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# A VINTAGE MODEL FOR THE SWEDISH IRON AND STEEL INDUSTRY

by

Leif Jansson

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## 1. INTRODUCTION

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] Of particular interest is therefore the impact of past investments, depreciations and choices of technique on future production and substitution possibilities. In ISAC the industrial sector consists of 15 subbranches, and in order to analyse the dynamics of growth, a vintage model has been set up for each branch.

Paucity of data has so far set narrow bounds to the possibilities of empirical work on the industrial production structures. However, for one branch - the iron and steel industry - a special effort has been made.

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[1] The growth model ISAC - Industrial Structure And Capital Growth - was developed on the basis of earlier macro-models used within IUI. The first model of this kind developed at the institute was designed for medium-term forcasting purposes. See Jakobsson, Normann and Dahlberg (1977).

To the next IUI economic survey, in 1979, this model was further developed by including i.a. investment functions and price formation equations. See Jansson, Nordström and Ysander (1977).

Since then a major restructuring of the model has taken place. The model now incorporates adjustment mechanisms for wages prices and industrial capital and i.a. local government actions and part of the industrial productivity development are endogenously explained. Se Jansson, Nordström and Ysander (1981).

The iron and steel industry was choosen because it is very energy intensive and a major energy consumer. This makes the branch very important in the energy studies with ISAC now in progress. Moreover, it is a highly capital intensive industry making a vintage approach, especially attractive to use, since it is very unlikely that the technique already installed could be adjusted to rapid price changes.

Another reason to use a vintage model rather than a less complicated putty-putty approach, with one homogenous production structure, is that the new techniques introduced during the estimation period has been distinctly different from the average existing production structure in this branch.

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

When only aggregate data is available such a general approach is difficult to test empirically. More stringent assumptions must then be imposed. Earlier studies tended to assume fixed factor proportions both ex ante and ex post the so called clay-clay type of the vintage model. This approach is used in studies by Alliyeh (1967), Smallwood (1972) and Isard (1973).

However, it is not possible to study the influence of changes in relative prices on the input factor mix with 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 used, the putty-clay version, allows for price substitution ex ante and assumes fix factor proportions ex post. This is the approach followed here and earlier adopted by Bishoff (1979), King (1972), Ando et.al. (1974), Mizon (1974), Sumner (1974), Görzig (1976), Hawkins (1977), Bentzel (1977) and Malcomson & Prior (1978).

With the exception of Hawkins (1978) earlier putty-clay studies have considered only two factors of production, labour 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 have been assumed in most of the putty-clay studies quoted above. Exception are Malcolmson & Prior, Bentzel and Görzing. In this study the depreciation rate is a function of gross profitability 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 devided in 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 years lag from the year of decision to the first year of operation of a new vintage. This choice of time lag is partly based on some initial estimation described in appendix 1.

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

The amount of new production capacity depends on net increase of total capacity and the scrapping of old units.

The net increase of capacity is assumed to depend on expected demand, utilisation of existing capacity and the profitability situation. The capacity growth model is further described 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 branch. The scrapped capacity is replaced by new cost minimising technique. We expect a priori the depreciation rate to be negatively correlated to the profit margin.

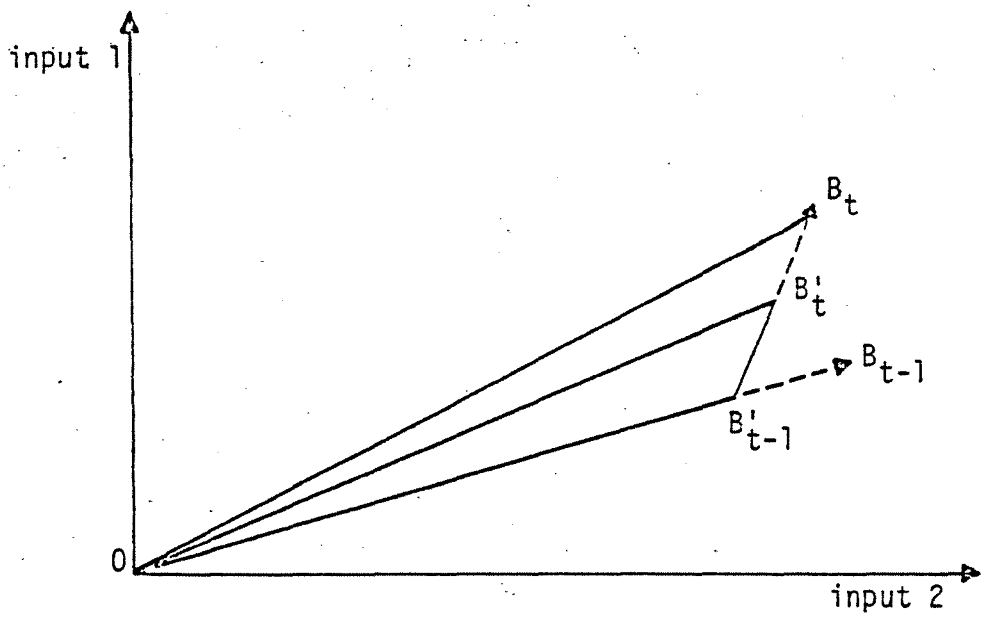
There is also reason to believe that the depreciation rate might vary across vintages due to differences in individual profit margins. But such an assumption would complicate the econometric model considerably.

The utilisation rate is assumed to be the same for all vintages. The approach can to some extent be justified in the following way. For a process industry like the iron and steel industry there is a serial dependence between different units since output from i.e. blast furnaces are used as input in the steel manufacturing. Since these vertically linked production units mostly are run under one company their production levels are jointly dimensioned. The impact of differential profitability on the utilisation in each unit is diminished in the short run by the fact that the branch mainly consists of large units of production each of which is often the major employer in its geographical vincinity. Because of this the production of unprofitable companies are often kept up by subsidies from the central government.

