Energy in Swedish Manufacturing 1980–2000

A Simulation Study of the Impact of Energy Prices and Capital Structure on Energy Use in Swedish Industry

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Energy Prices and Industrial Development

The experience of the 70s demonstrated the importance of energy prices for industrial development. More particularly it focused attention on two major reasons for looking well ahead in matters of energy policy.

One such reason is the inherent uncertainty and instability of the international oil markets. Whatever the fundamental causes of the drawn-out stagflation in the 70s, the two oil price hikes certainly had a decisive importance by triggering off spirals of price increases and severely affecting the external balances of small open economies like the Swedish.[1] The experience of the 70s also provided many instances of the political and economic difficulties of adjusting open economies to major shifts in the world markets and the consequent need to provide "hedges" against the risk of repeated upheavals in the coming decades. We have elsewhere tried to deal with this stability aspect of Swedish energy policy by exploring various means — including that of oil taxation — of "insuring" energy supply and price stability, using for these policy analyses a dynamic macro-model for the Swedish economy (Nordström-Ysander, 1983).

Our aim in this paper is to provide a starting point for the study of the second kind of long-term policy problem, which has to do with the drawn-out industrial adjustment to a new energy price structure.

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1 For a more extensive discussion of the relation between oil price hikes and the stagflation syndrome, cf. Eliasson-Sharefkin-Ysander (1983b).

The oil price hikes and their repercussions on other energy prices meant i.a. that a great part of industry was left with a built-in technology that was ill-adjusted to the new level and structure of energy prices. By reducing the quasi-rent earned and thus the economic value of older, less energy-efficient plants, the oil price hikes "eroded" or "exploded" part of the "capital stock" of industry.[1] The added costs of higher energy prices were thus translated into major, although hard to measure, "capital losses" for industry. These losses can by definition only be replaced by a technical change of capital equipment embodied through successive investments. This part of the adjustment to new relative prices is therefore a long-term proposition, which will in most cases continue into the next century, even without new changes in relative energy prices.

These adjustment needs are further compounded by long-term shifts in domestic energy supply schedules, due to decisions already made in Swedish energy policy. A heavily subsidized development of domestic fuels and other "alternative" energy resources and an almost complete veto against further expansion of Swedish hydro-power are two such instances. Of even greater importance is the decision taken some years ago not to replace the nuclear plants, which means that an electricity glut in the 80s may be replaced by a growing scarcity in the 90s.

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[1] These dramatic formulations are really based on some elementary facts about the way economic aggregates are formed. What we call the "capital stock" is simply an aggregate measure of miscellaneous production means weighted with their economic values. For a stringent discussion of this measurement problem, cf. Berndt-Wood (1983).

Even with a surprise-free future there are thus needs for long-term adjustment and reasons for looking well ahead in planning energy policy. To the direct effect on energy demand of industrial capital adjustment will successively be added the effect of a restructuring of the manufacturing sector due to world market trends including the shifts in energy price levels. To discern future trends in industrial energy demand one must therefore study the dynamics of industrial investment and growth not only with regard to specific energy use but also for tracing the changing branch composition.

This we have in the following tried to do by simulations on a dynamic macro-model for the Swedish economy, incorporating a vintage approach to industrial capital and a relatively detailed description of the different mechanisms for energy substitution. Many of these mechanisms have been modeled using the estimates for price elasticities derived by Dargay (1983b) and Jansson (1983) and reported in the preceding chapters in this volume. The model which differentiates between 26 types of "energy consumers" — 14 manufacturing branches, 9 other industrial sectors, households and central and local governments, respectively — has been documented elsewhere (Jansson-Nordström-Ysander, 1982) and has also been used earlier for studies of energy policy (Nordström-Ysander, 1983).

While referring to this documentation, we shall here merely summarize the main assumptions for the reference case used in the following simulations. Some aspects of the energy substitution mechanisms in the model will, however, be touched on later in discussing the simulation results.

Table 1 Assumptions for the eighties and nineties
Reference case

World trade development

	Annual increase, %			
	1980/1990		1990/2000	
	Volume	Price[a]	Volume	Price[a]
Raw materials and semifinished goods[b]	2.3	5.5	2.6	4.1
Finished goods	5.7	6.4	5.0	6.0
Services	4.5	7.0	5.0	6.0

[a] In international currency.

[b] Includes the following branches: agriculture, forestry and fishing; mining and quarrying; manufacture of wood products, pulp and paper; basic metal industries.

Labor supply development

	Annual increase, %	
	1980/1990	1990/2000
Number of persons[a]	32.3	14.2
Number of persons[b]	0.7	0.3
Hours worked per employee[b]	-1.0	-0.2
Labor supply, number of hours[b]	-0.3	0.1

[a] Yearly change in thousands of persons.

[b] Yearly percentage growth.

We assume that the rate of increase in the volume of international trade will be stable but somewhat lower than in previous postwar decades. For raw materials and semi-finished goods this will mean an annual rate of increase of 2.3 and 2.6 percent, respectively, during the 80s and 90s, while the trading in finished goods is supposed to increase annually 5.7 and 5.0 percent, respectively, and that of services 4.5 and 5.0 percent. A stagnating supply of labor is expected in the next two decades.

A model simulation also requires a number of policy variables to be given exogenously in order to reach announced targets of economic policy.

We have employed three main policy instruments: wage policy, income tax and public consumption. These instruments are used to determine the rate of unemployment, the balance of payment and the growth rate of public consumption.

The policies adopted in the reference case have had the following main targets. The current balance of payment deficit should be eliminated by 1990 and stay close to zero for the rest of the period. Unemployment should be kept around what is considered a "normal" rate of frictional unemployment — 2 percent of the labor force. The assumed strategy for public consumption has been to let it grow at a slightly faster rate than private consumption during the 80s but evening out the accounts in the 90s, thus attaining on the average a roughly proportionate increase over the two decades of public and private consumption.

Table 2 shows the simulated development of the economy in the reference case. The need to restore the external balance before 1990 is reflected in the gap between the growth of exports and imports during the 80s with repercussions primarily on private consumption growth. In the 90s a faster consumption growth compensates for the meager previous decade.

Table 2 Real GDP by expenditure 1980–2000
Reference case

	Annual increase, %	
	1980/1990	1990/2000
Consumption	1.3	2.4
Investments[a]	1.8	2.1
Exports	4.6	3.8
Imports	2.9	4.3
GDP	2.1	2.3

[a] Including changes in stocks.

