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**ENERGY USAGE AND ENERGY PRICES
IN SWEDISH MANUFACTURING**

by

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1 Introduction

The industrial sector accounts for somewhat less than 40 % of energy utilization in Sweden. This share has declined during the past three decades, from 45 % in 1950, mainly as a result of a more rapid expansion of other sectors of the economy, particularly of the public sector and the private service sectors, and of an increase in energy usage in the household sector. Despite industry's diminishing share of total energy usage, the effects of disturbances in energy supply or rising energy prices on economic growth and Sweden's competitive position are largely determined in the industrial sector.

In the following, we examine the development of energy consumption and energy prices in Swedish industries during the post-war period. Our intention is not to explain the many factors behind the changes in energy consumption patterns, but merely to describe the trends in energy use and factor prices during this period. No attempt has been made to correct the measures of specific energy use for either fluctuations in the business cycle or temperature variations.

The underlying data have been obtained primarily from Swedish Manufacturing Statistics and National Accounts. These data have also been used in the econometric studies presented in chapter x, where a detailed description of data sources and the construction of price and quantity series can be found. The energy forms considered are electricity, oil products and solid fuels (coal, coke and wood fuels). Only energy purchased from outside the establishment is included.

Section 1 concerns total Swedish manufacturing, with the exception of energy-producing sectors.¹ Trends in specific energy usage, fuel mix and nominal and real energy prices are discussed. These are compared with the inputs and prices of other factors of production - labour and capital. Section 2 investigates the development of specific total energy use and the use of electricity

and oil products in 12 subsectors of the manufacturing industry. Finally, implicit energy prices and aggregate energy price indices for the individual sectors are compared.

2 Total Manufacturing

Industrial energy usage increased an average of 4.3 % per year from 1950 to the mid 60's. The rate of increase was similar for other sectors of the economy, so that industry's share of total energy utilization remained constant during the 15 year period. From 1965 to 1970 energy demand in the industrial sector increased less rapidly than in the rest of the economy, with a rate of growth of 4.1 % per year as compared to 4.8 % for the economy as a whole. By 1970, industry's share of total energy usage had decreased to 42 %. The decrease in the rate of growth continued into the 1970's. From 1970 to 1973 the average yearly rate of growth had declined to 1.4 %. After 1973, and the first energy crisis, the absolute level of energy usage began to decrease.

The composition of energy usage in the industrial sector changed considerably during the after-war period. The most obvious change has been a substitution away from solid fuels and a rapid increase in the consumption of electricity and oil products. The use of solid fuels decreased 25 % during the 1950's and remained at the same level for much of the following two decades. Electricity consumption increased steadily over the entire period, although the rate of growth declined from the mid 60's. During the period 1952-1965 electricity usage rose by an average of 7 % per year, while the average growth for 1965-75 decreased to slightly less than one half this rate. The use of oil products increased somewhat more rapidly than electricity during the 50's and early 60's, at an average rate of 8.4 % per year. Oil usage continued to increase on an average of 3.6 % per year up until 1973, after which a sharp fall in consumption is noted.

The increase in energy demand in Swedish manufacturing since the 1950's is largely the result of an increase in manufacturing

production. We find, in fact, that for the larger part of the period production increased more rapidly than energy consumption, suggesting a decrease in specific energy use. During the period of the most rapid rise in energy usage, i.e. the 50's and early 60's, output increased by an average of 5.8 % per year. From 1965 to 1975 the average yearly growth in production had declined to 3.7 % per year. By 1975 production had begun to decrease, and continued to do so for much of the later seventies.

The development of the energy/output ratio in the manufacturing industry for the period 1952-77 is shown in Figure 1. A decrease in specific energy usage is evident for the entire period, with the largest decrease occurring during the post 1970 period. With respect to the various energy forms, the general trend is towards a reduction in the use of solid fuels and an increase in the specific usage of oil and electricity.

During the 1950's, the specific use of electricity and oil products rose considerably. This increase was, however, more than compensated for by a 50 % decrease in the use of solid fuels. Oil consumption per unit output increased at a slower rate during the 60's and by 1970 had begun to fall. Between 1973 and 1974 specific oil usage fell sharply in response to the exceptionally large price increases and shortages associated with the first oil crisis. This downward trend appears to have continued through 1975, after which the oil/output ratio remained more or less constant. A somewhat different development is noted for electricity. After a rapid increase in the 50's the specific use of electricity remained at a constant level during most of the 60's. The early 70's and particularly the most recent years exhibit once again a trend towards increasing electricity intensity. This, however, may in part reflect the low capacity utilisation associated with the post 1974 recession.

The observed development of specific energy use can partially be explained in terms of changes in relative energy prices. This can be seen in Table 1, which shows the price development of heavy

Figure 1 Specific energy usage (kWh/Kr production, constant 1975 prices) in manufacturing 1952-1977

