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Abstract

This study examines the historical relation between carbon dioxide emission and output growth in the Swedish pulp and paperindustry 1973-2006. We find that the industry achieved an 80 per cent reduction in CO2 emission. Foremost energy substitution but also efficiently improvement contributed to the reduction. Growing prices of fossil fuel due to market price change and taxes and subvention, explains most of the efficiency improvements and substitution. Taxes on energy explain 40 per cent of the total reduction in CO_2 intensity. Most of the reduction took place before the implementation of active climate policy in 1991.

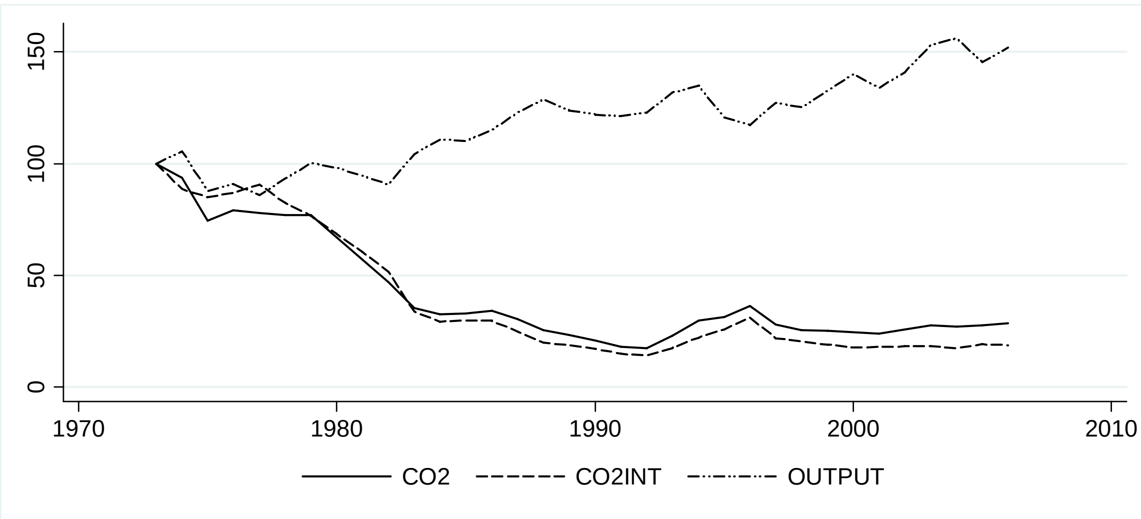
Keyworks: Sweden, Climate policy, economic growth, carbon dioxide reduction, carbon tax, paper and plant industry

Introduction

Sweden introduced an active climate policy during the early 1990s, with the CO2 tax as a main policy tool. Furthermore, Sweden ratified the Kyoto protocol in 2002 and became part of the EU-ETS in 2005 and is recognised as a country with high ambitions in the filed of climate policy. Especially the carbon dioxide tax has been advocated as the main explanation for the decupling between emissions and GDP (Johansson, 2001; Ds 1997:26**;** Ds 2005:55**;** ER 2006:06, Scrimgeour et al 2005) during the past 15 years or so. Still, it is worth noticing that the Swedish carbon dioxide emissions were reduced by approximately 40 percent between the early 1970s and the late 1980s. The greatest achievements took place within the manufacturing industry, the energy sector and dwellings/housing. Explaining the emissions cuts before the era of active climate policy may therefore usefully inform contemporary environmental policy makers and planners.

The manufacturing industry cut its emissions of CO2 emissions by approximately the same amount as the energy and housing sectors respectively. The largest cuts within the manufacturing industry took place within energy intense industries foremost the pulp and paper, chemicals and basic metal industries. Of these, the pulp and paper industry accounted to the largest reduction of CO^2 emissions, 80 percent, during the period 1973 to 1990, while at the same time increasing the output by 18 per cent (see figure 1).

Figure 1. Output and CO^2 emission in the Swedish pulp and paper industry 1973-2006



Sources: Own estimates based on Swedish Official Manufacturing Industry Statistics (*SOS Industrin*) and the Swedish National Accounts.

