exception of Hawkins (1978), earlier putty-clay studies considered only two factors of production, labor and capital, and used a Cobb-Douglas production function. In this paper energy is also included and a translog cost function is used to derive ex ante demand functions for the input factors.

A constant or infinite lifetime of capital equipment was assumed in most of the above putty-clay studies. Exceptions are Görzig, Bentzel, and Malcomson and Prior. In this study the depreciation rate is a function of gross profitability, thereby allowing the average life span of capital equipment to vary over time.

2 OVERVIEW OF THE MODEL

The decision to invest in new production capacity is assumed to be divided into two stages: one where the new technique is determined and one where the amount of new capacity is decided. It is also assumed that there is a three-year lag from the year of decision to the first year of operation of a new vintage. This choice of time lag is based on some initial estimations described in Appendix 1.

The new technique is chosen to minimize production cost with respect to input prices. The ex ante production structure is represented by a translog cost function (see Section 2.1).

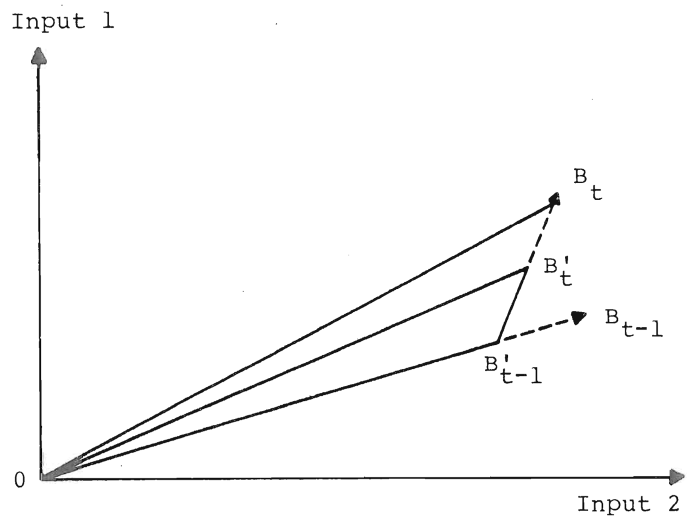
The amount of new production capacity depends on the net increase in total capacity and the scrapping of old units. The net increase in capacity is assumed to depend on expected demand, utilization of existing capacity and the profitability situation. The capacity growth model is described further in Section 2.2.

All vintages are assumed to have the same depreciation rate, which varies over time as a function of the gross profit margin of the subsector. Scrapped capacity is replaced by a new cost-minimizing technique. We expect a priori the depreciation rate to be negatively correlated with the profit margin.

There is also reason to believe that the depreciation rate might vary across vintages due to differences in individual profit margins. But this assumption would complicate the econometric model considerably.

The utilization rate is assumed to be the same for all vintages. This approach can to some extent be justified as follows. In a process industry such as the iron and steel industry, there is a serial dependence between different units since output from, i.e., blast furnaces is used as input in steel manufacturing. These vertically linked production units are run mostly under one company, so that their production levels are jointly dimensioned. The impact of differential profitability on the utilization in each unit is diminished in the short run by the fact that the subsector consists

Figure 1



mainly of large production units, each of which is often the major employer in its geographical vicinity. As a result, the production of unprofitable companies is often maintained by subsidies from the central government.

Changes in technique and capacity between two periods are outlined in Figure 1, where for simplicity only one old vintage is included. The arrow OB_{t-1} is the input mix which corresponds to the capacity available at t-1. The old unit is then partially scrapped, which decreases the maximal input demand from B_{t-1} to B'_{t-1}. The new vintage B_t is then added, which moves the maximal input mix to OB_t.

The putty-clay description of the model cannot be distinguished from a putty-putty interpretation since the same technique is used for both net investments and replacement. In other words, by means of the combined scrapping/reinvestment activity, the given capacity is modified from B_{t-1} to B'_t and then extended by the addition of net investment to B_t. In the following, however, we continue to express our arguments in terms of the putty-clay assumption.

It should also be emphasized that the role of the investment model in this study differs from that in other aggregate growth studies of production. Interest is usually focused on the model of investment. The development of production capacity is not observed directly and therefore has to be explained indirectly via investments and the capital/output ratio. The investment model then becomes the key to explaining the dynamic growth of production.

In this study, we have benefited from observations of capacity development which enable us to estimate a model that explains capacity growth directly. Thus, the equations which explain the net increase in production capacity replace the strategic position usually held by the investment model.

The investment equation is discussed further in Section 2.3.

2.1 Ex Ante Choice of Technique

In the ISAC model there are substitution possibilities between the following four aggregate inputs in each industrial subsector: energy, other intermediate goods, labor and capital. The time-series for the input/output ratios for intermediate goods in the iron and steel industry is extremely stable over the whole observation period. This suggests that they are perfect complements to the aggregate of the other inputs. As a result, the input share of intermediate goods, in both new and old plants, is constant and independent of price changes.

With constant i/o shares of intermediate goods and separability between energy, labor and capital, producers are assumed to minimize the cost of production of new vintages. The minimal cost function for energy, labor and capital is assumed to be represented by a translog form. The technology is restricted to be linear homogeneous, and embodied technical change to be neutral and an exponential function of time. The minimal cost function[1] for new units of production can now be written as

$$c = A\cdot q\cdot \exp\left[\Sigma\alpha_i \ln p_i + \sum_{ij}\Sigma\, \beta_{ij} \ln p_i \ln p_j + \lambda t\right] + p_m m, \qquad (1)$$

where

q = value added including energy
m = intermediate goods
i,j = e, k, l (energy, capital and labor, respectively).

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[1] A well-behaved cost function can be derived from a well-behaved production function by taking the input mixes which minimize cost of production at given prices and output. Denote these inputs $x_{i,min}(p,y)$ and then calculate the total cost for the input combination:

$$C = \sum_i p_i x_{i,min}(p,y).$$

This minimum cost function corresponds to c in (1). However, when c takes the form as in (1), an algebraic expression for the production function related to (1) cannot be given. However, a well-behaved production structure exists for every well-behaved cost function, and vice versa, as proved by Shephard (1953).

$$\Sigma\alpha_i = 1$$

$$\sum_j \beta_{ij} = 0, \ \sum_j \beta_{ji} = 0, \qquad \beta_{ij} = \beta_{ji}. \tag{1a}$$

The translog part of the above cost function is a second order local approximation of any regular cost function and its flexible form places few a priori restrictions on the production structure. However, it might not be a proper cost function in all instances. The questions of if and where (1) is a proper cost function have to be checked after the parameters have been estimated. Unfortunately, this is generally not an easy task and it has to be carried out for every set of input prices (see Berndt and Christensen, 1973). Other known flexible forms such as the generalized Leontief function also have these disadvantages.