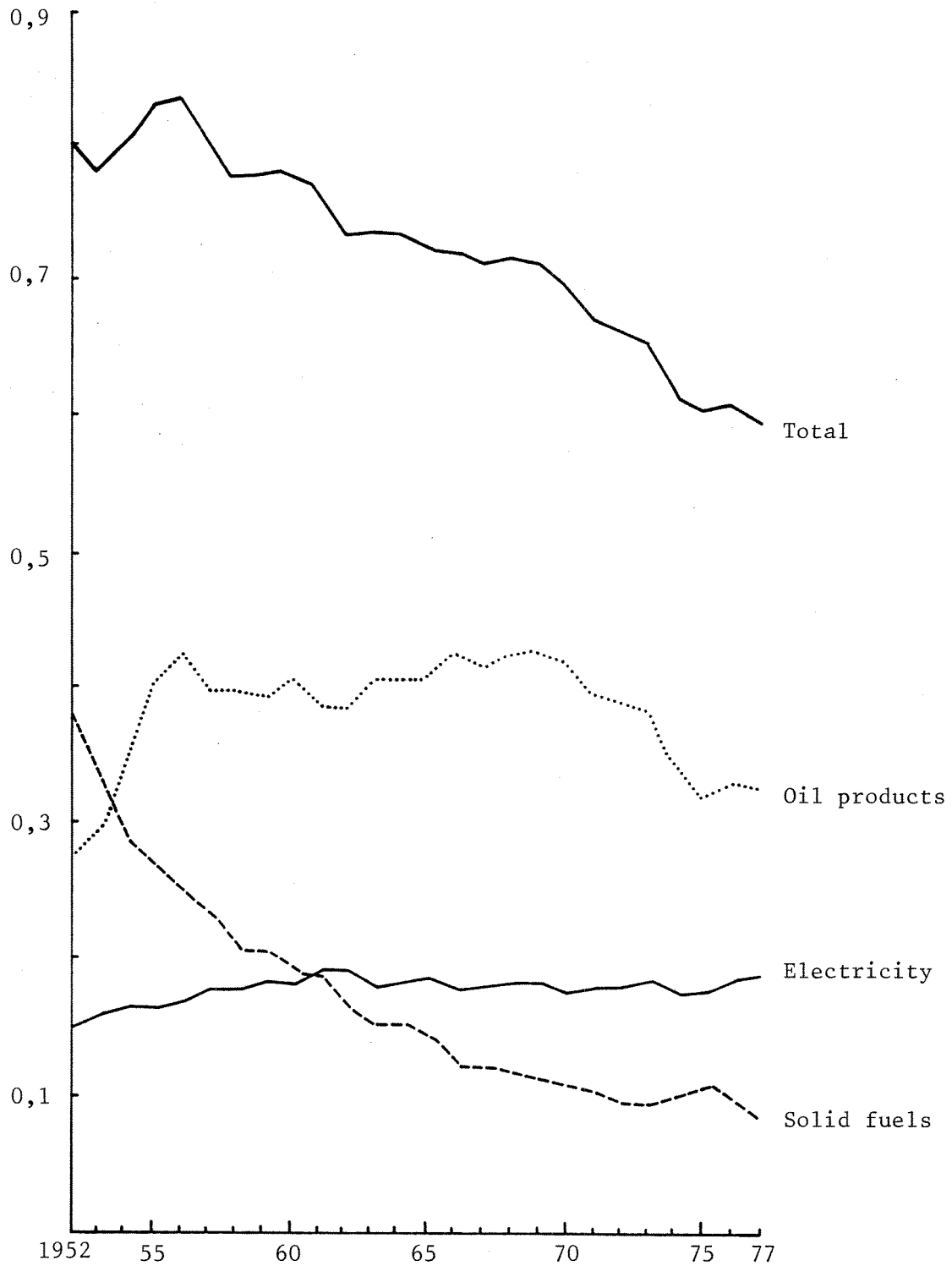


Table 1 Energy and factor prices in Swedish manufacturing
1950-1977
 Annual percentage change

	50-60	60-65	65-70	70-73	73-77	50-77
Heavy fuel oil	-0.5	0.0	4.3	11.5	26.0	5.4
Coal	0.5	0.8	4.4	0.4	26.0	3.5
Motor gasoline	0.0	1.0	1.7	7.5	11.2	2.9
Electricity ^a	7.6	-3.3	0.9	6.2	16.2	5.3
Energy price index	3.0	0.6	1.4	5.8	21.4	4.9
Producers' prices	3.8	1.9	2.2	5.2	12.8	4.6
Unit labour costs	8.9	10.4	9.7	11.8	16.4	10.7
User cost of capital ^b	-0.5	1.0	3.2	2.2	-16.3 ^c	-1.2 ^c

^a Average price/kWh for a supply of 20-40 kV, 2 000 kW, 4 000 hrs (Vattenfall) plus electricity tax.

^b The user cost of capital is calculated taking into consideration taxes and subsidies. Thus the large fluctuations.

^c To 1976. The large decline in the user cost of capital in 1976 reflects investment subsidies.

fuel oil, coal, motor gasoline and electricity for various subperiods, along with the corresponding development of the prices of manufacturing output, labour and capital services. We see that the prices of coal and motor gasoline increased slightly up until the mid 60's, while the nominal price of fuel oil fell somewhat. Although the relative prices of oil and coal changed only marginally, the relatively high labour requirements in the handling of solid fuels in combination with rapidly rising wages tended to accentuate this price difference. As shown in the diagram, this period is characterized by the continued substitution of oil for solid fuels.

After 1965, the nominal prices of both of these fuels began to rise, with the most dramatic increase occurring after 1973. It can also be noted that the price of coal closely followed that of oil during the larger part of the period. The comparatively small price increases for motor gasoline, particularly after 1973, can be explained by the fact that gasoline taxes and refining costs account for a large proportion of the price to consumers. The effect of crude oil price increases has therefore been of less significance than for other oil products.

The price of electricity, however, shows quite a different development: a considerable rise during the 50's was followed by a sharp fall in the early sixties. After the mid 60's, the nominal price began to rise gradually. The price development of electricity relative to fuels reached a turning point in the early 60's, after which relative electricity prices began a downward trend, the price gap between electricity and fuels widening substantially during the 70's. The reduction in oil and increase in electricity usage noted for this period may well reflect these relative price changes.

The development of the energy price index in manufacturing is also shown in Table 1.2 We see that aggregate energy prices fall only slightly in relation to the producers' price index during most of the pre-1973 period. This is explained by the fact that the fal-