Given these developments, the overall purpose of this paper is to explain the reduction of CO2 emission (consumption of fossil fuels) in Swedish pulp and paper industry over the period 1973 to 2006. The period is motivated by the 1973 OPEC I crises. Further more, the period is also motivated since the incitements and strategies leading to reduced fossil fuel consumption during the period are not fully explored in a long time perspective. A study by Liaskas et al (2000), which covers the

Swedish manufacturing industry between 1973 to 1993 points at comparatively large effects on CO2 emissions from improved energy efficiency and fuel mix, while the effects due to changes in the output structure, however small, tended to increase emissions. Also Torvanger (1991) included Swedish manufacturing industry in a comparison with the developments of CO2 intensities in manufacturing for nine OECD countries for the period 1973 to 1987. The results are, however, not fully compatible with contemporary official carbon reporting since Torvanger estimated CO2 emissions counted gross, while contemporary praxis is to assume zero net CO2 emissions for bio fuels. Neither of these studies addresses the determinants of CO2 emissions in terms of relative prices or other strategies.

Additionally, we recognise that the pulp and paper industry has been given attention in the contemporary and global climate policy debate. The IPPC have emphasised the importance of development and transfer of clean technologies in this sector (IPPC 2007). As the Swedish pulp and paper industry is noticed by the IEA as the most CO2 efficient in the world (IEA, 2007) there might be important experiences from the Swedish case to be transferred. Furthermore, and in comparison with the energy and residential sectors, we notice that the latter were heavily affected by political decisions, like the nuclear power program and subsidies directed to households for changing space heating systems. Since contemporary climate policy is often based on general economic policy tools it is in our view more informative to focus a competitive sector rather than the opposite[1]. Since contemporary climate policy often is based on economic policy tools such as taxes and/or tradable permits, we will focus price induced substitution and technical change. We will therefore investigate the reduced emissions in terms of substitution and technical change (see for instance Gillingham et al 2007; Popp, 2002; Newell et al 1999; Kumar and Mangi 2009). Finally, we will decompose the effects on CO2 emissions on price changes induced by market forces and price changes induced by energy taxation and subsidies.

The organization of the study is the following: The next section provides an outline of Swedish energy policy since the 1970s, thus providing the institutional context. Third section provides data and methodology applied in the study. The fourth and fifth section provides the result while the last section concludes.

Institutional background

Prior to the 1970s energy policy was not an independent policy field in Sweden. Energy issues were instead an integrated part of the industry policy with the basic goal to ensure cheap energy for the economy along with a favourable effect on the balance of trade and energy security in the case of future military conflicts. In 1956 an official investigation concluded that nuclear power based on domestic uranium was the preferred strategy to achieve this, (SOU 1956: 46). It was further concluded that steam generated electricity, in other words relatively capital extensive oil and coal plants, would first need to expand before nuclear power would be an option. In the wake of the 1973 oil crisis, and

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[1] Notice that the energy sector was not operating on an international market during this period.

subsequent deterioration of Sweden's terms-of-trade, energy policy became one of the most expanding policy sectors in Sweden (Vedung, 1982). Reduced dependency on imported (fossil) fuels in order to improve the balance of trade increasingly appeared as a main objective. Therefore, the further development of domestic (renewable) energy sources and the expansion of the nuclear power became cornerstones in the new energy policy. Worth mentioning is that the 1973 oil crisis happened to coincide with the starting of the first commercial nuclear reactor. Furthermore, energy conservation became an additional goal, and both administrative, market based and informative policy tools were used for this purpose. The basic outlines of this policy remained until the early 1990s, when climate policy that the reduction of CO2 emissions became an explicit goal in the Swedish energy and environmental policy.

Energy taxes were implemented for fiscal reasons in the 1950s (with the electricity tax in 1951 and the general energy tax in 1957). These taxes were raised in the 1970s as a mean to reduce oil consumption in the manufacturing industry and in the household sectors. This policy was reinforced by even higher taxes in the 1980s in order to speed-up the substitution from oil. Although the oil consumption was reduced, Andersson and Lindmark (2009) find that the government income/revenue increased as share of GDP (2.5 % in 1980 and 3.7 % in 1985). In addition to the substitution objective, we find also find support for energy saving targets.