The Future Supply of Energy

Primary fuels from domestic (wood, peat) and foreign (oil, coal) sources are assumed to be supplied in any quantity at given prices. The assumed price development for primary fuels in the reference case is given in Table 3. Oil prices are assumed to increase by 8% per year throughout the simulation period. This implies, that the real price of oil is assumed to grow by 1.5% per year during the eighties and some half percentage point faster during the nineties relative to the world market price for finished goods. Coal prices are assumed to be proportional or follow oil prices.

Table 3 Prices of primary fuels
Reference case

	Growth rate, %	
	1980/1990	1990/2000
Oil	8.0	8.0
Coal	8.9	8.0
Domestic fuels	6.0	5.0
CPI	6.2	6.5
GDP-deflator	6.7	7.2
World market price for finished goods	6.4	6.0

The difference in the rate of price increase during the 80s shown in Table 3 simply reflects the way the coal price after a certain time lag "catches up" with the oil price hike in 1978/80. This "catching up" is assumed to take place during the first years of the 80s. Prices for domestic primary fuels grow with costs in the forestry branch. Some allowance is made for improvements in the extraction technology, assuming a slight increase in productivity growth during the 90s. The price of domestic fuels relative to oil is therefore decreasing at an accelerating rate — from minus 2% per year during the first half of the period to minus 3% per year during the second half.

Since assumptions about future oil prices might be of key importance for the simulation we have throughout used for comparison an "alternative case" where the real price of oil is kept constant up till the turn of the century.

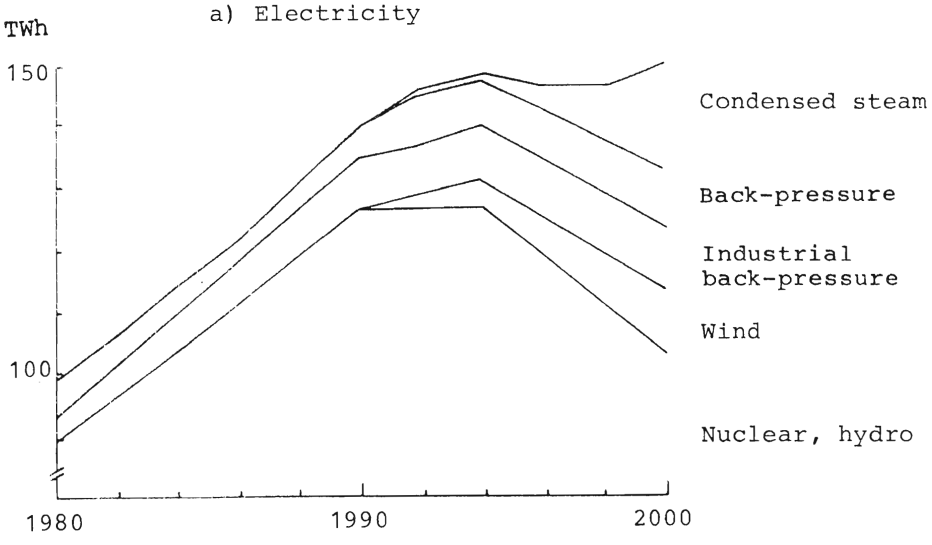
Turning to the supply of electricity and distant heating we noted already above the political restrictions imposed on the use of nuclear and hydro power in Sweden. Total gross production of nuclear and hydro power (i.e., including internal use in the power stations) is assumed to increase by almost 4 TWh per year during the 80s and then to decline at approximately the same rate from 1995 due to the gradual closing of nuclear power stations. Adding further exogenous assumptions on industrial production of backpressure power, wind power development, possible combined production of electricity and distant heating, etc., the production system shown in Figure 1 emerges. Although the assumptions made and the resulting supply structure may well be disputed, it seems necessary to account for the rather strong shifts imposed on the electricity-distant heating production system during the simulation period by political decisions. This will have strong implications i.a. on the use of fuels — domestic and imported.

As shown in Figure 1 production of electricity is assumed to increase fast during the 80s with the nuclear power still building up. Although direct use of electricity for heating purposes will also increase, there will still be capacity left to replace fuels in the distant heating system. However, when demand for electricity catches up with the stagnating production in the 90s, the use of electric power to boil water for distant heating will have to end.

The assumed decrease of fuel input in the distant heating system in the 80s may very well be reversed in the 90s. The same holds for the fuel input in electric power production. Part of the gradually reduced nuclear capacity may have to be replaced by condensed steam or combined power

Figure 1 Production of electricity and distant heating
Reference case

a) Electricity



b) Distant heating

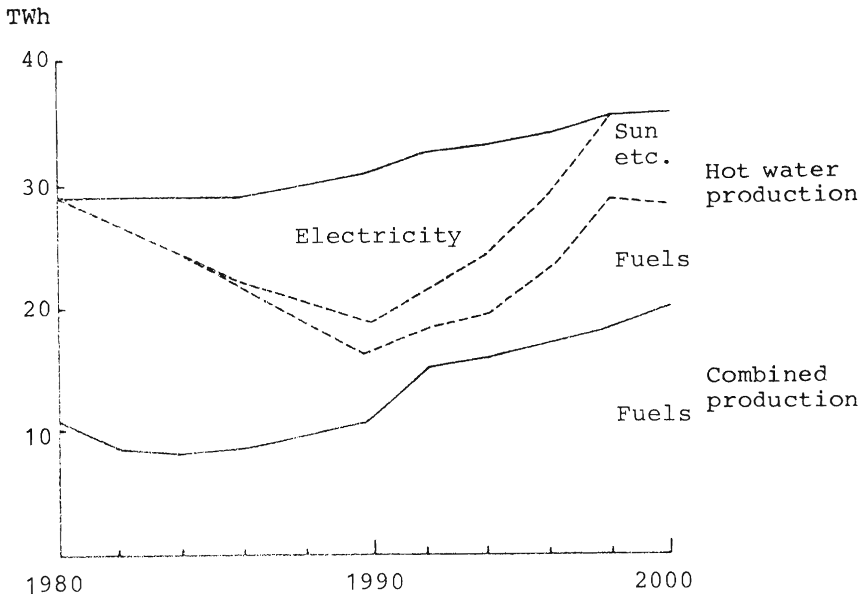
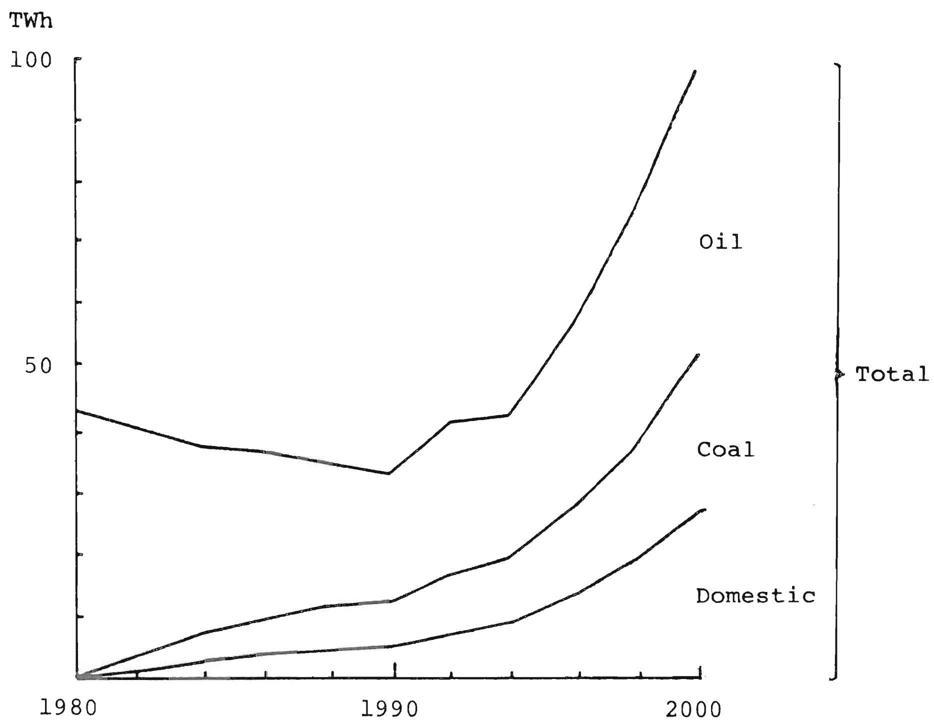