From Hotelling's Lemma (Hotelling, 1932), it is known that

$$\frac{\partial c}{\partial p_i} = x_i,$$

where x_i is the cost-minimizing input of good i.

If we incorporate the assumption of a three-year lag between the date of decision to invest in a new unit and the first year of operation, we get

$$\varepsilon_{t,i}(p,t) = \frac{p_{q(t-3)}}{p_{i(t-3)}} \cdot \left(\alpha_i + \sum_j \beta_{ij} \ln p_j(t-3)\right)\frac{q}{y}, \tag{2}$$

where the subscript t refers to the initial year of a vintage, t in parentheses denotes current time, ε_i is the i/o share x_i/y, and the aggregate i/o ratio q/y is calculated from the observations.

However, there are no observations of the unit cost of production p_q for separate vintages. The only index that can be observed is the average unit price for the whole subsector. Therefore, p_q for the new vintage which occurs in (2) is the unit cost index obtained from the translog cost function. Thus

$$p_q = e^{\lambda t} \prod_i p_i^{\alpha_i} \prod_j p_i^{\beta_{ij} \ln p_j} \qquad i,j=e,k,l \qquad (3)$$

Expression (2) now becomes nonlinear in the parameters, although the calculation cost remains modest. The price variables should express expected prices. Moving average price variables were tried as proxies. However, since the use of actual prices at time t-3 did not change the results, this alternative was chosen to keep the model as simple as possible.

The i/o ratios of installed vintages are assumed to be independent of the utilization rate. Some correlation between the cyclical changes in the utilization variable and the i/o ratios can indeed be observed. But this dependence does not appear too strong to prevent the above assumption from serving as a fairly good approximation. However, this approximation will probably not hold for the years after 1975 (which are not included in the observation period), since the utilization rate then dropped to its lowest level since 1950 and several disturbances occurred in the iron and steel industry.

2.2 The Model of Net Growth

We assume that firms base their decisions to expand or contract production capacity on expectations of future demand for their products. Since the iron and steel industry is a process industry with large units of production, several years elapse between the date a decision is made and the date of installation. With an assumed construction period of three years, today's investment plans will be influenced by the expected change in demand three years from now. The expected change in demand at year t+3 is assumed to be calculated at year t as

$$yp_t(3) = \sum_{i=1}^{3} y_{t-1} / \sum_{i=1}^{3} y_{t-i-1},$$

where

$yp_t(3)$ = expected change in demand at time t+3
y_t = total production level.

That is, the expected change in demand is the ratio between the two most recent three-year moving averages of production.

If firms base their decision to expand solely on expected growth in demand, the desired level of production capacity in three years' time would be

$$ycap^*_{t+3} = yp_t(3) \cdot ycap_{t+2}.$$

But if firms consider both adjustment costs such as costs for internal education of personnel, etc., and the costs of their inability to meet demand fully, they might partially adjust to the desired capacity level, see e.g. Griliches (1967).

In multiplicative form, the adjustment is given by:

$$ycap_{t+3} = ycap^{*\gamma}_{t+3} \cdot ycap^{1-\gamma}_{t+2}$$

or, in growth terms:

$$ycap_{t+3}/ycap_{t+2} = yp_t(3)^{\gamma}. \quad (4)$$

However, firms are certainly aware of the business cycle and it is therefore likely that predictions of growth by simple extrapolation are adjusted to take expected recessions and booms into account. One way of predicting the upswings and downswings around some long-term growth trend is to look at past utilization rates. We assume that past growth in capacity has been more smooth than demand development. This has definitely been the case during the estimation period. Capacity growth does vary with short-term swings in production, but to a lesser extent. This indicates that capacity growth has been affected similar to the business cycle.

The above argument suggests that the past utilization rate should also be included in the capacity growth model. Since we do not know with certainty the length of time involved until past utilization rates begin to influence investment decisions, the observed values for year t and the two preceding years are included. The new variables are included in such a way that the model remains log-linear in the estimated parameters. We then get

$$ycap_{t+3}/ycap_{t+2} = yp_t(3)^{\gamma_1} \cdot \prod_{i=1}^{2} ur_{t-i}^{\gamma_{i+1}}, \quad (5)$$

where the utilization rate is simply the ratio of production level to total installed capacity. Thus

$$ur_t = y_t/ycap_t.$$

The development of profitability is probably also an important factor in explaining past growth in the Swedish iron and steel industry. Increased competition on foreign markets during the past few decades has caused a declining trend in profitability during the 1960s and 1970s by way of decreasing world market prices relative to domestic production costs.

Profitability might also have other effects on decisions in addition to the formation of expectations of future profits. High profitability often seems to have a rapid positive effect on investments, even if prospects in a longer perspective appear gloomy. There are several explanations for such behavior, e.g., institutional inertia and tax legislation in Sweden which tend to "lock" profits inside a company.

There are then reasons to include a measure of both past and current profits in the growth model. The next problem is then the choice of profit measure. One is the gross profit margin, i.e., the ratio of value added minus wages to value added. Since the iron and steel industry is highly capital intensive and has undergone rapid technical change it is preferable, however, to use a measure that captures possible changes in the cost of capital over time. Therefore, we have chosen an "excess" profit variable defined as

$$ep = p^vV/[wL + p^i(r+dr)K],$$

where

$p^v V$ = value added (current prices)
wL = total wages
$p^i(r+dr)K$ = user cost of capital
r = discount rate[1]
dr = depreciation rate.

The way in which depreciation rates are determined in the model is described in the next section. The capital stock is a function of depreciation and consistent with the estimated depreciation rate; see Appendix 1.