During the early 1990s, the taxes on energy underwent significant changes. In 1990/91 VAT was introduced on all energy sources and was based on the price after adding the selective purchase tax. Furthermore, a carbon tax was implemented at 250 SEK per ton CO_2 in 1991. To balance the increased pressure of taxation due to the VAT and CO2 tax, the energy tax on electricity was reduced by 30 per cent while the energy tax on petrol was reduced by 50 per cent. An important consequence of the reforms was that the tax pressure on the households increased significantly, while the energy tax pressure on manufacturing decreased from 3.6 billion SEK in 1992 to 0.5 billion SEK in 1993. Since the total energy related tax revenue was unaffected between 1992 and 1993, the distribution of taxes had changed significantly.

In 1974, the Swedish government initiated the first program for subsides for energy saving measures in the Swedish industry (Government bill, 1974:69, decree 1975:422, reprinted 1977:388) with the purpose to improve industrial processes and constructions of prototype and demonstration plants (PoD). In 1981 the Oil Substitution Fund was established and provided funding for PoD facilities, oil substitution and small waterpower facilities between 1981 and 1986. Along with taxes also subsides and advantageous loans for investments in energy saving and oil substitution were at work. However the subsidies were modest compared to taxes. During the 1970s subsidies only amounted to 10 per cent of energy taxes revenue.

Specific policy measures to regulate energy use were also included in the Building Act, which prescribed specific conditions for building new or reconstructing old plants. Generally however, there was a tendency towards market based and informative policy measures at the beginning of the 1980s, where taxes on energy started to become a more important policy tool (SOU 1995:139, p 341). Simultaneously environmental consideration started to gain importance in energy policy during the 1980s, where the reduced coal became an additional policy goal, however, not an important fuel in the pulp and paper industry.

Method and data

To account for the impact policy measures and market price change on CO_2 emissions in the Swedish pulp and paper industry, the analysis is divided into two parts. In the first part we decompose the impact of substitution, efficiency and structural change on CO2 intensity. In the second part we test for the effect of market price, tax, subsides and other policy measures on substitution, efficiency and structural change.

To account for the decoupling between industry growth and carbon dioxide, the effect of energy substitution, energy efficiency and structural change is separated. For decomposing intensity changes, we use a shift-share decomposition method, which allows us to account for effects due to improvements within sectors and effects of structural change. The CO2 intensity, denoted COI, is defined as industry CO2 emissions/industry value added. Following the methodology suggested by Fagerberg (2000) and Pender (2003), equation (1) shows how we decompose the aggregate COI into three separate effects:

$$\Delta COI_T = \frac{\overbrace{\sum_{i=1}^{n} \Delta COI_i \cdot VAS_{i,b}}^{(1)\ WE} + \overbrace{\sum_{i=1}^{n} COI_{i,b} \cdot \Delta VAS}^{(2)\ SE} \overbrace{\sum_{i=1}^{n} \Delta COI_i \cdot \Delta VAS_i}^{(3)\ DE}}{COI_{T,b}} \qquad 1.$$

where COI is CO2 intensity; b is the base year; Δ denote the change between the base year and comparison year; VASi is the share of industry i of total value added (GDP). T denote ∑ over industries i;

The within effect (WE) measures the improvements that have taken place within an industry under the counterfactual constrain that no structural shifts have taken place. In other words; each industry has maintained its value added share as in the base year. The within effect may be caused by improved energy saving or substitution from high CO2 intense energy to low CO2 intense energy, but may also arise from such effects as improved output quality. The within effect is decomposed on energy intensity and energy carbon intensity according in eq 2.