Changes of technique and capacity between two periods is briefly illustrated in figure 1, where for simplicity only one old vintage is included.

The arrow $OB_{t-1}$ is the input mix corresponding 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 $OB_t$.

Figure 1.



The putty-clay description of the model cannot be distinguished from a putty-putty interpretation since the same technique is used in both net investments and replacement. Therefore you could equally well say that by the combined scrapping - reinvestment activity the given capacity has been modified from $B_{t-1}$ to $B_t$ and then extended by the addition of net investment to $B_t$. In the following we will, however, continue to couch our arguments in terms of the putty-clay assumption.

Before closing this overview of the model it should be emphasized that the investment model has a different role in this study than in other aggregate growth studies of production.

Usually the interest is focused on the model of investment. There are no direct observations on the development of production capacity which must therefore be explained indirectly via investments and the capital/output ratio. The investment model then becomes the key to explain the dynamic growth of production.

In this study we have benefitted from observations of capacity development which enables us to estimate a model that explains capacity growth directly. So the equations explaining the net increase of production capacity will replace the strategic position that the investment model usually has.

The investment equation is further discussed 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 within each industrial branch - energy, other intermediate goods, labour and capital. The time series for the input-output ratios for intermediate goods in the iron and steel indstry is extremely stable over the whole observation period, which suggests that they are perfect complements to the aggregate of the other inputs. This means that the input share of intermediate goods, both in new and old plants, is constant and independent of price changes.

With constant i/o shares of intermediate goods and with separability between energy, labour and capital, producers are assumed to minimise cost of production of new vintages. It is further assumed that the minmimal cost function for energy labour and capital can be represented by a translog form. The technology is restricted to be linear homogenous and exogenous 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

$$c = A \cdot q \cdot \exp[\Sigma\alpha_i \ln p_i + \sum_i \sum_j \beta_{ij} \ln p_i \ln p_j + \lambda t] + p_m m \quad (1)$$

where

q = value added inclusive energy

m = intermediate goods

i,j = e, k, l

e,k,l stands for energy, capital and labour respectively.

$$\Sigma\alpha_i = 1$$

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

The translog part of the above cost function is a second order local approximation to any regular cost function and its flexibel form put few a priori restrictions on the production structure. However, it might not everywhere be a proper cost function. If and where (1) is a proper cost function has to be checked after the parameters are estimated. Unfortunately, this is generally not an easy task to do and it has to be done for every set of input prices (see Berndt and Christensen 1973. Other known flexible form like the generalized Leontief function also have these disadvantages.

From Hotellings Lemma, see 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.

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[1] The cost function where it is well behaved can be derived from a well behaved production function by taking those input mixes that minimizes cost of production at given prices and output. Call these inputs $x_{i,min}(p,y)$ and then calculate the total cost for that 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 (1) an algebraic expression for the production function connected to (1) can not be given. Nevertheless a well behaved production structure exists to every well behaved cost function and vice versa as proved by Shephard (1953).

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

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

where the subscript t refers to the year of birth of a vintage and t within brackets denotes the current time $\varepsilon_i$ is i/o share $x_i/y$ and the aggregate i/o ratio q/y is calcuted from the observations.

However, there are no observations on 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 branch. Therefore, $p_q$ for the new vintage which is occurring in (2) is the unit cost index achieved from the translog cost function. Thus

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

(2) now becomes non linear in the parameters but the caculation cost nevertheless stays modest. The price variables should express expected prices and moving average variables of the prices were tried as proxies. However, since using 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 utilisation rate. Some correlation between the cyclical changes in the utilisation variable and the i/o ratios can indeed be observed. But the dependence does not seem too strong for the above assumption to be a fairly good approximation. However, for the years after 1975, which are not included in the observation period, this approximation will probably not hold since the utilisation rate then dropped to its lowest level since 1950 and several disturbances occured in the iron and steel industry.

## 2.2. The model of net growth

We assume that firms base their decisions to expand or contract the production capacity on expectations on future demand of their products. Since the iron and steel industry is a process industry employing large units of production several years will pass from the date a decision is made until the date of installation. With an assumed construction period of three years it will be the expected change of demand three years from now that will influence todays investment plans.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 $yp_t(3)$ = the expected change of demand at time t+3

$y_t$ = total production level,

i.e. the expected change in demand at is the ratio between the two most recent 3 years moving averages of production.

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

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

If firms however, consider both adjustment costs such as costs for internal education of personal etc and the costs of not being able to fully meet demand this could lead to firms partially adjusting to the desired capacity level, see eg. 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

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

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

The above argument suggests that also past utilisation rate should be included in the capacity growth model. Since we do not know for sure the time delay with which past utilisation rates will influence investment decisions the observed values of year t and the two preceeding years are included. The new variables are included in such a way that the model stays log-linear in the estimated parameters. We then get

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

where the utilisation 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 the past growth of the Swedish iron and steel industry. The growing competition on the foreign markets over the last decades has caused a declining trend in profitability during the sixties and seventies by way of decreasing world market prices relative to domestic production costs.

The profitability might also influence decisions in other ways than in forming expectations of future profits. A good profit situation often seem to have a rapid positive effect on investments even if the prospects in a longer perspective should look gloomy. There are several explanations for such a behaviour e.g. institutional inertia and tax legislation in Sweden which tend to "lock in" profits in the own company.

There are then reasons to include a measure of perhaps both past and current profits in the growth model. The next problem is 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 experienced a rapid technical change, it is, however, preferable 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

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

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 depreciation rates are determined in the model as described in the next section. The capital stock, being a function of the depreciation, is consistent with the estimated depreciation rate. Further details are given in the appendix.