The excess profit variable is incorporated in the same way as the utilization rate variable. The estimated growth model then has the following form.

$$ycap_{t+3}/ycap_{t+2} = A \cdot yp_t^{\gamma_1} \prod_{i=0}^{2} ur_{t-i}^{\gamma_{i+2}} \cdot \prod_{i=0}^{2} ep_{t-i}^{\gamma_{i+5}} . \qquad (6)$$

2.3 Depreciation

All vintages in the industry have the same depreciation rate, but this rate varies over time as a function of the aggregate gross profit margin. As for net investments, a time lag of three years is also assumed between the time of scrapping and the time of replacement. The replaced capacity of vintage v at time t is assumed to be the following function of the gross profit margin gp at time t-3:

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[1] Calculations of the discount rate are given in Bergström (1979).

$$d_v(t) = \delta \cdot [1 - gp(t-3)] \cdot ycap_v(t-3),$$ [1]

where

$$gp = 1 - \sum_i \varepsilon_i \, p_i/p_y \qquad i=1,e,m.$$

Thus the term 1-gp is equal to unit operating cost oc and we can write:

$$d(t) = \delta \cdot oc(t-3) \cdot ycap(t-3). \tag{7}$$

2.4 Average Input Shares and Investments

So far, only the net growth function can be estimated on the basis of available aggregate data. But owing to the assumed equivalence of depreciation and utilization rates across vintages and the assumed independence of the input shares of the utilization level, the average i/o ratios can be expressed in a form which can be estimated using aggregate data. The aggregated i/o ratio becomes

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[1] More correctly, depreciation at time t should be calculated with respect to earlier depreciation decisions according to the following formula:

$$d_v(t) = \delta[1-gp(t-3)] \cdot [ycap_v(t-3) - \delta \sum_{i=4}^{5} (1-gp(t-1)) \cdot ycap_v(t-1)], \tag{a}$$

i.e. the depreciation calculated at time t-3 should be made on the capacity of vintage v, minus the capacity decrease already decided at time t-4 and t-5, which is represented by the sum in (a). However, this last term will be of minor importance for likely values of δ since it is multiplied by the squared value of δ. Thus (6) is likely to be an acceptable approximation of (a).

$$\varepsilon_t(t) = \{\Delta ycap(t) + d(t)\}/ycap(t) \cdot \varepsilon_{t,i}(p,t) + \{ycap(t-1) - d(t)\}/ycap(t) \cdot \varepsilon_i(t-1), \quad (8)$$

where $\Delta ycap(t)$ is the net increase in capacity.

Thus, the aggregated i/o ratio is the weighted sum of the i/o ratio of the new vintage, which is a function of past prices, and of the fixed i/o ratio of the old vintages.

Investments are related to the net growth in capacity, the replacement of scrapped capacity and the capital output ratio of the new technique implemented. But the fact that construction time extends over four years — the year of decision and the remaining three construction years — complicates matters. The investments observed at year t should refer to all plants under construction, including all projects started during the years (t-3) to t. This can be exemplified by the following formula

$$inv(t) = \sum_{i=0}^{3} b_i \cdot \varepsilon_{t+i,k}\, ycap_{t+i} =$$

$$= \sum_{i=0}^{3} b_i\, \varepsilon_{t+i,k}[\Delta ycap_{t+i} + d(t-3)],$$

where $\varepsilon_{t+i,k}$ is the capital output ratio of the capacity to be installed at year t+i. The term $b_i \cdot \varepsilon_{t+i,k} \cdot ycap_{t+i}$ expresses the amount of investments caused by the construction of vintage t+i during year t.

Different variations of the coefficients in the investment function have been tried, but a simple weight scheme with the same weight on each element seems to work well. We then get

$$inv(t) = b \cdot \sum_{i=0}^{3} \varepsilon_{t+i,k}\, ycap_{t+i}. \tag{9}$$

3 EMPIRICAL RESULTS

A vintage model of the type used here is a hypothetical construction which cannot compete with studies that use data on actual firms and production units such as Johansen(1972), Førsund and Hjalmarsson (forthcoming) and Fuss (1977, 1978).

However, a special feature of vintage models is recognition of the fact that new production capacity might use technologies quite different from those of the old units. This property makes it possible, e.g., to describe developments which might otherwise seem odd such as the decrease in energy use per unit of output during a period with falling relative energy prices. An aggregate model must either describe energy as a complement to one or more of the other inputs and/or include energy-saving technological change. A vintage model can depict such a situation by adding units which are less energy intensive while in the ex ante production function, energy might still be a substitute for the rest of the inputs and technical change neutral, as in this study.

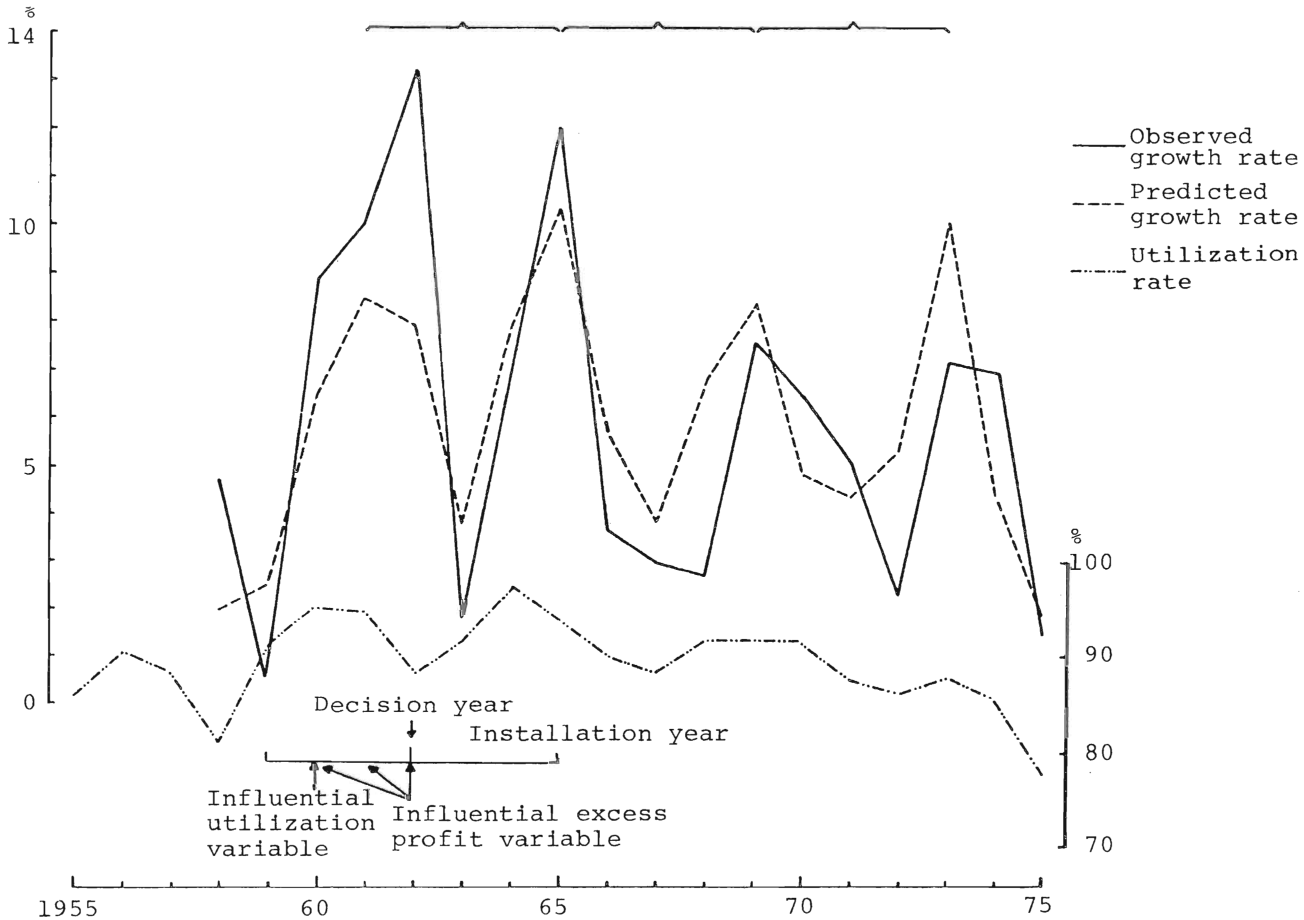
3.1 Past Development of Capacity Explained by the Growth Model