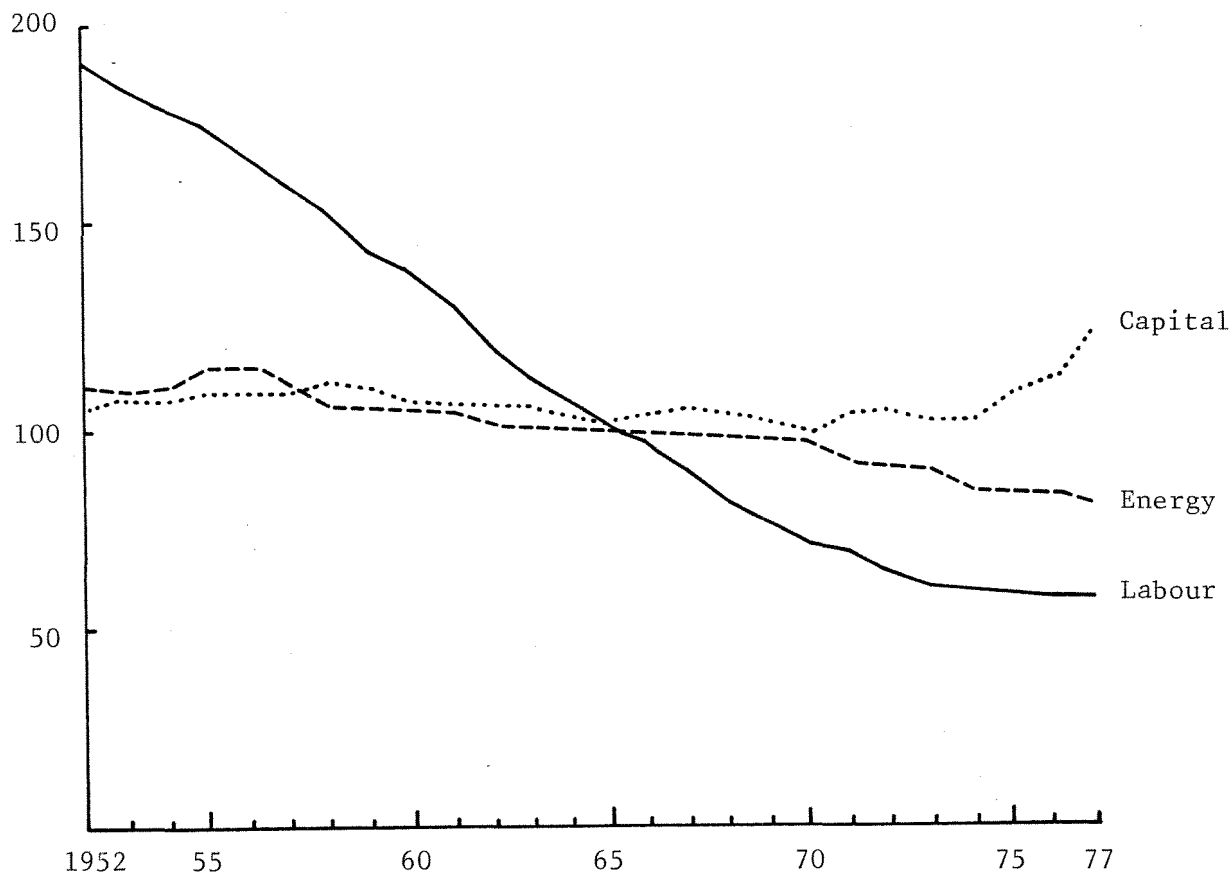
ling real fuel prices of the 50's were counterbalanced by rising real electricity prices. After 1973, however, a significant increase in real energy prices is evident.

The general tendency towards falling specific energy use cannot, therefore, be explained in terms of these relative price changes, nor can the rapid increase in electricity use during the 50's. Energy is, however, only one of many inputs in the production process. Changes in energy utilization patterns may also reflect a substitution between energy and other factors of production. As is evident from Table 1, labour costs have risen far more rapidly than the prices of both energy and capital over the period as a whole. Only after 1973 do oil and aggregate energy prices increase more rapidly, while electricity prices rise less rapidly throughout. Considering these changes in relative factor prices, one could expect a trend towards decreasing labour intensity and an increase in the relative use of energy and capital.

To explore the development in factor use, the inputs of labour, capital and energy per unit output are shown in Figure 2. It is apparent that the decline in specific energy use during this period is rather minimal in comparison to the dramatic fall in labour intensity. Energy and capital, on the other hand, follow very much the same path up until 1970, after which the continuing decline in specific energy usage is coupled with an increasing capital intensity. An ongoing rise in the capital/labour and energy/labour ratio is apparent, particularly from 1950-73, which is clearly a reflection of the continuous substitution of capital and energy for labour in production. The availability of relatively cheap energy has led to the introduction of less labour-intensive capital equipment.

Further, we note that the inputs of capital, labour and energy increased at a slower rate than output during the 50's and 60's. Technological development has thus led to an increased efficiency in the use of all production factors.

Figure 2 Inputs of labour, capital and energy per unit output
(1965 = 100) in manufacturing, 1952-1977



Labour: Hours worked.

Capital: Capital stock, constant prices.

Energy: kWh electricity, petroleum products and solid fuels.

Output: Gross production, constant producers' prices.

Source: National Accounts of Sweden; Manufacturing annual reports 1952-1977.

After 1973 the development is somewhat different. Specific energy use fell more rapidly than the labour/output ratio, while production appears to have become more capital intensive. These observations, and particularly the noted rise in the capital/output ratio must, however, be interpreted with caution. The period after 1973 is one of economic recession. Manufacturing output decreased between 1974 and 1977, and plants have not been operating at full capacity. Long-run changes in factor usage - at full capacity utilisation - are most certainly quite different from those observed here.

3 Energy usage in manufacturing subsectors

The noted decline in the energy/output ratio in manufacturing reflects not only an increased efficiency in energy usage but also the changing composition of manufacturing output. During the 50's and 60's energy-intensive industries, such as primary metals, paper and pulp, chemicals and rubber products, increased their shares of manufacturing output as did the less energy-intensive engineering industry. During the 1970's, however, production grew less rapidly in the energy intensive sectors than in total manufacturing. The relative decline of these industries in manufacturing production has played a major role in the observed decrease in specific energy usage after 1973.³

According to a recent study⁴ of the factors influencing energy usage in Sweden, approximately 1/3 of the reduction in specific energy usage in the production system⁵ from 1973 to 1980 can be attributed to structural change. For the manufacturing sector alone, the influence of structural change accounts for 1/4 of the observed decrease in energy intensity.⁶

In order to distinguish between the influences of changes in product composition and changes in specific energy usage it is essential to study the development of energy/output ratios on a more disaggregated level. In the following we shall examine 12 subsec-

tors of the manufacturing industry.⁷ The specific energy usage - subdivided into electricity and petroleum products - is calculated for each sector for the period 1965-1977 and displayed graphically in Figures 3 and 4. All series are normalised to 1 in 1965. It should be held in mind that the measure of specific energy usage reflects a combination of many divergent factors: both long- and short-term changes in energy utilisation as well as differences in capacity utilisation and climatic conditions over the period.

Before we examine these figures a few comments should be made concerning the development of specific energy use prior to 1965. During this period, the energy/output ratio rose appreciably only in 3 sectors: Printing, chemicals and shipbuilding. A rapid replacement of solid fuels with oil products is also apparent in all industries, as is a significant increase in specific electricity use brought about by the rapidly increasing mechanization of production. Further, all industries display a continually increasing capital/labour and energy/labour ratio well into the 1970's.

Total energy usage (electricity, petroleum products and solid fuels) per unit output is shown in Figure 3 for the 12 manufacturing subsectors.⁸ A downward trend in specific energy usage is discernible in the majority of industries. Only in the printing industry do we find an increasing energy intensity over the entire period. In the food industries, the large fluctuations make it impossible to distinguish any long-term changes in specific energy usage.