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

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

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[1] Calculations of the discount rate is given in V.Bergström (1975).

## 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 it is also assumed that there is a time lag of three years between the time of scrapping to the time of replacement. The replaced capacity of vintage v at time t is assumed to be following function of the gross profit margin gp at time t-3:

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

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

The scrapping model can be expressed as a depreciation rate that varies around a constant rate $\delta oc^*$ due to variations in unit operating cost oc relative to oc*, "normal" or average cost level.

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

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

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 order for likely values of $\delta$ since it is multiplied by the squared value of $\delta$. So (6) is likely to be a good enough approximation of (a).

## 2.4. Average input shares and investments

So far only the net growth function can be estimated on available aggregate data. But because of the of the assumed equivalence for depreciation and utilisation rates across vintages and the assumed independence of the input shares of the utilisation level the average i/o ratios can be expressed in a form estimable on aggregate data. The aggregated i/o ratios becomes

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

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 of capacity, the replacement of scrapped capacity and the capital output ratio of the new technique implemented. But the the fact that construction time stretches over four years - the year of decision and the three remaining 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 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 the construction of vintage t+i causes 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

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

## 3. The empirical results

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

However recognition of the fact that new pieces of production capacity might use technologies quite different from that of the old units, is a special feature of vintage models. This property makes it e.g. possible to describe developments that otherwise look odd like the fall of energy use per unit of output during a period with falling relative price of energy. 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 picture such a situation by adding units which are less energy intensive while energy might still in the ex ante production function be a substitute to the rest of the inputs and technical change neutral as in this study.

## 3.1 The past development of capacity explained by the growth model

Perhaps the most striking feature of the increase of capacity in the Swedish iron and steel industry is the four years 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 the 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 5 years. Such a response pattern could be interpreted to mean that a trade cycle is recognised and taken into account by the decision makers. The reoccurance of a boom in demand at the expected time confirms the impression of a cycle and triggers the decision to expand capacity o meet the next peak of demand.

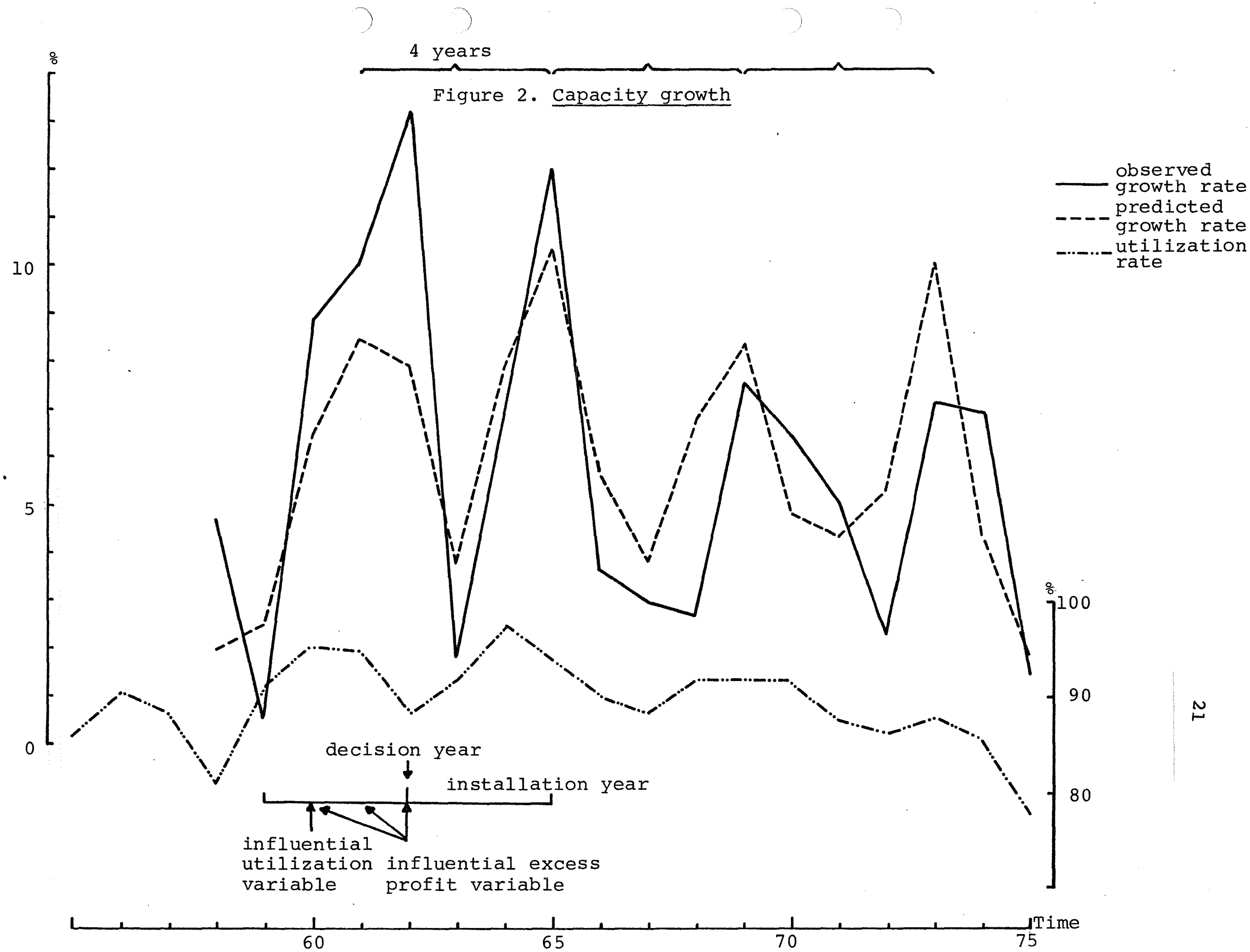

Figure 2. Capacity growth

Past and current profits and expected demand also explain the short term swings in growth but their contribution differ over time. Thus the level of the first and also 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 mostly explained by expected increase in demand. Past growth also gives a positive contribution to the explanation of the remaining two peaks.