Perhaps the most striking feature of the increase in capacity in the Swedish iron and steel industry is the four-year cycle encountered during the estimation period. Since the utilization rate variable has the same frequency, reflecting the international trade cycle, this variable is important in predicting the swings in capacity growth. As indicated in Figure 2, the time lag between the upward pressure of the business cycle and the responding increase in capacity growth is five years. This response pattern could be interpreted to mean that the decision-makers recognize a trade cycle and take it into account. The reoccurrence of a boom in demand at the expected time confirms the impression of a cycle and triggers the decision to expand capacity to meet the next peak in demand.

Past and current profits and expected demand also explain the short-term swings in growth, but their impact differs over time. Thus, the level of the first and largest peak around 1961 is mostly due to a rapid increase in profitability during the years 1957-59. On the other hand, the size of the second peak is to a large extent explained by an expected increase in demand. Past growth also has a positive effect on the explanation for the two remaining peaks.

The regularity of the growth pattern might, of course, be accidental. The strong correlation with the utilization rate is then spurious and should not be expected to continue in the future.

Figure 2 also indicates a slow decline in the growth trend over time. The average growth rate for the first nine years is 6.2 percent, after which it decreased to 5.5 percent. This drop in average growth is explained mainly by the decrease in profits over time. The average decline in the profit variable alone would have caused growth to


%
14
10
5
0
Observed growth rate
Predicted growth rate
Utilization rate
%
100
90
80
70
Decision year
Installation year
Influential utilization variable
Influential excess profit variable
1955
60
65
70
75

decrease by 1.4 percent. The decline due to a slowdown in expected demand is only .4 percent. However, an increase of 1.1 percent due to a higher average utilization rate counteracts these declining tendencies and in fact limits the decline in capacity growth to .7 percent.

The short-term growth pattern is thus highly dependent on the upswings and downswings of the utilization rate. Profit and growth expectations, however, do have an effect, but in different ways during different time periods. On the other hand, the long-term decline in average growth is due mostly to a fall in profitability.

3.2 Estimated Input Shares and Investments

The price elasticities for the input shares of new vintages, calculated at the mean value of the exogenous variables, are presented in Table 1 along with the Allen partial elasticities of substitution (AES) at the same point. Since the variations in these elasticities over time are slight, the mid-point elasticities give a fair indication of how the model predicts that new techniques will respond to prices during the observation period.

All inputs are estimated to be substitutes and the factor relation most sensitive to changes in relative prices on the margin is energy and labor, which had the highest elasticities of substitution. Capital and labor are estimated to be almost perfect complements on the margin.

It should be emphasized, however, that it is difficult to compare the properties of the ex ante function estimated in this study, which describes how

Table 1 The AES and price elasticities of the ex ante function

	Price elasticities			The Allen elasticities of substitution[a]		
	$\eta_{.,e}$	$\eta_{.,k}$	$\eta_{.,l}$	σ_{ek}	σ_{el}	σ_{kl}
$\eta_{e,.}$	-.98	.43	.55	.82	2.63	.07
$\eta_{k,.}$	.08	-.10	.02			
$\eta_{l,.}$	.35	.06	-.41			

[a] The Allen (partial) elasticity of substitution measures, for a constant output level the percentage change in the input mix between two production factors due to a 1 percent change in their relative prices when all other inputs adjust optimally to the price change.

technique is chosen on the margin, with the production structures usually estimated, where a whole subsector is regarded as a single homogeneous production unit. The reason is that in the latter approach, price changes and other explanatory variables affect the average technique of an entire subsector in exactly the same way. In a vintage model, new vintages are distinguished which generally have different properties than already installed capacity.

The only aspect of changes in technique over time which is not explained by changes in input prices and the implementation of new vintages, is the embodied trend factor in the unit output cost of new vintages. This trend factor, which is the inverse of the neutral technical change factor in the production function, is important in explaining the development of the ex ante function, i.e., the marginal input shares. However, the dominant factor in explaining the development of average input shares is the addition of new production units.

This may be illustrated by separating the effect of adding new production from the embodied technical change and price adjustment of the new vintage. The percentage change in the average input share can be split into two terms accordingly:

$$\frac{\varepsilon_i(t) - \varepsilon_i(t-1)}{\varepsilon_i(t)} = \frac{ycap_t(t)}{ycap(t)} \frac{(\varepsilon_{t-1,i} - \varepsilon_i(t-1))}{\varepsilon_i(t)} +$$

$$\frac{ycap_t(t)}{ycap(t)} \cdot \frac{(\varepsilon_{t,i}(p,t) - \varepsilon_{t-1,i})^{1,2}}{\varepsilon_i(t)} .$$

The first term describes the effect which results from including a vintage of the optimal technique at time t-1. The second term describes the effect of adjusting the technique of the new plant to today's prices and embodied trend changes. The effects of these two causes of change are listed in Table 2, along with the total predicted and observed percentage change for each input share.

The distinction between vintage and marginal effects is illustrated in Figure 3. For simplicity, embodied technical change is omitted. An assumed positive price substitution moves the input mix of

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1 $\varepsilon_{t-1,i}$ should be written $\varepsilon_{t-1,i}(p(t-1),t-1)$.