Of the remaining industries, all, with the exception of rubber products, exhibit a clear reduction in energy intensity during the period prior to 1974. The most significant decreases have occurred in chemicals, engineering, textiles and shipbuilding. Of the most energy intensive sectors, only wood, pulp and paper shows a decline in specific use of much less than 10 % during this period. This has to do mainly with our aggregation of two vastly different sectors: The energy intensive pulp and paper industry and the low-energy, wood and wood product industry. Disaggregating

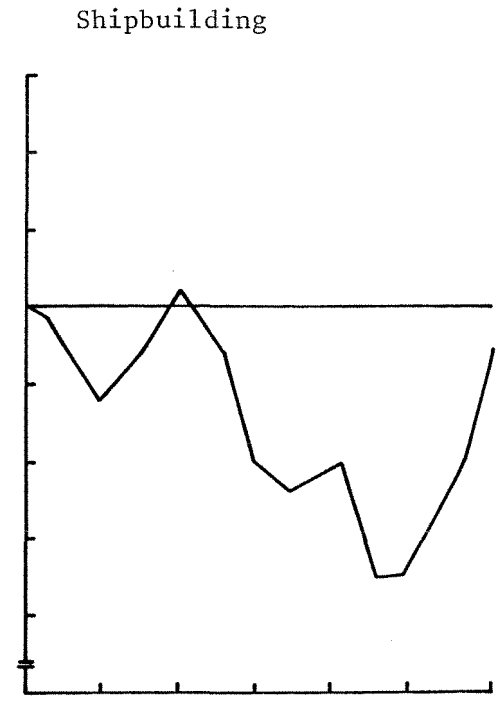
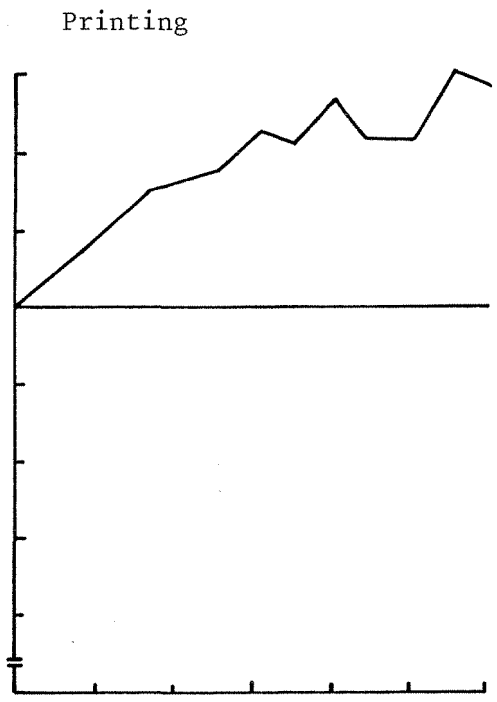
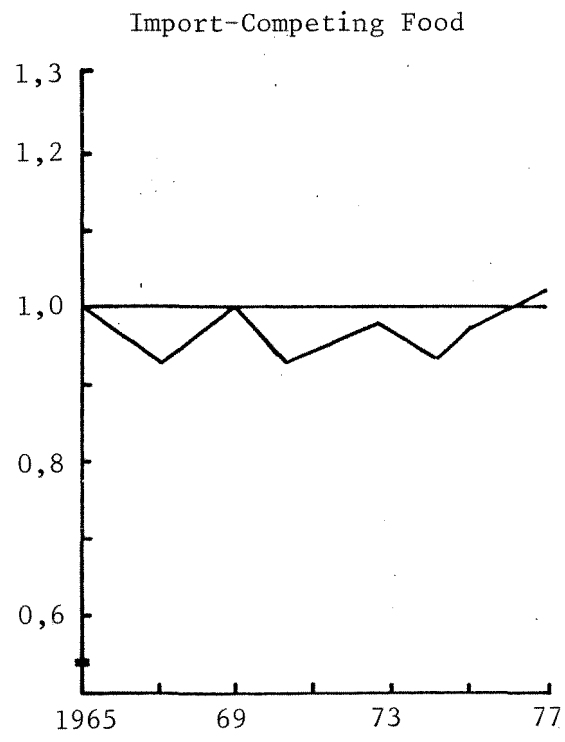
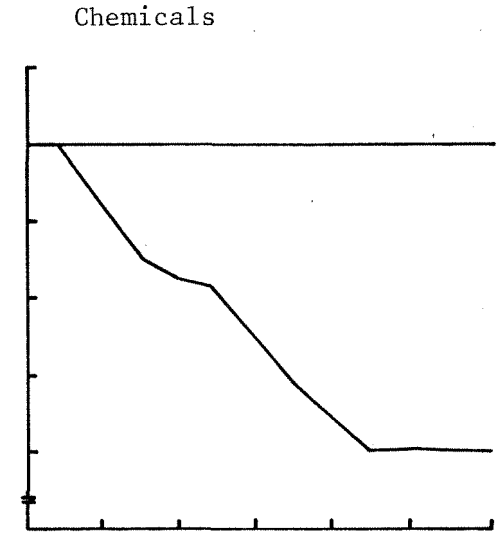
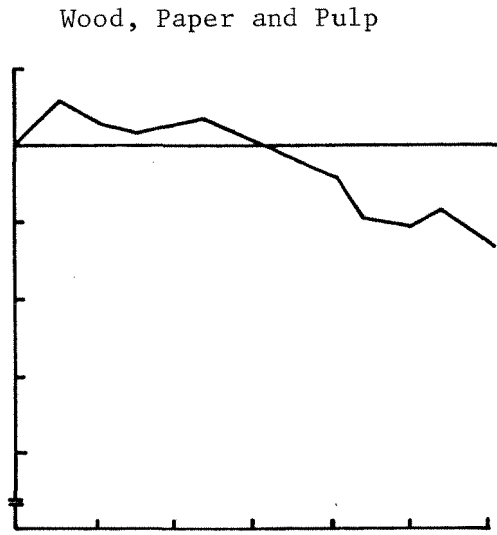
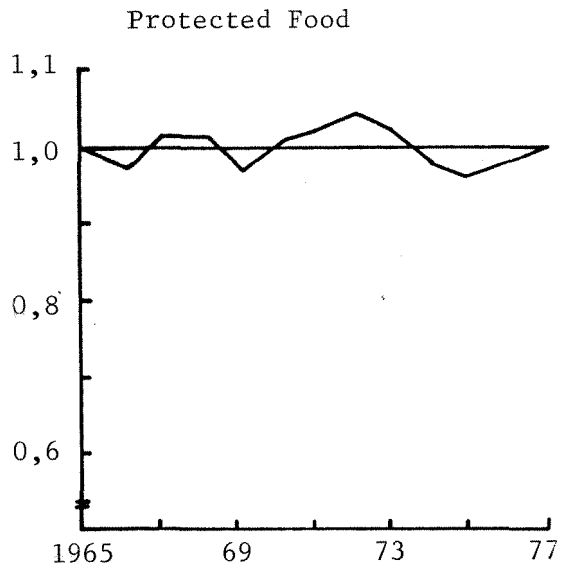
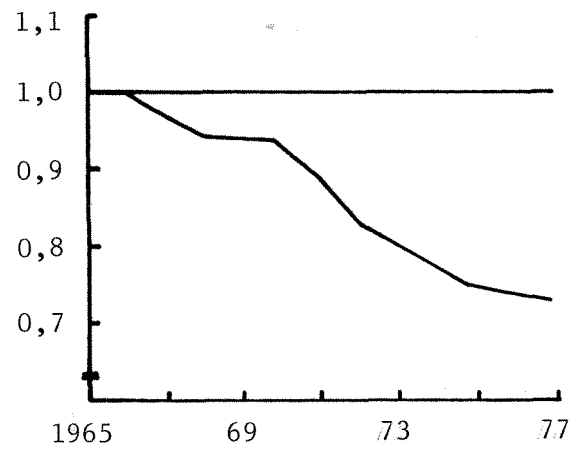