The static shift effect (SE) is the sum of relative changes of value added across industries between the base year and the comparison year, where value added is weighted with the COI in the base year. The static effect is accordingly resulting from changes in the production structure. The static effect may contribute to an improved aggregated COI if low COI industries expand and high COI industries stagnate (3) The Dynamic shift effect (DE), is calculated as the sum of changes in VAS and COI. The dynamic effect will have an impact on the aggregated COI if e.g. that expanding VAS also improve COI. The combined shift effect (SE and DE) is a measure of how structural change affect COI.

In equation 2, the within effect is decomposed into two separate effects,

$$\Delta IE_T = \sum_{i=1}^{n} (\Delta EI_i + \Delta ECI_i) \cdot VAS_{ib} \qquad 2.$$

where IE is the within effect; b, base year, Δ change between base and final year; T denote, ∑ over industries i; VASi is the share of industry i of total value added. EI is energy intensity and ECI is the CO2 per unit of energy.

EI is calculated as follows from equation 3,

$$\Delta EI_i = \frac{\Delta E_i}{\Delta VA_i} \qquad 3.$$

where E is energy and VA is value added. A reduction in energy intensity arises as a result of an improved relation between industry output and energy use. The latter processes is denoted energy saving, while the opposite (declining EI) is denoted energy squandering.

ECI is calculated according to equation 4,

$$\Delta ECI_i = \frac{\Delta CO2_i}{\Delta E_i} \qquad 4.$$

where CO2 is carbon dioxide and E is energy. A reduction in the COI of energy may occur due to a shift between energy carriers with different carbon intensities, such as a shift from oil to electricity. The latter process is denoted energy conversion.

To test for the effect of market price, tax, subsides and other policy measures on substitution, efficiency, a regression method is applied. To examine the factors affecting energy substitution, we test the elasticity of changes in relative price across energy carriers. The model is based on the reasoning that firms will substitute from energy carriers with increasing relative prices to energy carriers with decreasing relative prices, given the substitution elasticity between the energy carriers. The relative price is based on the price of oil in relation to a weighed index of external and internal biofuel, electricity. All prices are the market prices, except internal biofuel where we use investment prices. The reason is that a shift from oil into biofuel comes with an investment cost. The regression model is based on the following equation:

$$ECI_{ts} = \beta_0 + \beta_1 RP_{ts} + \beta_2 D_{ts} + \varepsilon_{ts} \qquad 5.$$

Where energy composition denotes the share of fossil fuels in relation to other non-fossil fuels, while the right hand side denotes the relative price between fossil and non-fossil fuels at time t in sector i and the sector dummy. The coefficient estimates can be utilized to account for the effect of taxes and subventions, by excluding tax and or subvention from the market price index.

In order to test for the factors effecting energy intensity, a model based on the priced induced hypothesis, is estimated. The model is based on the assumption that firms with higher energy prices have a more to save on reducing the energy intensity by improving energy efficiently. Energy price is measured as the weighted energy price for respective sector and year. The price for each energy carrier is weighted by its input share. The model is based on the following equation:

$$EI_{ts} = \beta_0 + \beta_1 EP_{ts} + \beta_2 D_{ts} + \varepsilon_{ts} \qquad 6.$$

Where EIts is the energy intensity in sector i at time t, while the right hand side denotes the weighed energy price and the sector dummy. The coefficient estimates can be utilized to account for the effect of taxes and subventions, by excluding tax and or subvention from the market price index.