Figure 2 Use of fuel in the electric power/ distant heating production system Reference case

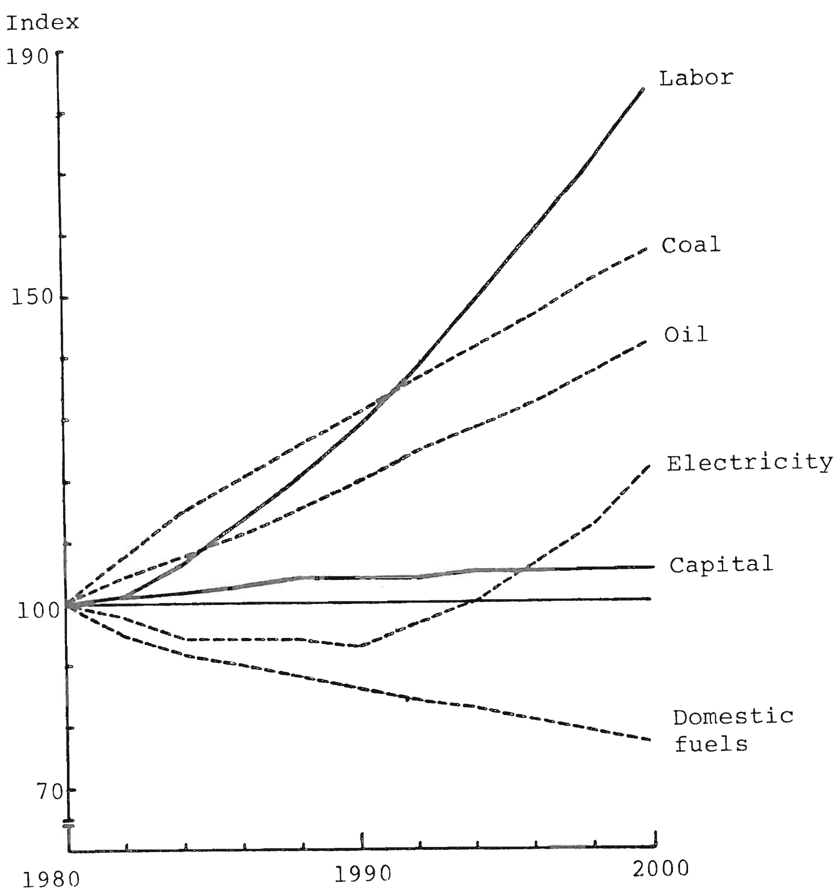


plants using domestic or imported fuels. The reference case development of fuel use in electric power/distant heating production is summed up in Figure 2. With the assumptions made, the figures show a very fast increase in fuel input and even a slight increase in the use of oil towards the end of the 90s. Increased use of imported fuels with rising relative prices will make the real price of electricity and distant heating rise in the 90s. This will slow down demand growth but — according to the model — not enough to prevent large increase in the use of fossil fuels in power plants.

Changing Factor Prices and Factor Mix

The changing structure of factor prices that emerges in the reference case is shown in Figure 3. Relative labor costs continue to rise annually on the average with 2.5% during the 80s and with 3.6% in the 90s, while user cost of capital stays almost constant. The oil and coal prices climb slowly but steadily as assumed, while productivity gains are reflected in an equally steady decline

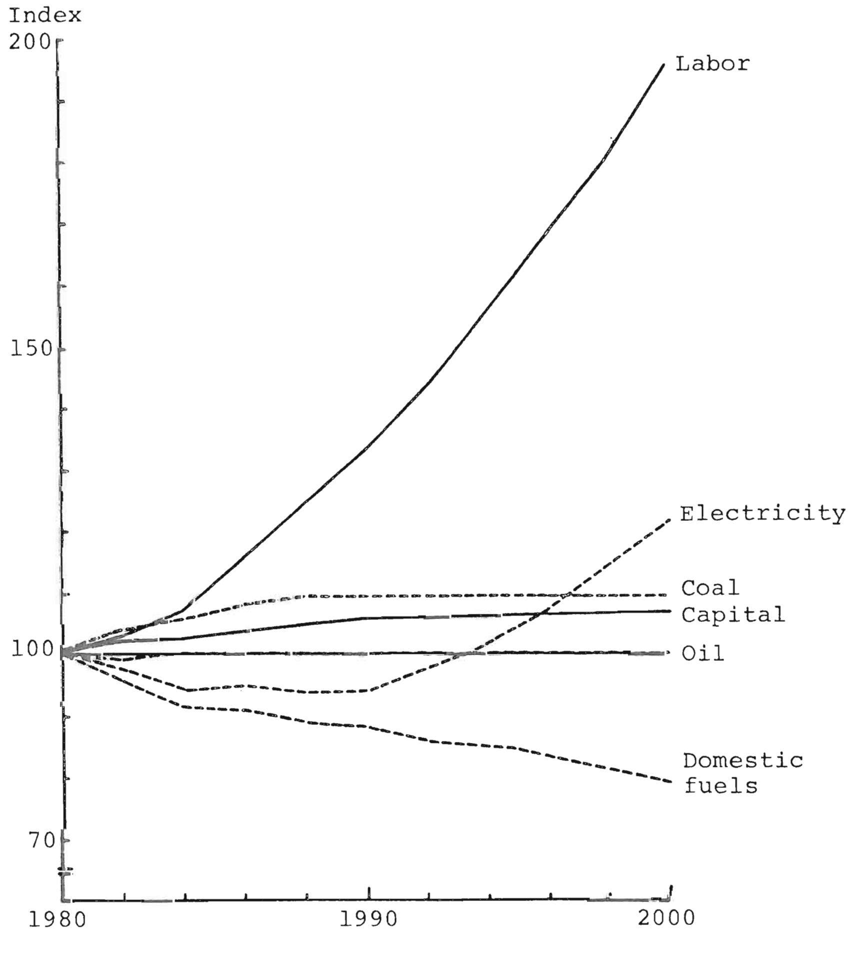
Figure 3 Relative factor prices in manufacturing, 1980-2000. Reference case.
Producer price = 100