2 If the term $ycap_t(t)/ycap(t)\ \varepsilon_{t-1,i}$ is added and subtracted from $\varepsilon_i(t)$ it can be written:

$$\varepsilon_i(t) = ycap_t(t)/ycap(t) \cdot \varepsilon_{t-1,i} + (1-ycap_t(t)/ycap(t)) \cdot \varepsilon_i(t-1) + ycap_t(t)/ycap(t)(\varepsilon_{t,i}(p,t) - \varepsilon_{t-1,i}).$$

Table 2 Changes in input shares, 1960–75

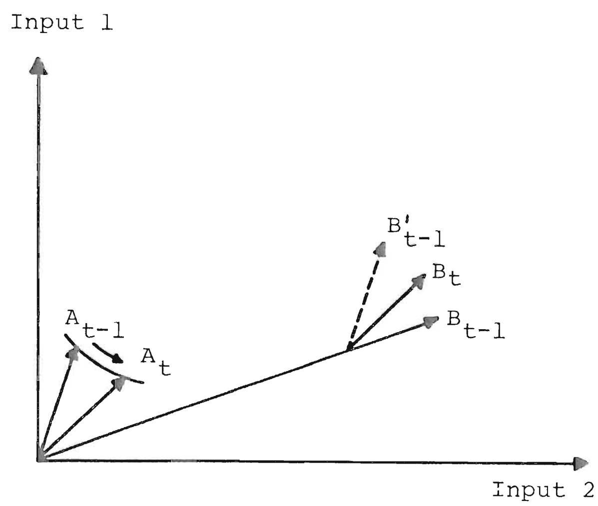
	Energy				Capital				Labor			
	Marginal effect	Vintage effect	Pre-dicted total	Ob-served total	Marginal effect	Vintage effect	Pre-dicted total	Ob-served total	Marginal effect	Vintage effect	Pre-dicted total	Ob-served total
1960	-.6	-5.1	-5.7	1.6	-.4	- .6	-1.0	-	-.3	-5.9	-6.2	-6.7
63	.6	-1.7	-1.1	-5.7	-.4	- .3	- .7	-	-.4	-3.3	-3.7	-8.9
66	.4	-2.0	-1.6	- .9	-.5	- .7	-1.2	-	-.7	-5.6	-6.3	- .2
69	.4	- .3	.1	-1.	-.5	-2.	-2.5	-	-.6	-6.6	-7.2	-6.3
72	-.3	- .0	- .3	-1.	-.2	-1.2	-1.4	-	-.3	-3.8	-4.1	-7.3
75	.8	-1.6	- .8	5.8	-.3	-1.4	-1.7	-	-.4	-4.2	-4.6	8.9

the new vintage from A_{t-1} to A_t. If the vintage with a technique optimal at time t-1 is added to the old production capacity surviving in period t-1, the aggregate input mix will move from B_{t-1} to B'_{t-1}. This illustrates the "vintage effect" in Table 2. The substitution due to a relative price increase for input 1 will then move the aggregate mix from B'_{t-1} to B_t, which illustrates the "marginal effect" in Table 2.

The "vintage" effect explains most of the decrease in the i/o ratios for both energy and labor. The vintage effect of the changes in the capital share depends on the assumed initial capital stock value. The hypothetical average capital input share happens to be similar to that of new vintages. So, in this instance, the two effects are of the same magnitude.

The vintage effect is a function of the differences between the i/o ratios of the new vintage

Figure 3



and the total aggregate. This fact may help to explain (without introduction of elaborous time-dependent nonneutral technical change) why an aggregate input share decreases at the same time as its own price falls, relative to prices of the other input factors. This is illustrated in Figure 3, which shows a positive elasticity of substitution on the margin, i.e., a relative incease in the price of input 1 will cause the ratio of input 1 to input 2 to decrease. But the aggregate effect of adding new production is the opposite, since the intensity of input 1, relative to input 2, increases. In a two-factor input case, a regular production model cannot reflect such an increase without the introduction of nonneutral technical change. In a case with more inputs this situation can be modelled by making the input with the decreasing input share a strong complement to another input with increasing own prices.

The preceding issue of complementarity or substitutability between inputs has lately been discussed a great deal, particularly in connection with energy due to its important policy implications (see Berndt and Field, 1981.) Suppose the aggregate model describes energy and labor to be complements. This would indicate that an increase in energy prices caused, e.g., by an extra tax would lead to a reduction in employment per unit of output. A vintage model, however, can describe the simultaneous decrease in the input share of energy and in the relative energy price by adding a new unit which is less energy intensive than the average. Still, energy might be a substitute for the other inputs in the ex ante production function. Even if the new vintage has a higher energy share than it would have had without a decrease in prices, the average use of energy might well decrease per unit of output, after the introduction of the new plant. This situation occurred for instance during the period 1960-64, where the price of energy relative to output and capital was almost constant, whereas its price relative to labor fell drastically by approximately 9 percent per year. As shown in Figure 4, this leads to an increase in energy intensity per unit of output on the margin, but since the marginal capacity has a lower level of energy use, total energy use still decreases.

The ratio of the labor share of a new vintage to the average value fluctuates between 45 and 50 percent during the estimation period (Figure 5). This high labor productivity, predicted for new production capacity, might well be biased upward because of the rigidity of the model specification, which does not allow for any increase in labor productivity for already installed units.

The model predicts the upswings and downswings of the investments poorly (Figure 6). This is not too troublesome, however, since this study has focused mainly on the model for capacity growth.