The regularity in the growth pattern might of course be just accidental. The strong correlation to the utilization rate is then spurious and one could not expect them to be so connected in the future.

Figure 1 also indicates a slow decline in the growth trend over time. The average growth rate for the first 9 years is 6.2 % , whereas that of the last years amounts to 5.5 %. The major factor explaining this drop in average growth is the decrease in profits over time. The average decline in the profit variable would alone have caused the growth to decrease with 1.4 %. The decline due to a slow down in expected demand is just .4 %. However, a increase of 1.1 % due to a higher average utilization rate counteracts these declining tendencies and in fact limits the decline in capacity growth to .7 %.

The short term growth pattern is thus highly dependent on the ups and downs of the utilisation rate. The profit and the growth expectation however do contribute but in different ways during different periods of time. The long term decline in average growth on the other hand is mostly due to a fall in profitability.

## 3.2 The 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 together with the Allen partial elasticities of substitution (AES) at the same point. Since the variations of these elasticities over time are slight the mid point elasticities presented give a fair description of how the model predicts new techniques to 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, having the highest elasticities of substitution. Capital and labor are estimated to be almost perfect complements on the margin.

It must, however, be emphasized that it is difficult to compare the properties of the ex ante function estimated in this study, which describes how technique is chosen on the margin, with the production structures more usually estimated where a whole branch is considered to be one homogenous production unit. The reason is that in the latter approach price changes and other explanatory variables affect the average technique of a whole branch in exactly the same way. In a vintage model new vintages are distinguished which generally have different properties than already installed capacity.

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

| Price elasticities | | | | The Allen elasticities of substitution[a] | | |
|---|---|---|---|---|---|---|
| | $\eta_{.,e}$ | $\eta_{.,k}$ | $\eta_{.,l}$ | $\sigma_{ek}$ | $\sigma_{el}$ | $\sigma_{kl}$ |
| $\eta_{e,.}$ | -.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 of the input mix between two production factors due to a 1 % change in their relative prices when all other inputs adjust optimally to the price change.

The only part of changes in technique over time that 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 trendfactor 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. The dominant factor explaining how the average input shares develop is, however, the adding of new production units.

To illustrate this, we may separate the effect of adding a new piece of production from the embodied technical change and price adjustment of the new vintage. The percentage change of the average input share can be split into two terms accordingly

$$\frac{\varepsilon_i(t) - \varepsilon_i(t-1)}{\varepsilon_i(t)} = \frac{ycap_t(t)}{ycap(t)} \frac{(\varepsilon_{t-1,i} - \varepsilon_i(t-1))}{\varepsilon_i(t)} + \frac{ycap_t(t)}{ycap(t)} \cdot \frac{(\varepsilon_{t,i}(p,t) - \varepsilon_{t-1,i})}{\varepsilon_i(t)}$$ [1, 2]

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[1] $\varepsilon_{t-1,i}$ should correctly 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 substracted from $\varepsilon_i(t)$ it can be written

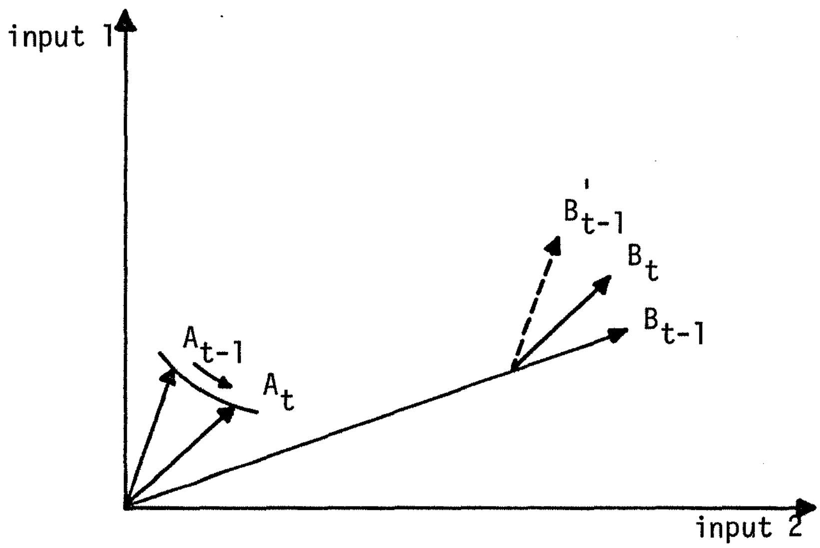
$$\varepsilon_{i(t)} = ycap_t(t)/ycap(t) \cdot \varepsilon_{t-1,i} + (1-ycap_t(t)/ycap(t)) \cdot \varepsilon_i(t-1) + ycap_t(t)/ycap(t)\ (\varepsilon_{t,i}(p,t) - \varepsilon_{t-1,i})$$

Straight forward calculations then give the formula above.

Table 2. Changes in input shares

| | Energy | | | | Capital | | | | Labor | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Marg effect | Vintage effect | Pred total | Observed total | Marg effect | Vintage effect | Pred total | Observed total | Marg effect | Vintage effect | Pred total | Observed total |
| 60 | -.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 |

Figure 3.