of the cost or domestic fuels. The electricity glut in the 80s causes the price to dip in the 80s but electricity costs then rises fast during the following decade.

Figure 4 demonstrates that keeping the relative oil price constant — the alternative case — affects factor prices other than the coal price only marginally.

Figure 4 Relative factor prices in manufacturing, 1980–2000. Alternative case
Producer price = 100. Constant real oil price



Changing factor prices affect the factor use in manufacturing in three main ways in the model. Firstly, by changing the relative profitability — and plant utilization — of the different branches, it influences the relative rate of scrapping and investing and thus the branch composition with structural effects on the use of the various production factors. Secondly, for each vintage of investment in each branch, it determines the choice of technology, i.e., the cost-minimizing factor mix of new plants. This technological decision is modeled in terms of five types of factors: labor, capital, fuels, electricity and intermediate goods. Lastly, changes in the relative prices for different fuels will give rise to ex post substitution between different fuels within plants of all vintages.

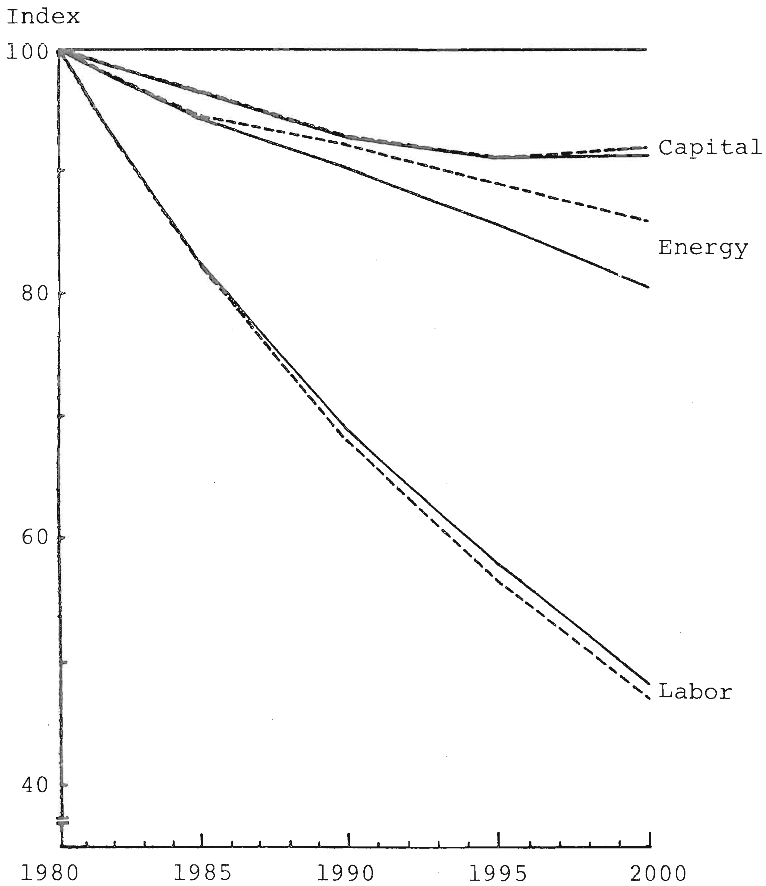
Let us begin by looking at the change in specific use of capital, labor and energy in manufacturing, as depicted in Figure 5. We see, both in the reference case and in the alternative case, a continuing mechanization which is far more labor-saving than energy-saving. However, if we compare this with the corresponding developments during the first three postwar decades (see Dargay, 1983a, in this volume) there are still noticeable differences. Since the capital-labor price relation developed even more favorably in earlier decades, the increase in capital-labor ratio was then faster. The lower relative level of energy prices then meant less interest in energy saving and an almost parallel development of the specific use of capital and energy, up to the time of the oil price hikes. For the coming decades the ongoing adjustment to higher energy prices will be reflected — according to the simulation results —

Figure 5 Input coefficients in manufacturing, 1980-2000

Index 1980 = 100; constant 1980 prices

—— = Reference case

---- = Alternative case



Capital: Capital stock/Production

Energy: KWh electricity, petroleum products and solid fuels/Production

Labor: Hours worked/Production

in a faster decrease of specific energy use relative to the use of capital. This is also true, although to a much smaller extent, in the alternative case with approximately constant relative oil prices.