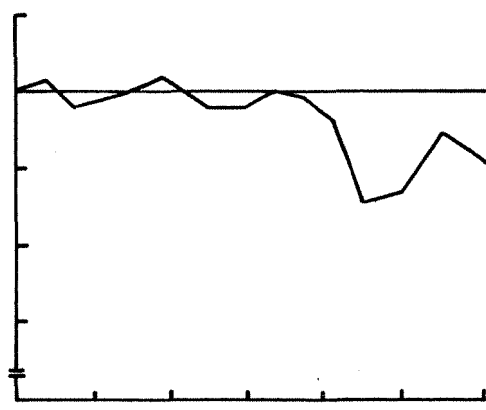
Figure 3A Specific energy use in manufacturing sectors, 1965-
1977.
 (1965 = 1.0)

Figure 3B Specific energy use in manufacturing sectors, 1965-1977.
(1965 = 1.0)

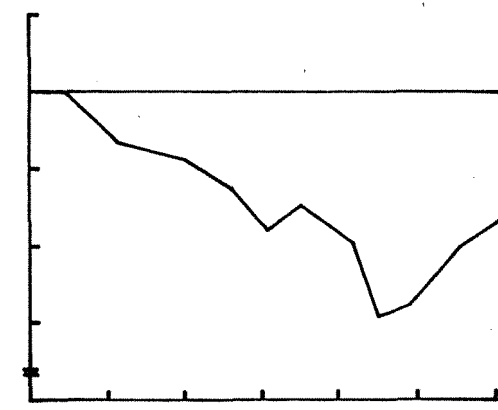
Beverages and Tobacco



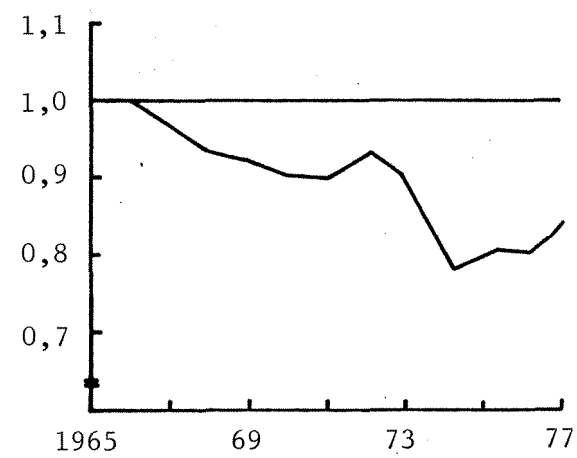
Rubber Products



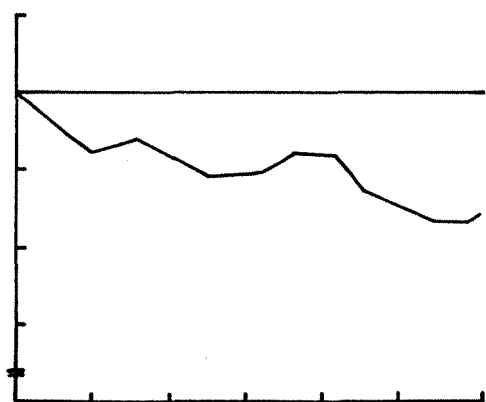
Engineering



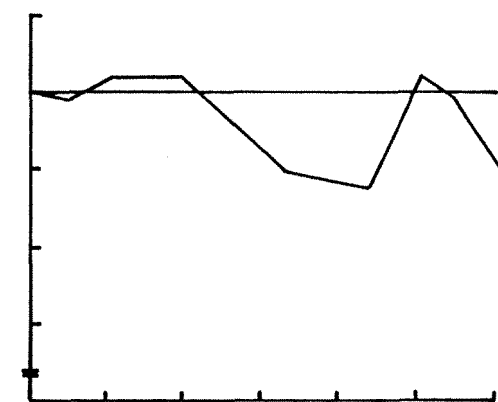
Textile



Non-metallic Mineral Products



Primary Metals



these two sectors, Sohlman-Stillerud-Östblom find a 7 % decline in the energy-output ratio in the pulp and paper industry and a 35 % increase for wood and wood products over the period 1965-1973.

The development after 1973 is somewhat more difficult to interpret. In all sectors, with the exception of primary metals, the specific energy usage fell rapidly during 1974 and 75. After 1975, however, we find a tendency towards increasing energy usage in many subsectors. The most notable exceptions are 4 of the 5 most energy intensive sectors: non-metallic mineral products, wood, pulp and paper, chemicals and rubber products. As noted earlier, the apparent increase in energy intensity may, in fact, reflect the low capacity utilisation of the post 1974 period.