Figure 4 Energy output ratio, 1958–75

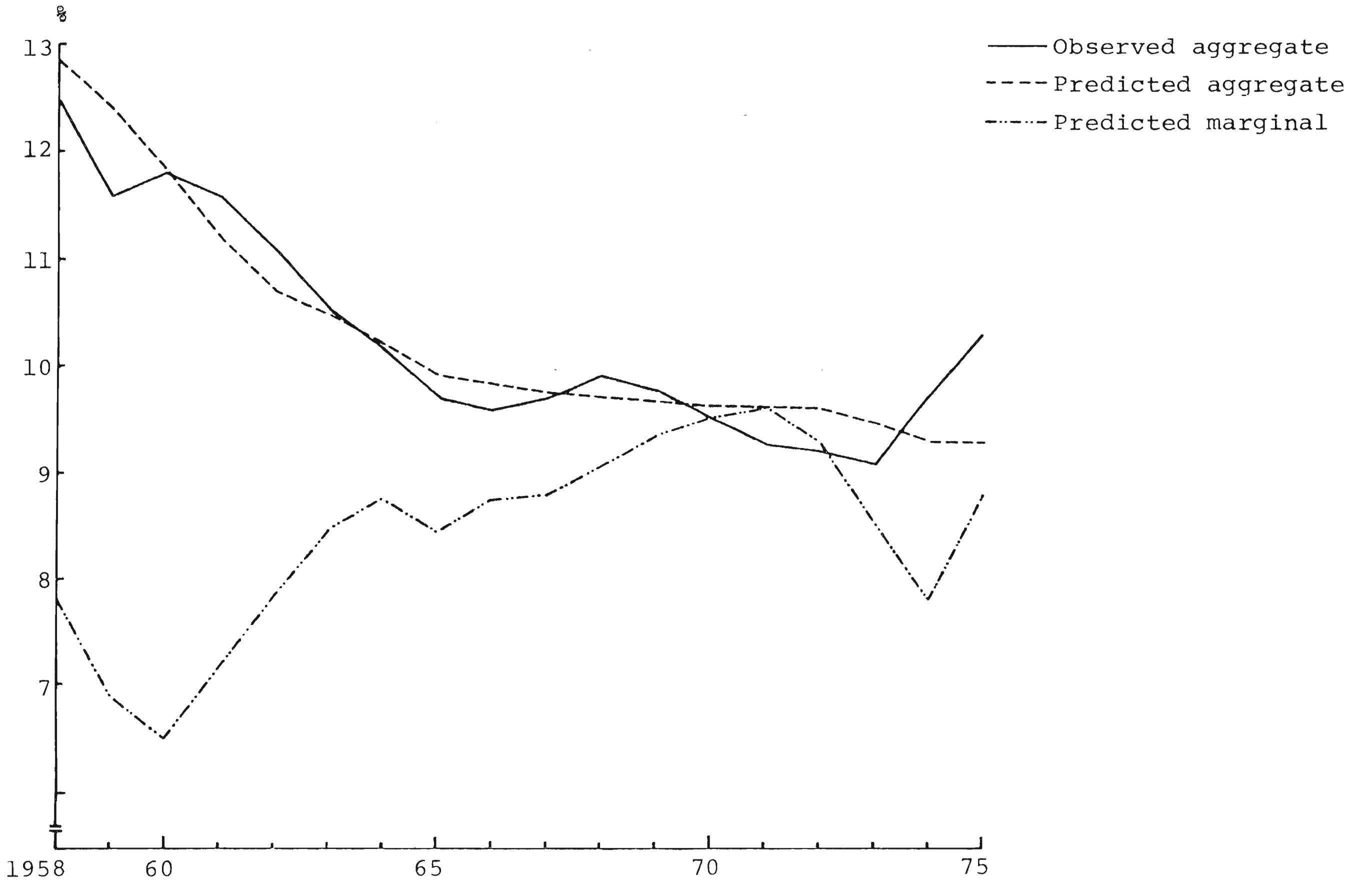
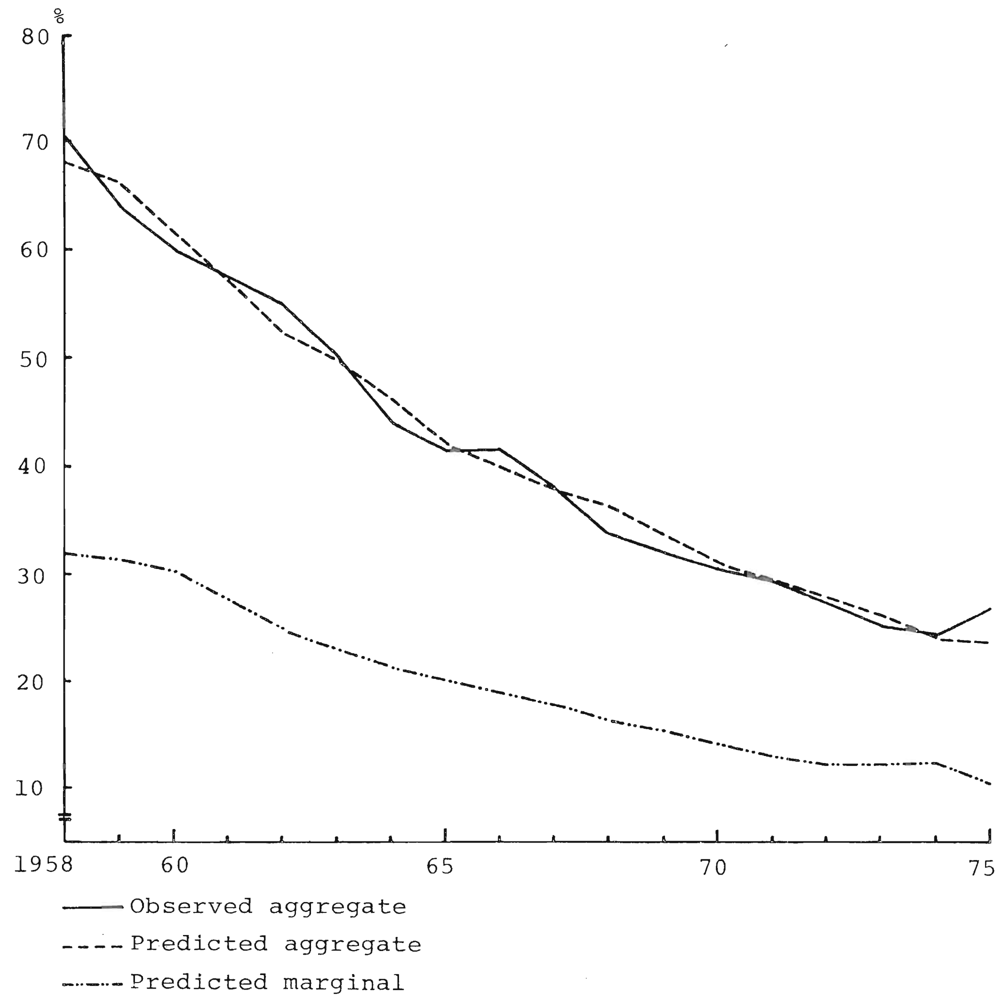
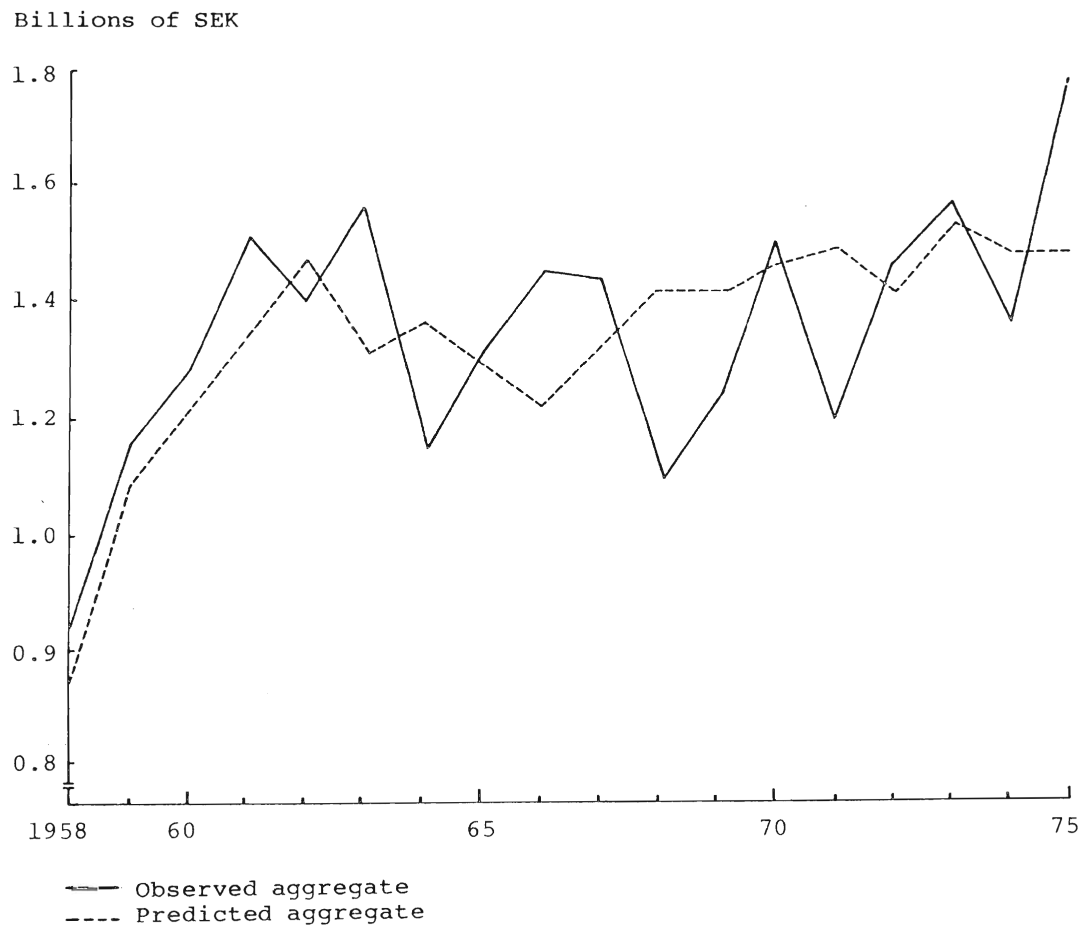