Substitution between Energy Inputs

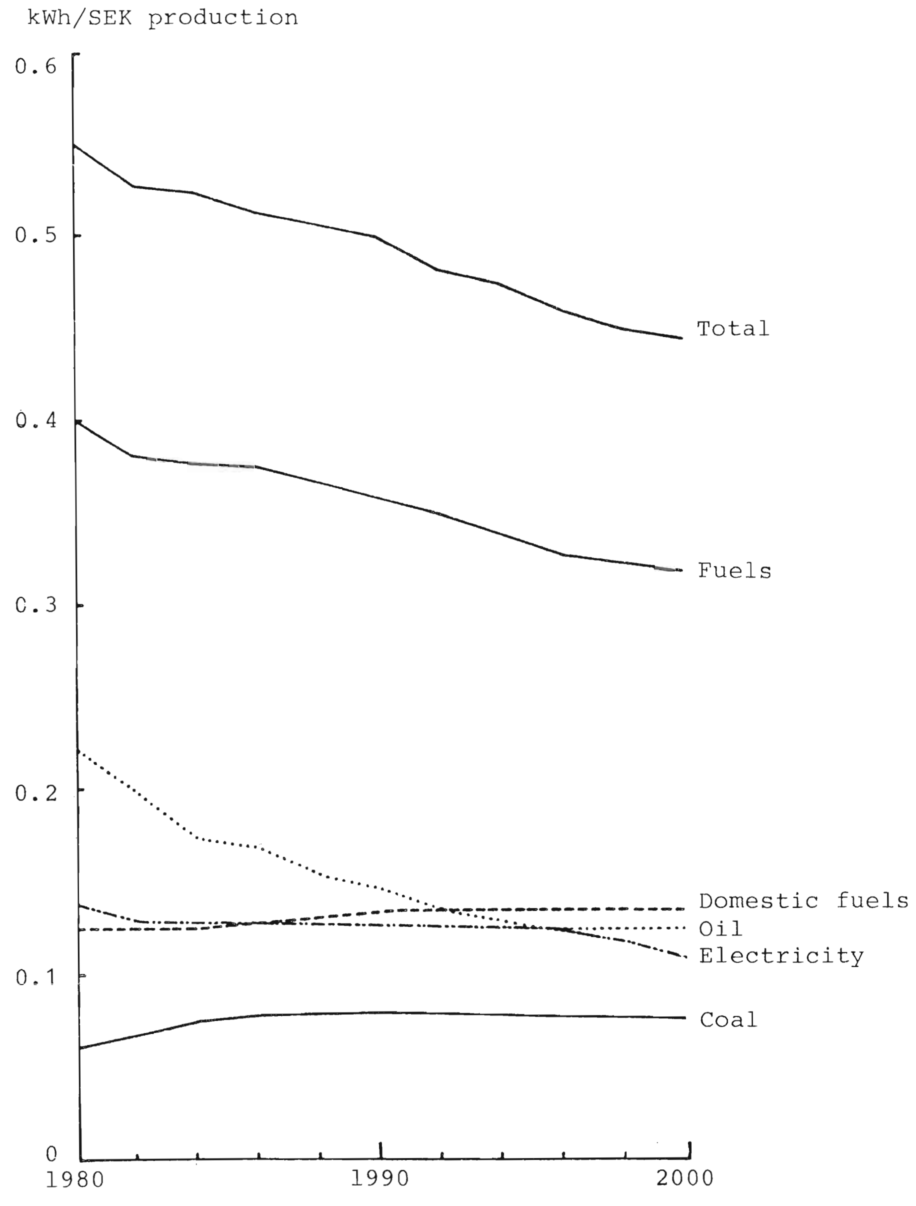
The changing price structure will not only affect the use of energy in manufacturing but also the choice between different forms of primary energy. As already noted above, such substitution within the sector is determined in the model by three mechanisms: the vintage or investment effect, the ex ante substitution between aggregate inputs due to choice of technology and finally the ex post substitution between fuels.

Before reporting the simulation results we should however note that there are deficiencies in the econometric estimates on which our modeling of the two first mechanisms are based. This probably implies that our results concerning the future possibilities of saving energy are biased in a downward direction, i.e., are too low.

The main problem with the original estimates (cf. Dargay, 1983b) is that they are based on data which are too aggregate in several respect. Aggregating machinery and buildings probably means, e.g., that you tend to underestimate that part of medium-term possibilities of energy substitution, which depend on investment in machinery and equipment. Of even greater importance is the fact that the estimates concern observed substitution within total branch capacity, instead of just measuring changes in the marginal or new capacity. Using the estimates as a description of the ex ante technological choice in a vintage model then means introducing two kinds of biases. The estimated energy price elasticities will throughout be too low. We have however tried to correct for this by a scaling-up procedure. Secondly, treating today's average input coefficients as technically optimal for new plants will certainly mean underestimating future factor productivity in general and energy-efficiency in particular. We have used other data to correct for this in respect to labor productivity but we have not had access to the kind of blueprint technological data needed to make similar corrections for energy and capital. This means that all our projections will tend to underestimate the level of future energy savings in manufacturing. The importance of this bias can be illustrated by noting that if you had used instead the ad hoc assumption that today's marginal input coefficient is only 60% of the average, the average coefficient at the turn of the century would have decreased about 50% more than in the reference case reported here.

Let us with these reservations in mind look at the simulation results as illustrated in Figures 6-8. Figure 6 shows the development of energy input coefficients in the reference case. We see that the decrease of the total energy coefficient is mainly due to fuel saving while the electricity coefficient remains relatively stable up to the middle of the 90s. The sharp rise in electricity prices from then on means however that electricity use — and related to that productivity gains in capital use — will decline somewhat. This in turn will to some extent be compensated by use of oil, putting an end to the decline in specific oil usage.

Figure 6 Energy coefficients in manufacturing 1980–2000
Reference case
KWh/SEK production; constant 1980 prices



As for substitution between different fuels we see that only a smaller part of the overall saving in oil use will be compensated for by increased use of coal and domestic fuels. There will not be any major technological switch towards coal.

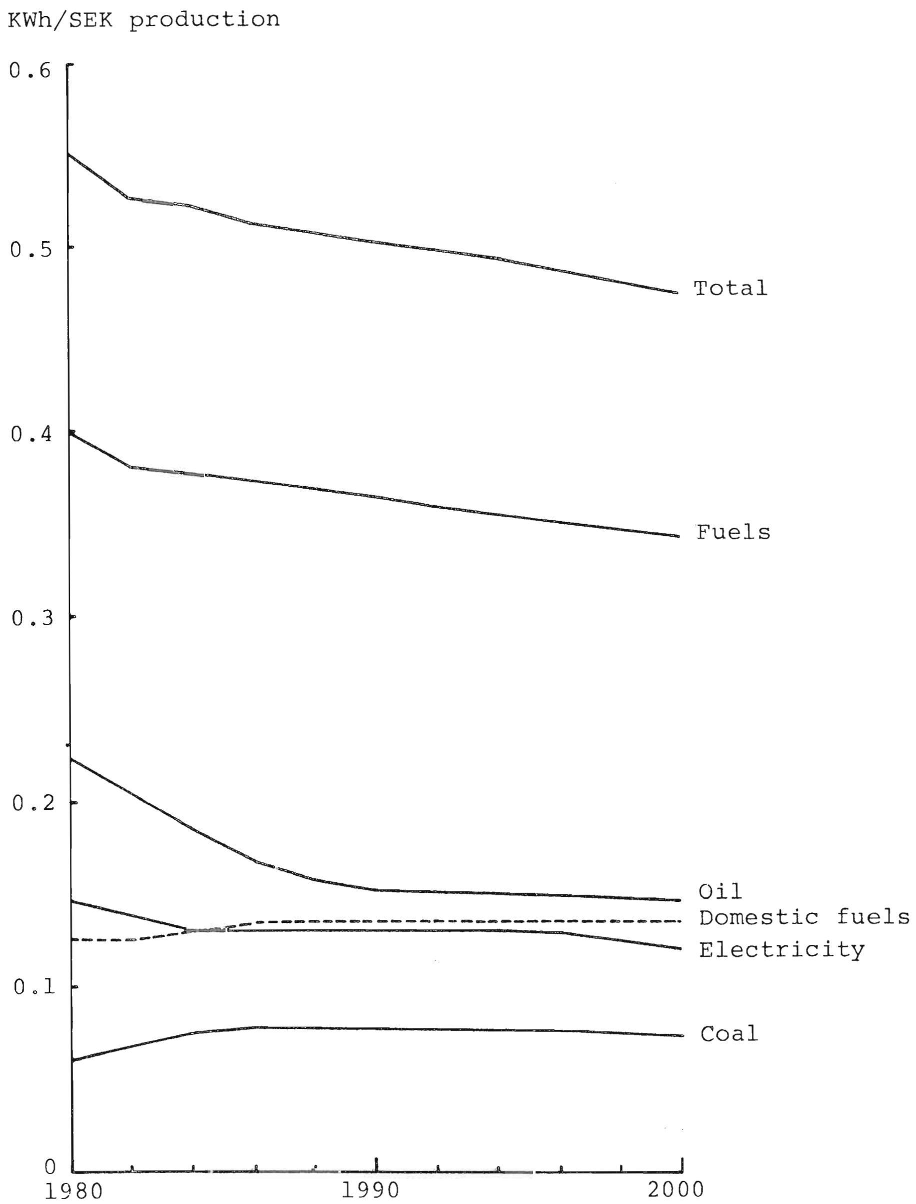
From Figure 7 we learn that a complete stagnant oil price, as in the alternative case, will not only break the decrease in oil usage but will also somewhat modify the decline in electricity use foreseen in the reference case. Apart from this the overall picture of energy usage, will not be markedly affected.