The specific use of electricity and petroleum products in the twelve subsectors is shown in Figure 4. Regarding petroleum products we find a gradual decline from 1965 to 1973 in over half of the subsectors, and a significant increase only in the printing industry. During the two years following 1973, a considerable reduction in oil usage is apparent in all sectors. After 1975, the tendency is similar to that found for total energy, i.e. a trend towards increasing specific use in a number of industries. All but 3 of the subsectors, however, have a lower specific oil use 1977 than 1973. From these results, it would appear that the events of 73-74 have had a long-term effect on oil usage. It is, of course, impossible to draw any definite conclusions regarding the effects of the 1974 oil price increases on the basis of the data presented here. The number of observations after 1974 is too few and the influence of differences in capacity utilisation and climatic conditions have not been taken into consideration.

As mentioned previously, the increased mechanization of industry has resulted in a steady increase in electricity consumption in all sectors during the 50's and early 60's. We see that this trend towards rising electricity intensity has continued in the majority of subsectors during at least some part of the post 1965 period. The

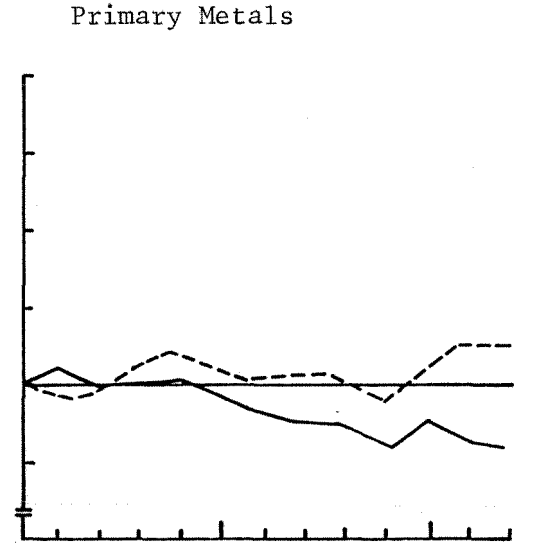
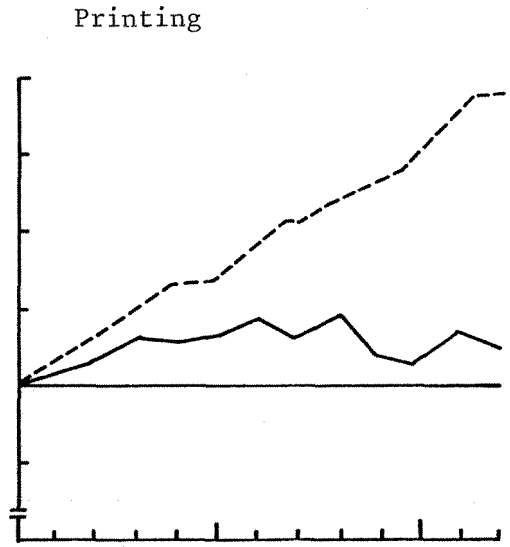
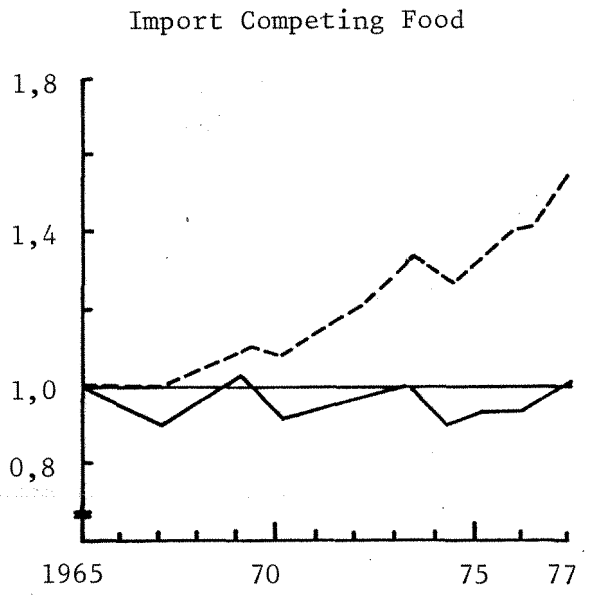
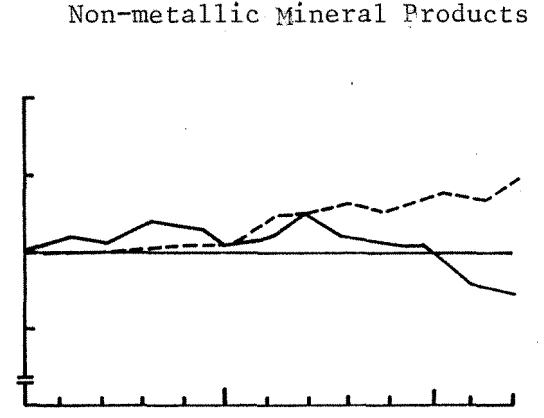
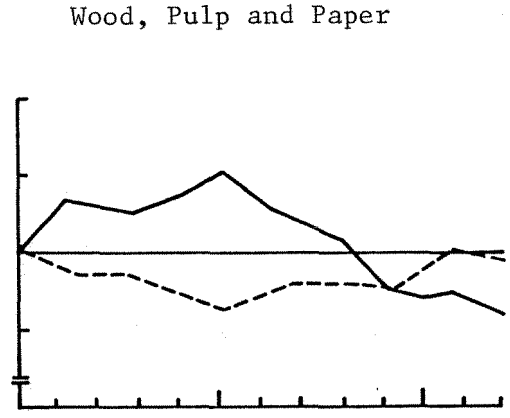
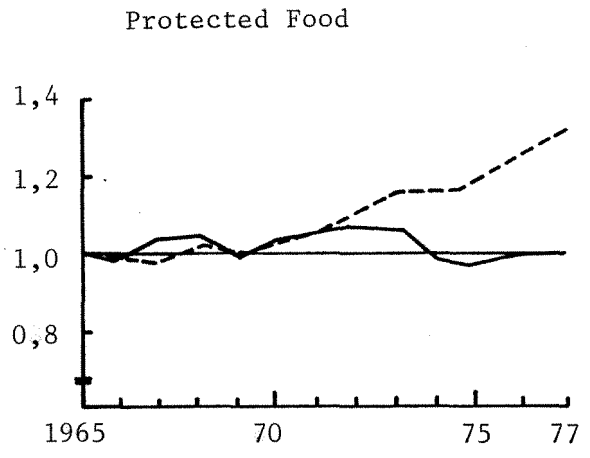
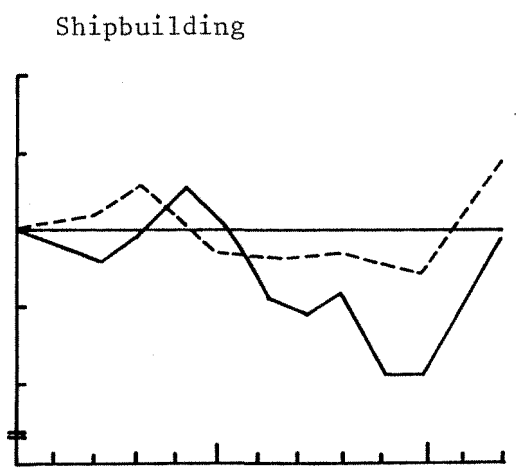
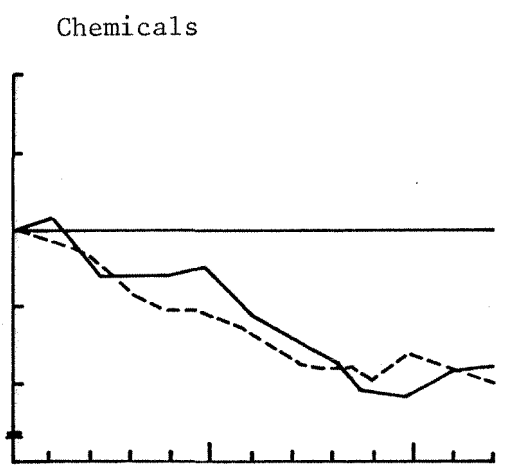
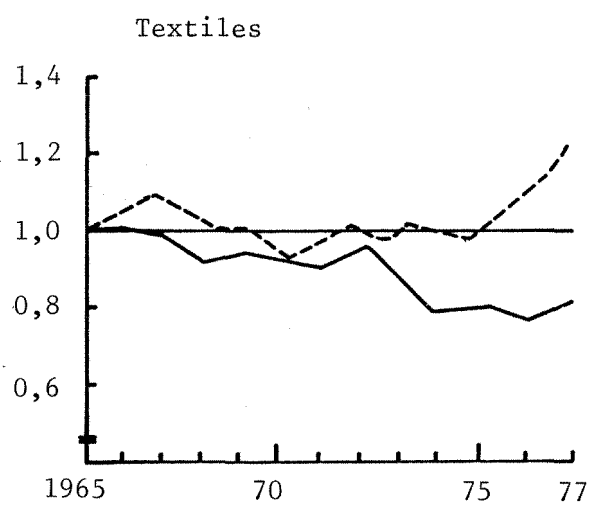
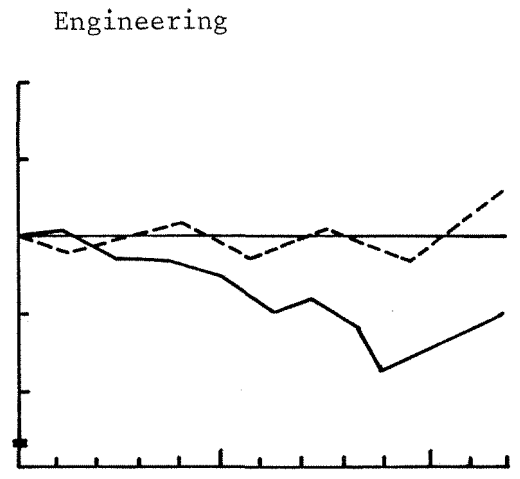
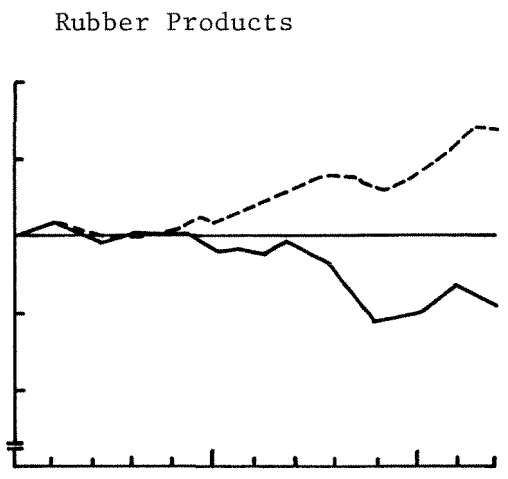
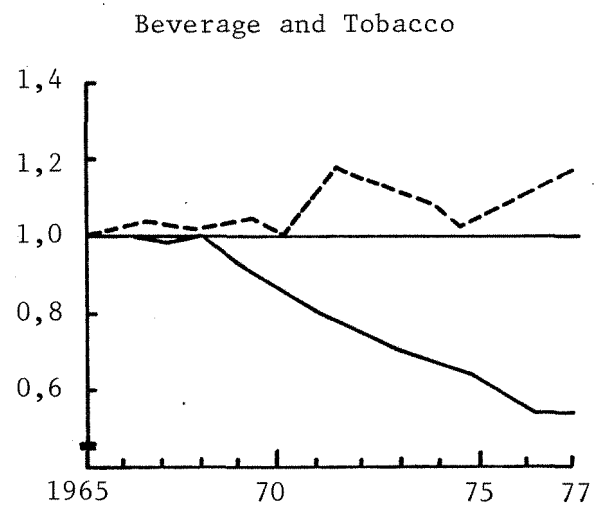