The first term describes the effect which results from including a vintages of the optimal technique at time t-1. The second term describes the effect of adjusting the technique of the new plant to todays prices and embodied trend changes. The contribution from these two causes of change are listed in table 2 together with the total predcicted and observed percentage change for each input share.

The distinction between vintage and marginal effects is illustrated in figure 3.Embodied technical change is left out for simplicity.

An assumed positive price substitution moves the input mix of 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 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 of input 1 will then move the aggregat mix from $B'_{t-1}$ to $B_t$, which illustrates the "marginal effect" in table 2.

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

The vintage effect is a function of the differences between the i/o ratios, capacity of the new vintage and of the aggregate branch. This fact may well help to explain (without introduction of elaborous time dependent non neutral 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 by figure 3, which shows a positive elasticity of substitution on the margin, i.e., a relative increase in price of input 1 will cause the ratio of input 1 to input 2 to decrease. But the aggregate effect of adding a new piece of 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 picture such an increase without the introduction of non neutral 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.

This last issue of complementarity or substitutability between inputs is of interest especially in connection with energy since it has important policy implications. Suppose the aggregate model describe energy and labour to be complements. This would indicate that an increase of energy price, caused, e.g.,by an extra tax would lead to a reduction of employment per unit of output. A vintage model can, however, describe the simultaneous decrease in the input share of energy and in the relative energy price while energy in the ex ante production function is a substitute to labour and other inputs, by adding a new unit which is less energy intensive than the average. Even if the new vintage has a higher energy share than it would have 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 occured for instance during the period 1960-64 where the price of energy relative output and capital is almost constant, whereas its relative price to labour falls drastically with ca 9 %/year. As can be seen from figure 4 this leads to an increase of the 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 labour share of a new vintage to the average value fluctuates between 45 %-50 % during the estimation period. This high labour productivity predicted for new production capacity might well be biased upward because of the stiffness of the model specification which does not allow for any increase in labour productivity of already installed units.

The model predicts the ups and downs of the investments poorly as seen from figure 3. This is not too worrying though since the attention in this study is mainly focused on the model for capacity growth.

Figure 4. Energy output ratio

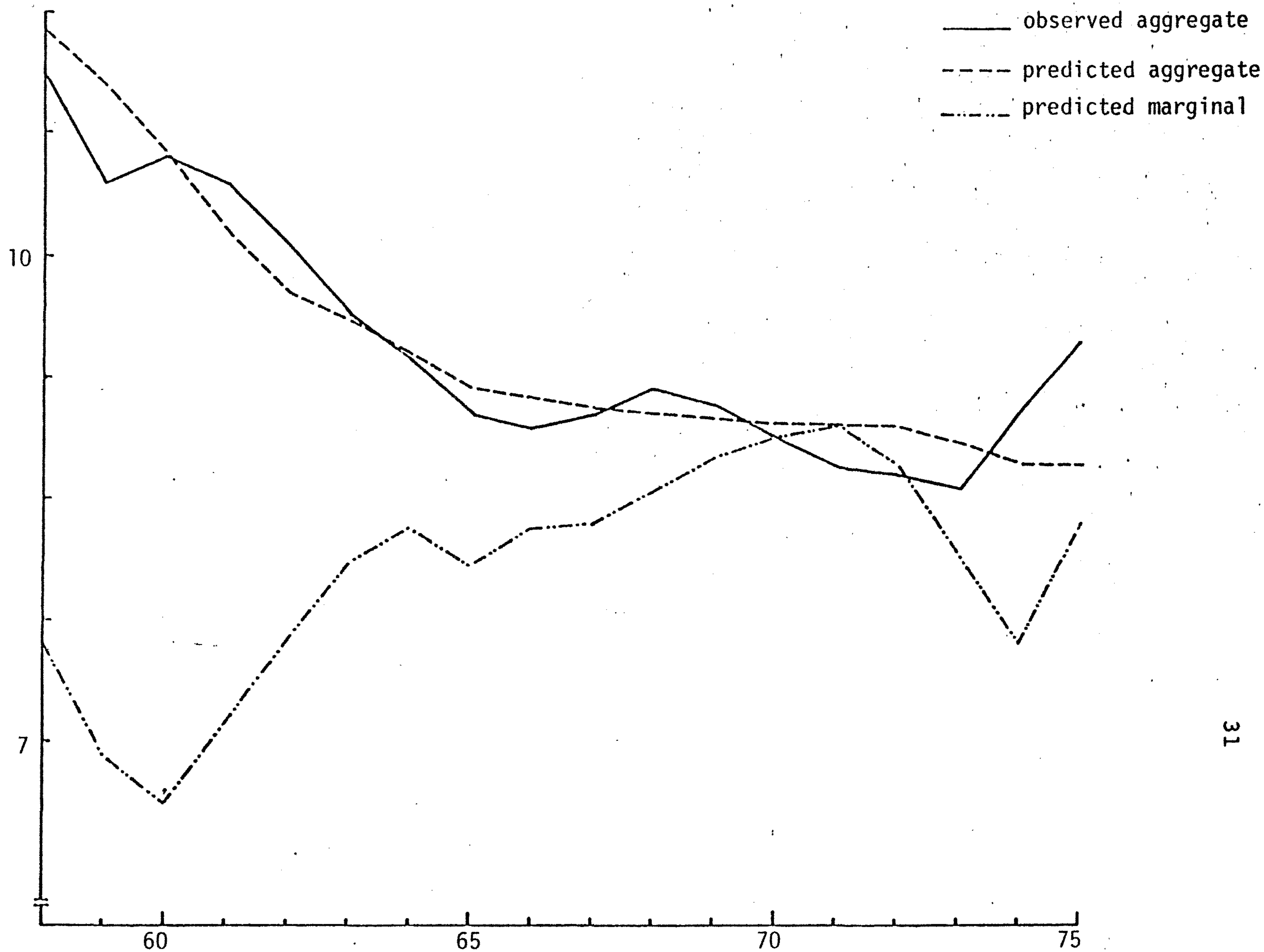


Figure 5. Labour output ratio.