If we multiply the energy coefficients with the projected growth of production in the manufacturing sector we get the development of total use of energy as depicted in Figure 8. The figure reminds us of the fact that total oil saving within manufacturing will be rather moderate despite the sharp decline in oil coefficient. The use of fuels will increase about a quarter while electricity use at the turn of the century will be more than a third larger than today in spite of the high relative price of electricity.

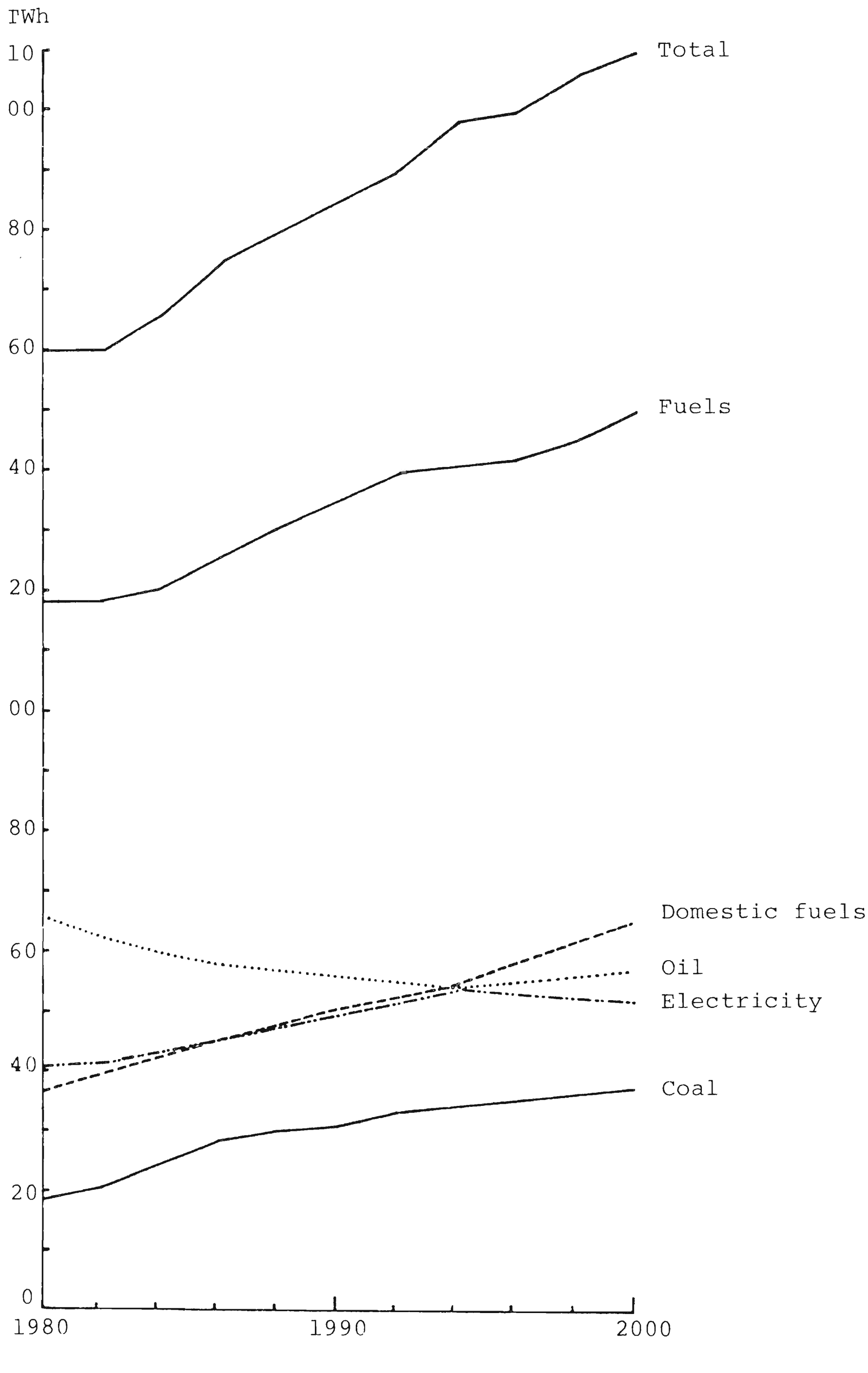
Structural Change and Energy Use

Our discussion so far has dealt with the aggregate manufacturing sector. Part of the total change in energy use during the period studied is however simply due to a changing branch structure within manufacturing. For interpreting and understanding the projected energy substitutions it is vital to separate the structural effect from the change within branches. It should however be noted that