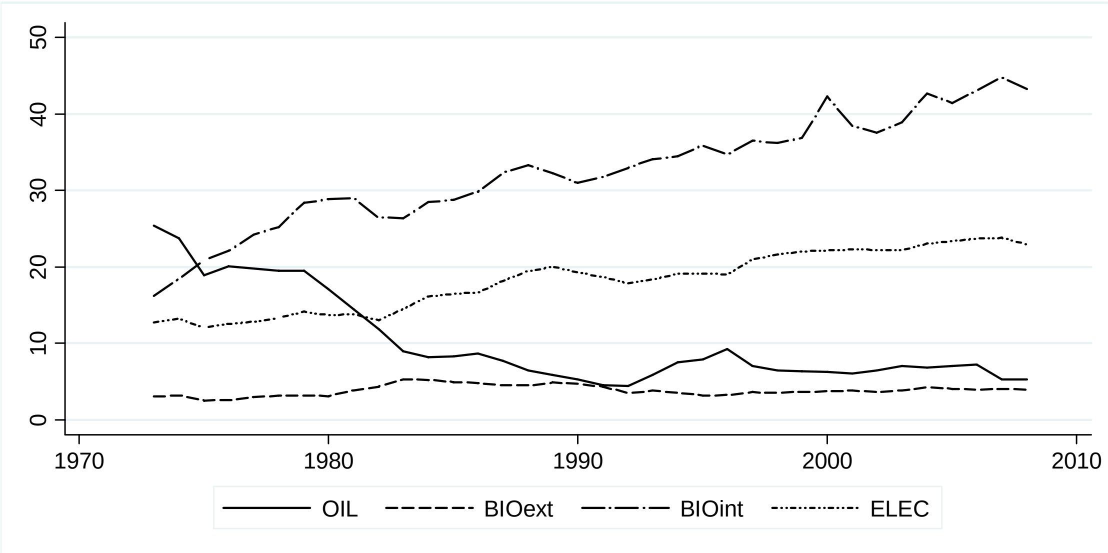
The shift effect (dynamic and static) derived from the accounting method is not tested in a regression method. The analysis is limited to a discussion of the potential effects of administrative policy measures and market changes.

The analysis is based on data derived from Official Statistics of Sweden manufacturing (SOS Industrin) and Swedish Statistical Yearbook of Forestry (SOS Skogsstatistisk årsbok) during the period 1970-2008. Data include information of input of energy, services, capital, labour and output of paper and pulp products. Volume, value and prices of input and output variables are at hand for the input-output variables. We have based calculated the CO2 emission from the input of oil, coal and gas and emission coefficient from Statistics Sweden. The pulp and paper industry is divided into five sectors: 1. Mechanical pulp, 2. Chemical pulp, sulphate, 3. Chemical pulp sulphite, 4. Paper and 5. Packing. All five sectors have different characterises on both input and output side.

Efficiency performance and substitution

The energy mix in the Swedish pulp and paper industry changed substantially after the first OPEC crises in 1973. Oil inputs were substituted by non-fossil fuels on a massive scale during the 1970s and 1980s. The abundance of bio fuels was put into more intense use in the pulp industry. The internal bio fuel (BIOint) increased significantly and the external bio fuel (BIOext) remained fairly constant. Foremost the sulphate industry made use of wood waste to increase the share of internal fuels in the energy mix. As a result the industry managed to reduce the oil input by up till 80 percent. Between 1973 and 2006 the oil input was reduced by 20 000 Twh, while the input of internal fuels (BIOint) increased by 30 000 TwH. It serves to be noticed that oil was not substituted with bio fuels in the same extent over the full period. Most of the substitution took place in the period 1973 to 1984. The energy mix in the pulp and paper industry is shown in figure 2.

Figure 2. Energy mix in pulp and paper industry (1000 TwH) 1973-2006



Source: Swedish Official Manufacturing Industry Statistics (*SOS Industri*)

The change in energy mix also invoked a more intense use of electricity (ELEC). In contrast with the growth of internal bio fuels, the input of electricity increased not until the early 1980s. The growing demand was concentrated to the paper and mechanical pulp industry. It is worthy of notice that the latter industries could not make an intense use of waste wood to increase the input share of internal bio fuels.

To develop measures to substitute from oil and to save on total energy input, we recognise that not only firm or plant specific programs was put into place. A seemingly important part at the time was the growing cooperation between firms on environmental and energy related issues (Bergquist & Söderholm, 2010). As an immediate response to the oil crises, a number of committees were put into place to evaluate measures to accomplish the overriding goals of reduced oil and cut energy costs. Furthermore, the cooperation is also seen in areas such as training of the personnel and certification, implying unified standards for controlling industrial processes (Robertsson, 1975, Svensk Papperstidning 1975). The measures taken could potentially have facilitated the changing of the energy mix, as argued in the industry magazine in the mid 1970s