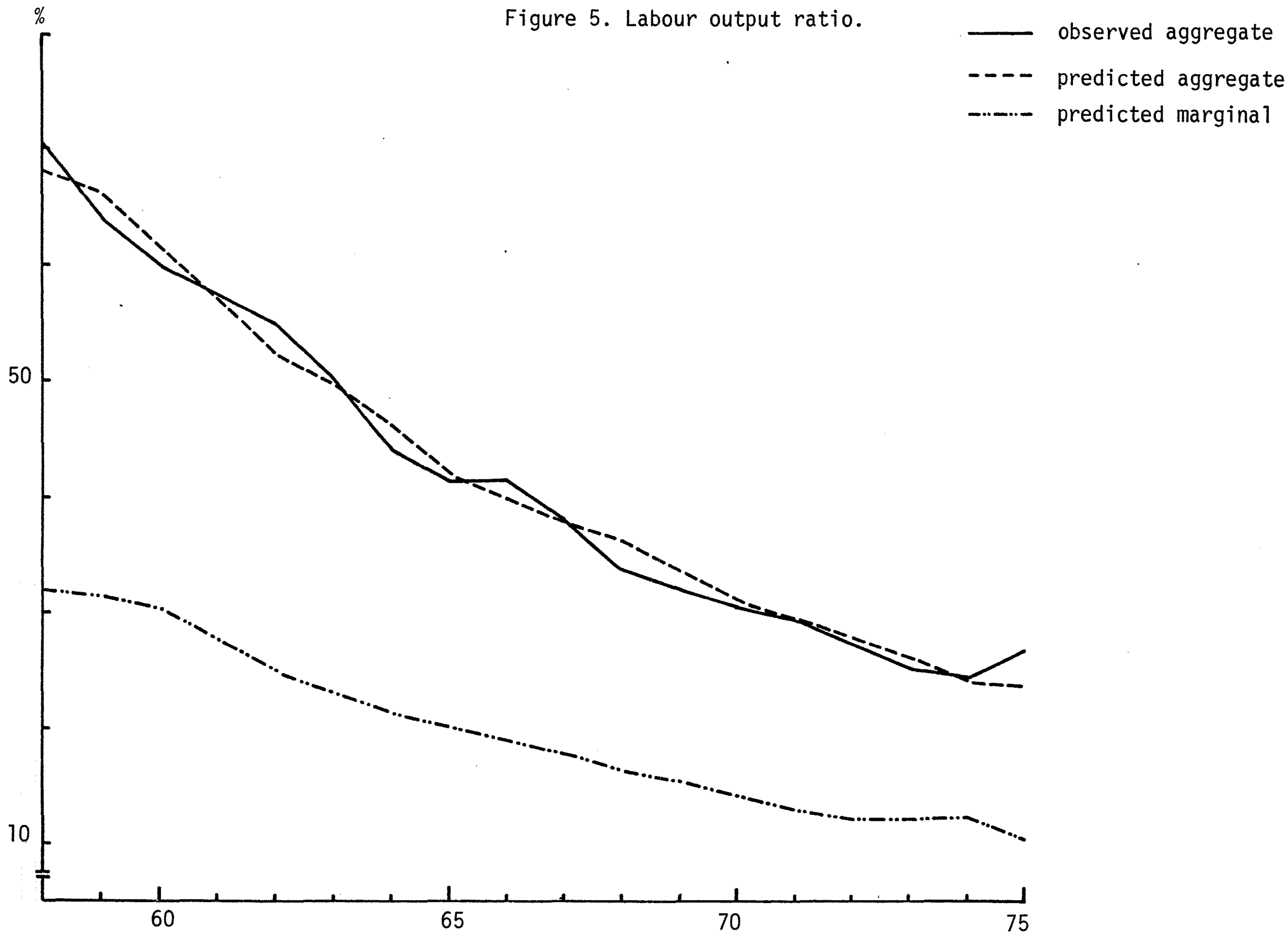
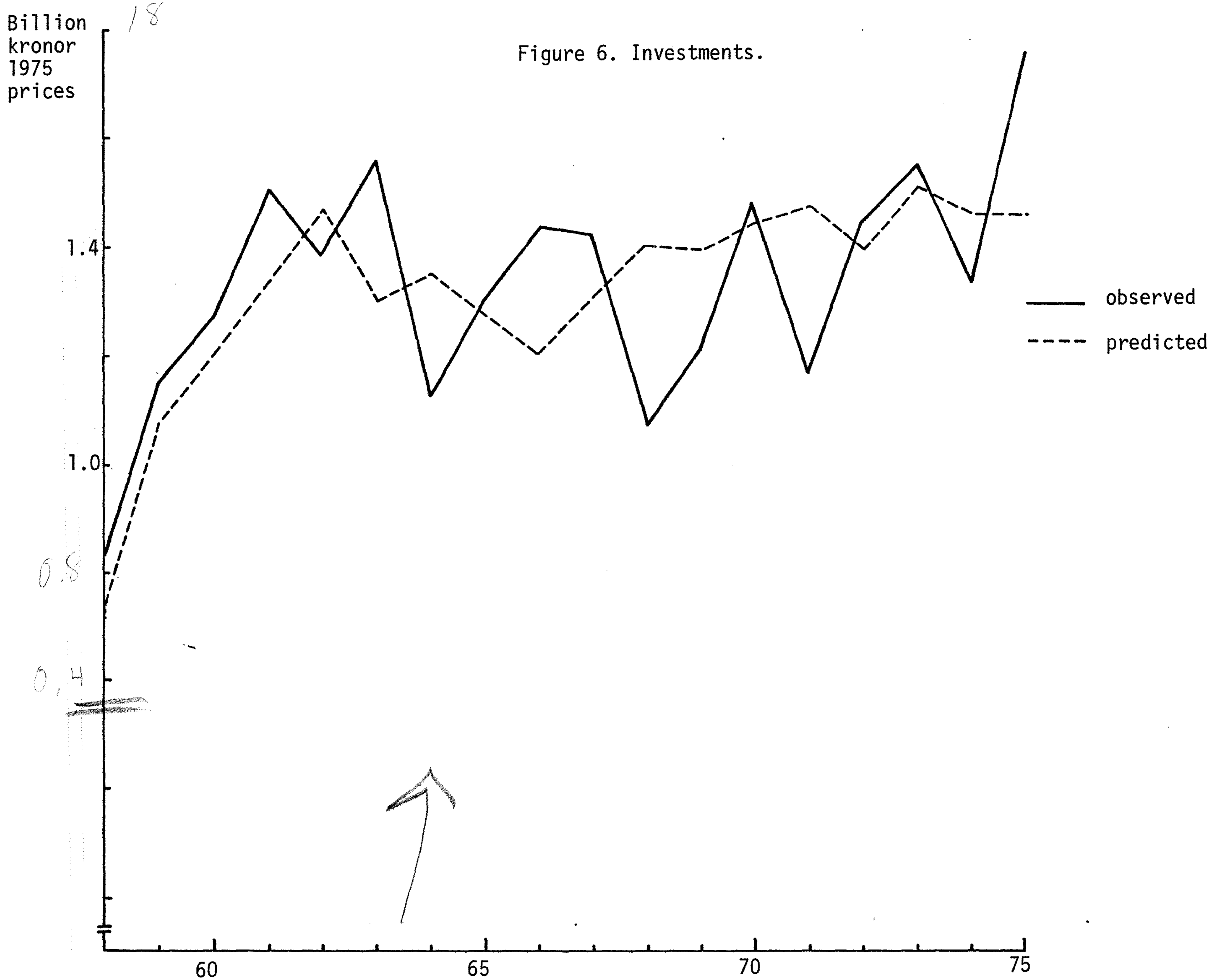