Figure 7 Energy coefficients in manufacturing 1980-2000
Alternative case
Constant real oil prices



igure 8 Energy use in manufacturing 1980–2000
Reference case

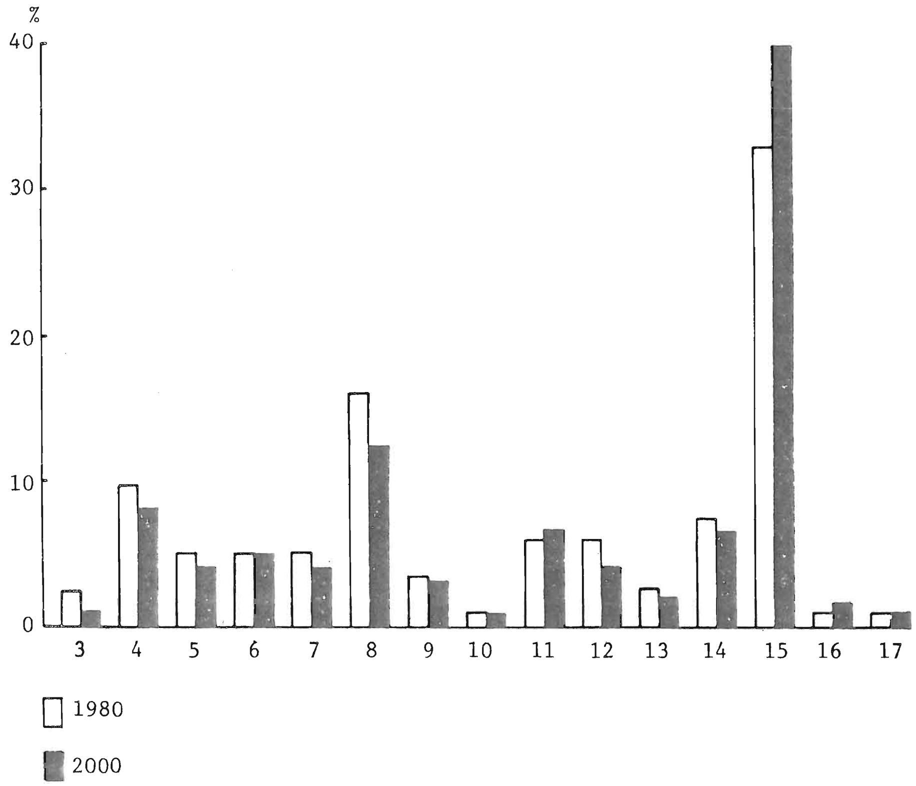


these two factors affecting total energy use are not independent of each other. Large possibilities of energy saving within a certain branch will affect its overall profitability and by that also its rate of capacity expansion. A fast expansion will in turn make possible a rapid exploitation of the saving potential which will be reflected in the change of the average energy coefficients for the branch.

The projected change of branch structure within the manufacturing sector is described in Figure 9. Among the big "losers" are those basic industries, which are also energy-intensive like mining, pulp and paper, and iron and steel. In these cases rising energy costs are of course only one marginal factor adding to the dominant effects of changing international market conditions and of domestic restrictions on raw materials. A continued decrease in production shares is also registered for food and textiles. On the "winning" side is first and foremost the engineering industry but also an energy-intensive branch like chemicals will have an increased share of production.

How these structural changes affect aggregate energy use is shown in Table 4. For each form of energy the change of total use in manufacturing during the projection period is recounted as the change in production volume multiplied first by the change in energy coefficients (structure being held constant) and then by the change in energy use structure (energy coefficients being kept constant). Depending on whether we use a Laspeyre or Paasche kind of index, we get the results with or without brackets in Table 4.

Figure 9 Branch shares (%) of gross production of manufacturing 1980 and 2000 Reference case



3. Mining and quarrying
4. Manufacture of food (sheltered)
5. Ditto (exposed)
6. Manufacture of beverages and tobacco
7. Textile, wearing apparel
8. Manufacture of wood, pulp and paper
9. Printing and publishing industries
10. Manufacture of rubber products
11. Manufacture of non-metallic and other chemicals, and plastic products
12. Petroleum and coal refineries
13. Manufacture of non-metallic products (except products of petroleum and coal)
14. Basic metal industries
15. Manufacture of fabricated metal products, machinery and equipment, excl. shipbuilding
16. Shipbuilding
17. Other manufacturing industries

Table 4 Factors determining change of energy use in manufacturing, 1980–2000

	Relative change 2000/1980 in:					
	total production volume	•	specific energy usage[a]	•	use structure[b]	= energy use
Oil	1.65		0.52 (0.56)		0.93 (0.85)	0.79
Coal	1.65		1.46 (1.54)		0.86 (0.81)	2.07
Domestic fuel	1.65		1.29 (1.23)		0.83 (0.88)	1.77
Total fuel	1.65		0.90 (0.91)		0.87 (0.85)	1.29
Electricity	1.65		0.92 (0.92)		0.91 (0.90)	1.38
Total energy	1.65		0.90 (0.91)		0.88 (0.87)	1.31

[a] Weighted average of specific energy usage with 1980 production shares as weights. The result of using instead production shares for 2000 is shown in brackets.

[b] Weighted average of production shares with specific energy usage in 2000 as weights. The result of using instead specific energy usage in 1980 is shown in brackets.

Note

The construction of Table 4 can be explained by a simple formula.

Let us use the following symbols.

E_j^t = Energy use (TWh) in manufacturing branch j at time t. (t=1 denotes 1980 and t=2 stands for 2000)

$$E^t = \sum_j E_j^t$$

Note to Table 4, cont.

V_j^t = Production volume (1980 prices) in manufacturing branch j at time t.

$$V^t = \sum_j V_j^t$$

$$e_j^t = \frac{E_j^t}{V_j^t} = \text{Specific energy usage.}$$

$$v_j^t = \frac{V_j^t}{V^t} = \text{Production share.}$$

From this definition it follows that:

$$\frac{E^2}{E^1} = \frac{V^2}{V^1} \quad \frac{\sum_j v_j^2 e_j^2}{\sum_j v_j^1 e_j^1} =$$

$$= \frac{V^2}{V^1} \cdot \frac{\sum_j v_j^1 e_j^2}{\sum_j v_j^1 e_j^1} \cdot \frac{\sum_j v_j^2 e_j^2}{\sum_j v_j^1 e_j^2} = \qquad (1)$$

$$= \frac{V^2}{V^1} \cdot \frac{\sum_j v_j^2 e_j^2}{\sum_j v_j^2 e_j^1} \cdot \frac{\sum_j v_j^2 e_j^1}{\sum_j v_j^1 e_j^1} \qquad (2)$$

The figures without brackets in the first three columns in the table represent the three consecutive terms in (1), while figures for the corresponding but different terms in (2) are given in brackets. The first term measures the change in production volume. The second represents the change in specific energy usage, employing as weights the production shares for the year 1980 (1) or 2000 (2). The third term shows the change in "use structure", computed by averaging the production shares using as weights the specific energy usage in the year 2000 (1) or 1980 (2). The fourth column finally, shows the product of the figures in the preceding three columns, measuring the change in energy use.