Figure 4A Specific use of electricity and oil in manufacturing sectors, 1965-1977.
(1965 = 1). Electricity (---). Oil (—)

Figure 4B Specific use of electricity and oil in manufacturing sectors, 1965-1977.
 (1965 = 1). Electricity (- - -). Oil (-----)



only exception is the chemical industry in which a sharp and more-or-less continuous downward trend is evident. Between 1965 and 1973 we find that specific electricity use increased markedly in 6 of the remaining 11 subsectors. Most of these are industries with relatively low energy intensity. After 1973, however, the electricity/output ratio rose substantially in all 11 industries.

Although this appears to suggest a tendency towards increasing electricity intensity, it may also to some extent be a reflection of under capacity utilisation. As noted earlier, the price of electric power relative to oil products fell somewhat during the 60's and considerably after 1973. The general trend towards increasing electricity and decreasing oil use seems to reflect these relative price changes.

4 Energy prices in manufacturing subsectors

In section 1 we traced the development of average fuel and electricity prices to industrial consumers and the aggregate energy price index in manufacturing. The individual subsectors of the manufacturing industry have, however, faced slightly different price trends. As we have seen, the prices of individual energy forms have not necessarily followed the same paths. After 1965, the prices of electricity and motor fuels, for example, increased less rapidly than coal and considerably less than fuel oil. Thus, the development of the 'price of energy' for a particular industry depends largely on the composition of its energy consumption. As the relative use of electricity and fuels varies greatly among industries, we would expect significant differences in aggregate energy price development.