Figure 5 Labor output ratio, 1958-75



Billions of SEK. 1975 prices.



Appendix 1 ESTIMATION PROCEDURE AND PARAMETER ESTIMATES

It is difficult to obtain a proper empirical base for the dynamic structure of the model. The maximum number of observations is 27 and long time lags are to be expected. This is because the construction time for new production units might be several years and the decision to build a new plant is likely to depend on economic results several years in the past. These factors can add up to quite long lags between an event and its impact on the installation of new capacity. Estimation of all the coefficients of all lagged variables without constraints would leave too few degrees of freedom.

One way of reducing the number of parameters is to specify, e.g., a quadratic Almon lag structure. But it is difficult a priori, to believe in a specific lag distribution, since the observed aggregate dynamic structure depends on several economic agents who might well have different reaction patterns. On the other hand, the amount of new production capacity installed by each economic agent is expected to be positivly dependent on the explanatory variables, e.g., an increase in profits should lead to an increase in new capacity. If this is true on the micro level, then the variables will also be positively correlated on the macro level. Since a constant elastic functional form is used, the above reasoning suggests that the coefficients should be estimated under the restriction that they all are greater than or equal to zero. These restrictions are imposed on the estimated elasticities. The following two constraints are also added in order to increase the degrees of freedom further: economic events during the construction period, which is f years long, will not affect either the size or technique of the new production plant, and only the two preceding years plus year t are assumed to influence the construction of a new plant.

The model of capacity growth was then estimated for different construction times of one to four years under the above assumptions and coefficient restrictions. A three-year construction period gives the highest R^2 and the largest number of significant coefficients.

These initial runs were based on the profit variable derived from the capital stock data reported by the SCB.[1] Since a construction time of three years seems reasonable, it has been used throughout the study.

The equations for the input shares of energy and labor and the investment function were estimated simultaneously, using a nonlinear FIML procedure. A new capital cost variable was then calculated using the estimated depreciations. The growth model could then be estimated with a capital cost variable which corresponds to the rest of the model.

The model equations which are explained in Section 2 are listed below, along with the statistical assumptions.

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[1] SCB is the Swedish abbreviation for National Central Bureau of Statistics.

Aggregate input share (see 2.4)

$$\varepsilon_i(t) = ycap_t(t)/ycap(t) \cdot \varepsilon_{t,i}(p,t) +$$

$$[ycap(t-1)-d(t)]/ycap(t)\cdot\varepsilon_i(t-1)+v_{t,i}, \qquad \text{(A1)}$$

$$i = 1,2$$

where

$$\varepsilon_{t,i}(p,t) = p_q(t-3)/p_i(t-3)\cdot[\alpha_i+\Sigma\beta_{i,j}\ln p_j(t-3)]$$

$$d(t) = \delta \cdot oc(t-3) \cdot ycap(t-3)$$

$$p_q(t-3) = e^{\lambda(t'-3)}\Pi p_i^{\alpha_i}\Pi_j p_i^{\beta_{i,j}\ln p_j} \; {}^{1}$$

Investments (see 2.4)

$$inv(t) = b \cdot \sum_{j=0}^{3} \varepsilon_{t+j,i}\; ycap_{t+j}(t) + v_{t,3} \qquad \text{(A2)}$$

Capacity growth (see 2.1)

$$\ln[ycap(t+3)/ycap(t+2)] = a + \gamma_1\ln(yp) +$$

$$\sum_{i=0}^{2}\gamma_{i+2}\ln(ep_{t-i})+\sum_{i=0}^{2}\gamma_{i+5}\ln(ur_{t-i})+v_{t,4}. \qquad \text{(A3)}$$

v_t denotes the vector of error terms and is assumed to be normally distributed with zero mean and the following covariance matrix

$v_t \sim N(0,\Omega)$,

where

$$\Omega = \begin{bmatrix} \Sigma & 0 \\ 0 & \sigma \end{bmatrix}$$

[1] t'=t-1975. This transformation is made in order to set the price index p_q equal to unity in the base year 1975.

and

$$E(v_t \; v'_s) = \delta_{ts}$$

and

$$\delta\tau\sigma = \begin{cases} 1 \text{ if } t=s \\ 0 \text{ if } t \neq s \end{cases}$$

where Σ is the covariance matrix corresponding to the equations (1) and σ is the variance of the error term for the growth model.