We see that for total energy the structural effect is of the same magnitude as the change in specific energy usage. The same is true for total fuels and for electricity. We find however, not surprisingly, that the change in specific usage varies between the fuels both as to sign and magnitude. While specific usage is halved in the case of oil it increases almost half a time for coal and some thirty percent for domestic fuels. Counted for the whole fuel group these divergencies, however, tend largely to cancel out, leaving only a ten percent reduction in specific usage for total fuels or about the same as the concomitant structural change.

One way of summarizing these findings would be to note that half the total energy savings up to the turn of the century would be realized even if the average energy-efficiency remained unchanged within each manufacturing branch.

The Vintage Effect

To gain a better understanding of the energy substitution process on a more "micro" level, one should go also below the branch structure and look at the development of energy use for succeeding vintages within a branch.

We will here illustrate the substitution embodied in capacity renewal and expansion by looking, for the year 2000, at the energy coefficients for the different vintages of an energy intensive branch — the wood, pulp and paper industry.

As shown in Figure 10 the renewal of this industry is not expected to proceed very rapidly. About a third of the operative capacity in the year 2000 will have been built before 1980. For this industry, as for most of others, we unfortunately lack data on the initial vintage distribution. This has forced us to let the initial marginal energy coefficients be equal to the average, introducing an upward bias in the estimates of future energy use.

For the successive new vintages Figure 10 however shows a relatively rapid decrease in the coefficients for both fuels and electricity. If we should disaggregate the vintages further into the low energy wood industry and the energy-intensive pulp and paper industry, one would suspect the decrease in energy coefficients to be even faster for the pulp and paper part. With the sharply increasing electricity prices in the 90s there is also a tendency reflected in the figure to substitute fuels consuming processes for electricity consuming processes.

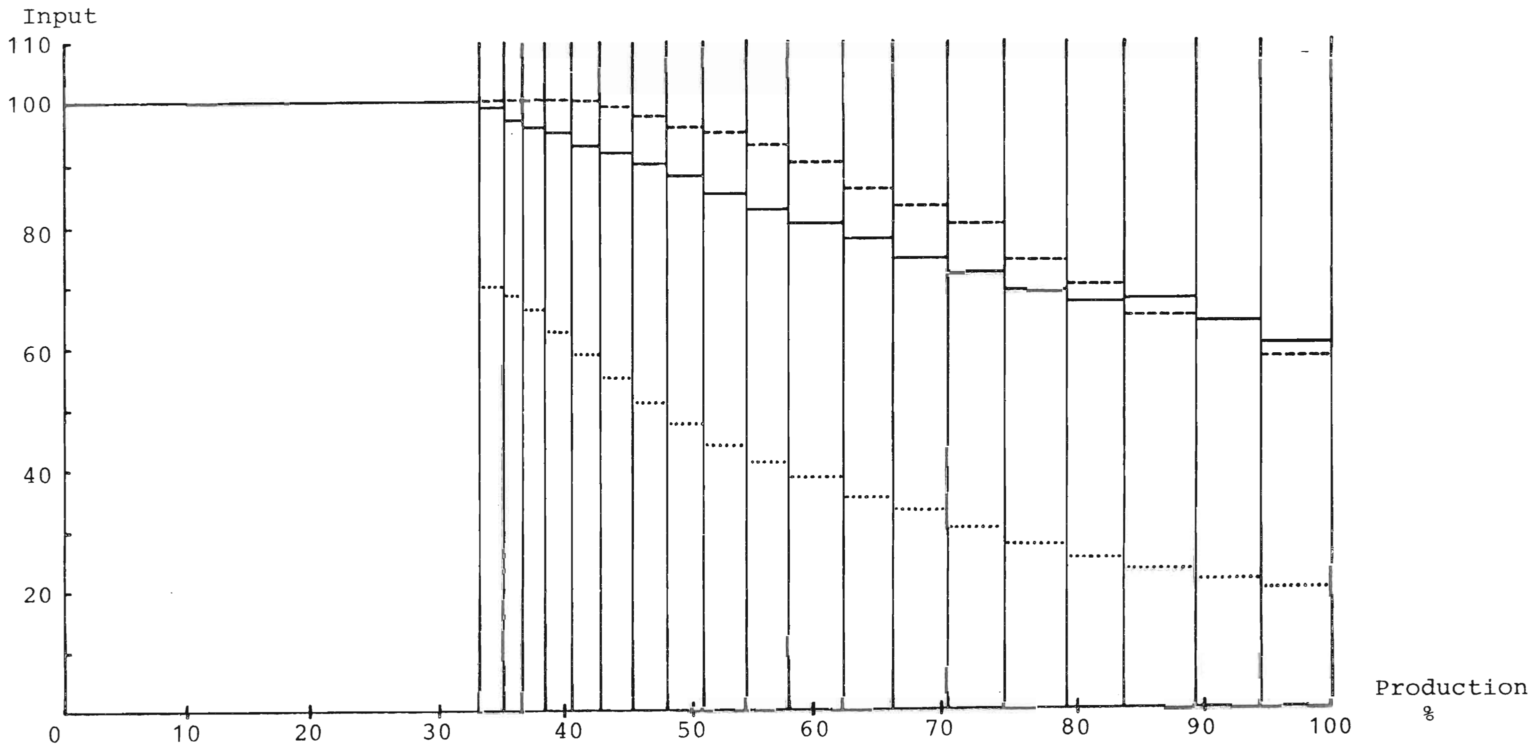
Summing Up

Telling the story of energy use in Swedish manufacturing over the next two decades means tracing the interwoven paths of structural adjustment and energy substitution. The structural change emerges from our study as a strategic factor in determining future energy use in two ways. First, half the total saving both of fuels and of electricity was seen to stem from the change of branch structure. Second, the rate of industrial renewal and expansion will to a great extent determine the amount of potential energy savings that can be realized before the turn of the century.

Figure 10 Inputs of labor, electricity and fuels per unit output for different vintages in the pulp and paper industry in 2000. Reference case

1980 average = 100

.... Labor --- Electricity —— Fuels



The closing down of nuclear reactors beginning in the 90s, will mean higher electricity prices, and can be expected to cause a certain slow down both of mechanization and electrification and of oil savings in manufacturing.

The continued decrease of oil use was mainly realized by saving fuels and was only to a minor extent due to substitution between fuels. The specific usage of coal in manufacturing was thus not projected to increase further during the 90s.

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