In the following, we shall investigate energy prices in manufacturing subsectors. These are calculated from yearly data on expenditures for and quantities of energy consumed in the various industries. The energy forms included are electricity, motor fuels, fuel oils, gas oil, coal, coke and wood fuels. Electricity and fuels produced and used at the same plant are excluded from the data.

The effect of the omission of these fuels on aggregate energy prices is most serious in the pulp and paper industry, where internal supplies of wood fuels constitute an important energy source.

The average annual percentage change in the energy price index, and the prices of petroleum products, electricity and heavy fuel oil for the period 1968-1975 are shown in Table 2.

Aggregate energy price indices for each sector are calculated as cost-share weighted average of the implicit prices of electricity, petroleum products and solid fuels. On average we find that the price of energy increased at a rate of 10 % per annum during this period. There are, however, marked variations among the subsectors. Energy prices rose more substantially in the energy-intensive industries, at an average rate of 12.4 % per annum as compared to less than 9 % in other sectors. Of the high-energy sectors, the chemical industry has experienced the smallest price-rise, mainly as a result of the large proportion of electricity usage in this sector.

The differences in the development of energy prices are explained not only by differences in electricity intensity, but also by the composition of fuel usage. This can be seen by comparing the price development of petroleum products for the subsectors. Again, we find that prices increased more rapidly in the energy intensive sectors than in others, 18 % per year as opposed to 13 %. This discrepancy is explained mainly by the relatively high proportion of motor fuels in the less energy-intensive industries. As seen in section 2, the price of these fuels increased considerably less than that of heavy fuel oil.

Implicit prices for heavy fuel oil (No 4) in the different industries for the years 1968 and 1975 are also shown in the table. We find considerable differences in average prices, particularly for 1968. The lowest prices are noted for the largest consumers, the energy intensive industries. On average we find a price reduction of 14 %. In conjunction with the dramatic oil price increases of

Table 2 Energy prices in manufacturing subsectors and average annual percentage change 1968-1975

	Energy price index	Petroleum products ^a	Heavy fuel oil ^a			Electricity		
	%	%	Price Kr/m ³		% change	Price öre/kWh		% change
	<u>68</u>	<u>75</u>	<u>68</u>	<u>75</u>		<u>68</u>	<u>75</u>	
<u>Energy-Intensive sectors</u>								
Pulp and paper	12.3 ^b	20.1 ^b	80	333	22.7	3.0	5.8	9.9
Chemicals	10.8	16.3	84	340	22.2	3.4	6.1	8.4
Non-metallic mineral products	13.1	17.0	88	348	21.7	5.4	9.0	7.6
Primary metals	13.3	19.8	88	344	21.6	3.3	5.9	8.7
Average	12.4	18.3	85	341	22.1	3.8	6.7	8.7
<u>Other sectors</u>								
Sheltered food	8.5	9.4				6.7	10.7	6.9
Import-competing food	9.5	13.4	97	348	20.1	7.6	11.3	5.8
Beverages and tobacco	7.9	9.1	107	359	18.9	7.8	10.9	4.9
Textiles	10.0	15.3	95	364	21.2	7.8	11.9	6.2
Wood products	101	337	18.7	7.7	11.3	5.6
Printing	7.3	11.0	107	396	20.6	8.7	12.1	4.7
Rubber products	10.4	16.8	95	343	20.2	6.4	10.2	6.7
Engineering	8.4	13.9	94	363	21.2	7.0	10.2	5.5
Shipbuilding	8.0	15.4	94	360	21.1	7.5	10.3	4.6
Average	8.8	13.0	99	359	20.3	7.5	11.0	5.7

a Excluding energy tax.

b Includes wood product industry.

1973-74 and thereafter the prices tend to converge. In 1975 we find the large consumers still paying less, but only 5 % less on average.

The differences in prices reflect price reductions to large consumers, for example, in the form of long-term contracts; or even the possibility for these consumers to purchase oil when prices are most advantageous. The rising uncertainties on the oil market since the 1st major OPEC crude oil price increase ought to have led to shortened contract lengths as well as reduced the significance of rebates to large consumers. In any event, the result appears to have been that large consumers have experienced a somewhat higher than average percentage price increase.

Finally, average electricity prices for 1968 and 1975 and the average annual percentage change during this period are given in the last three columns of the table. For both years we find that electricity prices vary considerably amongst industries. These price variations are primarily explained by differences in supply voltage. Also, because electricity tariffs are composed of a fixed charge and a kWh charge, the average price per kWh decreases with increasing consumption.

Energy intensive industries such as primary metals, pulp and paper etc. generally purchase electric power at 130 kV, whereas smaller consumers - printing, textiles and most less energy-intensive industries - contract at a lower voltage, i.e. 6-40 kV. In 1968, the average price for a large industrial consumer (130 kV, 10 000 kW, 5 000 hrs) was about 4 öre/kWh and for a small consumer (10 kV, 500 kW, 3 000 hrs) was slightly less than twice this.⁹

We note also that average electricity prices increased more rapidly for energy-intensive sectors than for others. This, too, corresponds quite well to the average annual price changes 1968-75 of 9.6 % and 6.1 % for the large and small industrial consumers above. Changes in electricity tariffs and the introduction of the fuel price supplement have led to a price increase of approx-

imately 4 öre/kWh for both types of consumer during this period. The result has thus been a proportionally higher price increase for large consumers with lower average prices.

In conclusion, it appears evident that the energy price increases of the mid 70's have been a double burden for energy-intensive industries. The impact on production costs has been greater for these industries not only because of their relatively high energy dependence, but also because of a diminishing price advantage on energy markets.

NOTES

- ¹ I.e. petroleum refining is excluded from ISIC division 3.
- ² The energy price index is calculated as a cost-share weighted average of the prices of electricity, oil products and solid fuels.
- ³ Östblom (1980, 1981).
- ⁴ Sohlman, Stillerud and Östblom (1982).
- ⁵ Besides manufacturing, this includes mining, agriculture, fishing, forestry, transport and communication, commerce, utilities, private services and construction.
- ⁶ Calculated from the figures given in Sohlman et al.
- ⁷ Only the sector miscellaneous manufacturing is excluded.
- ⁸ Electricity and fuels produced and used at the same plant are not included.
- ⁹ Vattenfall.

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