There are no constraints on the parameters in equation (A3), which connects it to the first three equations for the input shares (A1) and investment (A2). This implies that the estimation of all four equations can be divided into two parts — one which simultaneously estimates the first three equations and one which estimates the single equation for capacity growth. This follows from the structure of the covariance matrix and the fact that no endogenous variables from the upper block of equations appear in the fourth equation. Since depreciation is estimated consistently in the first block of equations, the capital cost derived from these estimates will also be consistent. This ensures that the link between the blocks will not affect the consistency of the single equation estimate of the growth model. Efficiency, however, will be lower than in an estimate which would incorporate all four equations simultaneously.

The estimated parameters are listed in Table 3. The restrictions which constrain the cost function of new vintages to be linear homogeneous are imposed on the estimates.

Table 3

	α_i	β_{i1}	β_{i2}	β_{i3}	b	λ	d^a	R^2	DW
Energy share	.154	-.015*	.045	-.030*				.80	.87
Labor share	.265	.045	.080	-.125				.98	1.40
Investments	.581	-.030*	-.125	.155	.642			.12	2.11
Common parameters						-.0380	.0644		

	α	yp	ep	ep_{-1}	ep_{-2}	ur	ur_{-1}	ur_{-2}	$\bar{R}^2$	DW
Growth equation parameters	.106	.512	.266	.030*	.005*	.0*	.0*	.268	.54	2.01

* Not significantly different from 0 on the 5 percent level.

[a] The d reported is δ multiplied by the average unit cost of production. This implies that the average depreciation rate during the observation period is 6.4 %.

Appendix 2 DESCRIPTION OF THE DATA

One strategic variable was not explained in the text, namely the data used for capacity growth. Observations of production capacity are seldom available, although time series on the development of capacity and production of crude iron were made available through the kind cooperation of the Swedish Ironmasters' Association.

Under the assumption that the utilization rate is the same for the sector as a whole as for crude iron production, a capacity variable for the entire iron and steel industry can be constructed as:

$$(ycap_I / y_I) \cdot y_{IS} = ycap_{IS},$$

where the index I denotes crude iron, IS iron and steel, ycap production capacity and y actual production.

Since all crude iron produced in Sweden is processed further in the domestic steel industry, it is likely that the steel industry has developed in close connection with the crude iron industry. The assumption of the same utilization rate in the two subsectors therefore seems justified. However, if e.g. the amount of special steel produced has increased relative to other steel products, then a trend shift might occur between the output of crude iron and the aggregate measure of steel.

This would also cause the calculated capacity measure to depart from the observed capacity of crude iron production over time. Such a departure has not occurred, as indicated in Figure 7.

All but two of the variables used in this study are the same as those in Dargay (1983), where a further description can be found. The exceptions are the capital cost component in the excess profit variable and the capital price variable used to estimate the input shares. In the first case, the calculated depreciation and rate of return for each year have been inferred, since the excess profit variable might be regarded as an ex post cash flow variable rather than an ex ante planning variable. The capital stock which appears in the profit variable also has to be accumulated using the estimated depreciation rate. The value of the initial stock is not known, however; it is calculated under the assumption that the cost of capital, reported by the SCB, is equal to the cost given by the different depreciation models used in this study, i.e.,

$$(p_{KO}\ K_O)_{SCB} = p_{KO}\ K_O$$

and

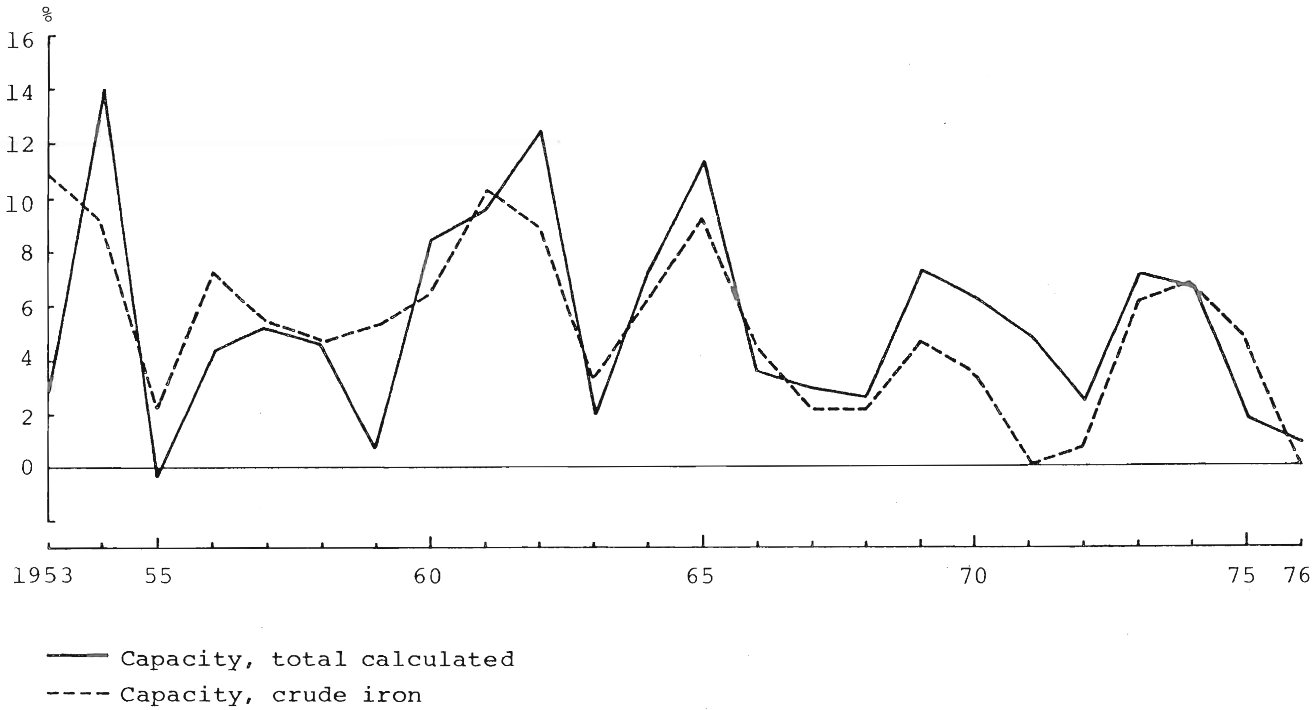
$$K_O = (p_{KO}\ K_O)_{SCB}/p_{KO}.$$

The capital stock series has then been calculated accordingly

$$K_t = I_t + (1-dr_{t-1})K_{t-1}.$$

In the second case, on the other hand, it seems more natural to regard capital price as an ex ante planning variable. Therefore, the depreciation rate and internal rate have been considered as constants. Since all prices are in index form, the capital price will be equal to the investment price index.

Figure 7 Capacity growth, 1953–76



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