Figure 6. Investments.



## APPENDICES. THE ESTIMATION PROCEDURE AND ESTIMATED PARAMETER

It is difficult to get a proper empirical base for the dynamic structure of the model is difficult since the maximum number of observations is 27 and long time lags are to be expected. This is so because the construction time of new units of production might be several years and the decision to build a new plant is likely to depend on economic results several years back. This can add up to quite long lags between an event and its impact on installation of new capacity. To estimate all coefficients in front of all lagged variables without constraints would leave too few degrees of freedom. One way to reduce the number of parameters is to specify e.g. a quadratic Almon lag structure. But it is hard to a priori believe in a specific lag distribution since the aggregate dynamic structure which is observed is a result of several economic agents who might well have different patterns of reaction. On the other hand one expects the amount of new production capacity installed by each economic agent 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 be positively correlated also 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. Two more constraints are added in order to further increase the degrees of freedom; no economic events during the construction time which is f years long will influence the new production plant neither to size nor technique, and only the two preceding years plus year t are supposed to influence the decision of a new plant.

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

Those initial runs were based on the 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 labour and the investment function were estimated simultanously using a non-linear FIML procedure. A new capital cost variable were 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 together 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)

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

$$+ [ycap(t-1) - d(t)]/ycap(t) \cdot \varepsilon_i(t-1) + v_{t,i}; \quad (10)$$
$i = 1,2,$

where

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

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

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

Investments (see 2.4)

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

Capacity growth (see 2.1)

$$\ln[ycap(t+3)/ycap(t+2)] = a + \gamma_1 \ln(yp) + \quad (11)$$

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

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

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

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

and

---

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

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

and

$$\delta_{ts} = \begin{cases} 1 \text{ if } t=s \\ 0 \text{ if } t \neq s \end{cases}$$

where $\Sigma$ is the covariance matrix corresponding to the equation block (1) and $\sigma$ the variance for the error term for the growth model.

If there are no constraints on the parameters in the last equation that connects it to the first three equations the estimation of all four equations can be separated in two parts - one which simultanously estimates the first three equations and one which estimates the single equation for the capacity growth. That follows from the structure of the covariance matrix and that no endogenous variables from the upper block of equations appear in the fourth equation. Since the depreciation is consistently estimated in the first block of equations also the capital cost derived from these estimates will be consistent. This ensures that this link between the blocks will not effect the consistency of the single equation estimate of the growth model. The efficiency though will be lower than in an estimate simultanously incorporating all four equations.

The estimated parameters are listed in table 4. The numbers with a * are not significantly different from 0 at a 5 % level. The restrictions that constrain the cost function of new vintages to be linear homogenous are imposed on the estimates.

Table 4.

| | $\alpha_i$ | $\beta_{i1}$ | $\beta_{i2}$ | $\beta_{i3}$ | b | $\lambda$ | $\delta^a$ | $R^2$ | DW |
|---|---|---|---|---|---|---|---|---|---|
| Energy share | .154 | -.015* | .045 | -.030* | | | | .80 | .87 |
| Labour share | .265 | .045 | .080 | -.125 | | | | .98 | 1.40 |
| Investments | .581 | -.030* | -.125 | .155 | .642 | | | .12 | 2.11 |
| Common parameters | | | | | | -.0380 | .0644 | | |

| | $\alpha$ | 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 significant separated from 0 on a 5 % level.

[a] The $\delta$ reported is $\delta$ estimated multiplied by the average unit cost of production. This implies that the average depreciation rate during the observed period is 6.4 %.

Data description

Apart from what has already been stated about the variables in the model section there is one strategic variable in this study that remains to be explained namely the data used for the capacity growth. Observations of production capacity are seldom available but with kind cooperation by the Swedish Ironmasters' Association time series on the development of capacity and production of crude iron has been made available.

Under the assumption that the utilisation rate is the same for the total branch as for the crude iron production a capacity variable for the whole iron and steel industry can be constructed as follows

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

where index I stands for crude iron and IS for iron and steel and ycap stands for production capacity and y for actual production.

Since all crude iron produced in the country is further processed in the domestic steel industry it is likely that the steel industry has developed in close connection to the crude iron industry and to assume the same utilisation rate in the two subbranches 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.

That 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 by figure 1 which shows the observed and calculated percentage capacity growth of crude iron and the total iron and steel industry respectively.

The rest of the variables used in this study are the same with two exceptions as those used in Dargay (1981), 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 in the estimation of the input shares. In the first case the calculated depreciation and rate of return for each year has been inferred since the excess profit variable might be thought of as an ex post cash flow variable rather than an ex ante planning variable. Also the capital stock appearing in the profit variable needs to be accumulated using the estimated depreciation rate. The value of the initial stock though is not known but is calculated under the assumption that the cost of capital reported by the SCB is equal to the cost given by the different depreciation model used in this study, i.e.

$$(p_{K0}\ K_0)_{SCB} = p_{K0}\ K_0$$

and

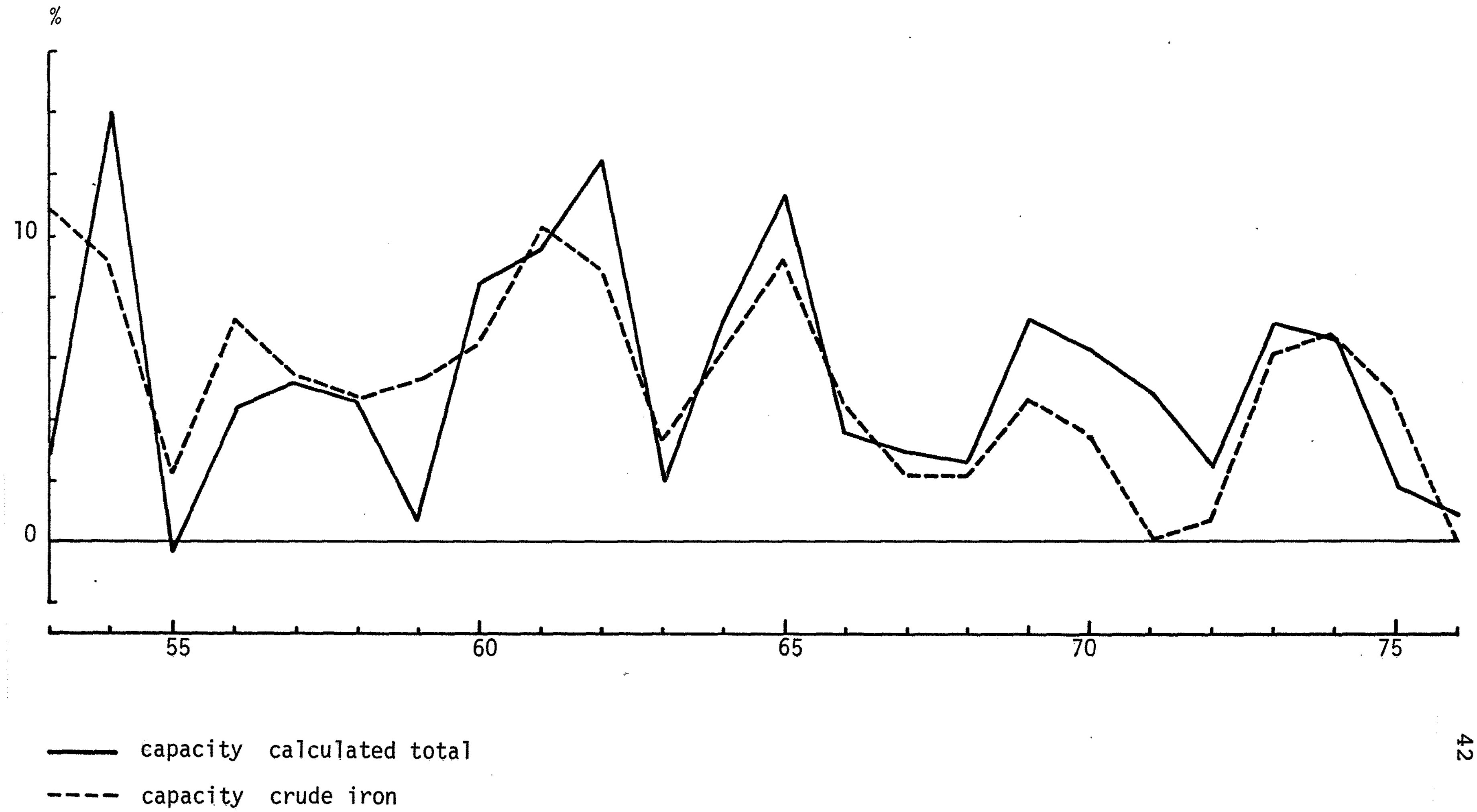
$$K_0 = (p_{K0}\ K_0)_{SCB}/p_{K0}.$$

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 look at the capital price as an ex ante planning variable and therefore the depreciation rate and internal rate been considered as constants and since all prices are on index form the capital price will be equal to the investment price index.

Figure 7. Capacity growth.



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