After the initial steps in the early 1970s, a more intense cooperation on R&D program was put into place in 1975 with the main objective to cut energy costs. A R&D program was initiated by the energy committee of the Swedish Wood-pulp and Paper Association (Svenska Cellulosa- och Pappersbruksföreningen, SCPF) to inventory the need and possibilities to save energy and substitute oil. In order to substitute from the expensive oil, a major concern was to invest in technologies that could increase the input of cheaper energy carriers. The program concluded that the most cost efficient measure was to develop new technologies on the 'heating side' in the production process. This included the more efficient use of internal fuels such as black liquor, bark and chips in sulphate pulp plants. Also increased 'heat exchange' and heat recovery along with a more effective drying of bark and pulp were considered to have a strong potential (Wohlfahrt, 1977, Regestad, 1977, Sundblad, 1977). In retrospect is seems to hold that inter-firm collaboration on developments in new technologies facilitated the substation from oil to internal bio-fuels.

Growing environmental concerns (1969 Environmental Protection Act) put pressures on firms to reduce emission/pollution. Plants that were not able to meet these environmental demands were either rebuilt or forced to close down (Skogsindustriernas samarbetsutskott, 1971b, p 320). A substantial part of the emissions stemmed from the sulphite pulp industry. Sulphite plants were therefore partly closed down in order to address problems associated with discharges. Calcium based sulphite mills, which were most common, had many environmental disadvantages as regards of discharges of BOD, lignin, gases and dust that demanded radical external purification measures. In turn, sulphate plants that managed to make more intense use black liquor for energy generation (combined heat and power, CHP) and recover chemicals became the basis for business expansion. Even sulphate plants were forced to improve the exchange of pulp wood, implying that less wood was wasted in the pulp making process, due to environmental reasons. Especially fibre waste, which damaged coastal waters and eco-systems, had to be taken care of at the mills by process alterations (Skogsindustriernas samarbetsutskott, 1971a, p 432). All in all, increased heat-exchange from bark combustion, more efficient energy generation of black liquor, bark and chips in the sulphate pulp industry, increased use of electricity in mechanical pulp plants, are important strategies to reduce the oil consumption. In 1982, it was also concluded that a considerable drop in oil consumption between 1979 and 1981 was due to less need for oil in generating combined heat and power (CHP) (Axelsson, 1982). Furthermore, as integrated facilities became more common, the fuel consumption in the paper production could be reduced by using waste heat from the pulp plant (Norrström, 1997). Accordingly, substituting oil and avoiding waste fibre emissions could partly be solved by increasing the use of internal bio fuels. As sulphite plants consumed more oil, changing output share from sulphite to sulphate, mechanical and paper reduced the aggregated oil consumption and CO_2 emissions.

The pressure of environmental issues put on the industry together with rising oil prices, was indeed met by new technologies and structural changes favouring larger and integrated plants which served to improve productivity, increase energy efficiency and cut energy costs. It is therefore reasonable to assume that both economies of scale and the development of new technologies affected the total factor productivity, and not only energy and environmental performance. Energy productivity (or efficiency) should therefore be related to measures of total factor productivity.

Energy productivity may be seen from two distinctive perspectives. First, it may relate energy inputs in physical units to output. This measure is however not well suited to analyses of firm behaviour, since the energy carriers are weighted strictly according to their heat content and not to their economic qualities, i.e. the price per unit of energy, which may vary across energy carriers. The energy productivity in terms of physical energy inputs do therefore not correspond to the real cost reductions experienced by the company. It is therefore in our context instead more appropriate to relate output to the economic energy volume. In the latter it is the cost share of energy carriers as a percentage of the total energy cost that are used as weights. Formally we write for the thermal (physical) energy volume:

$$W_P = \sum W_{1..n} \times C_{1...n}$$

Where W_n is energy carrier n expressed in thermal units (such as Joule) or volume units and C_n is the energy conversion factor for energy carrier n (i.e. Joule per ton or cubic metre). For the economic energy volume we write:

$$W_E = \sum W_{1...n} \times C_{1...n} \times a_{1...n}$$

Where a_n is the cost share of total energy costs.

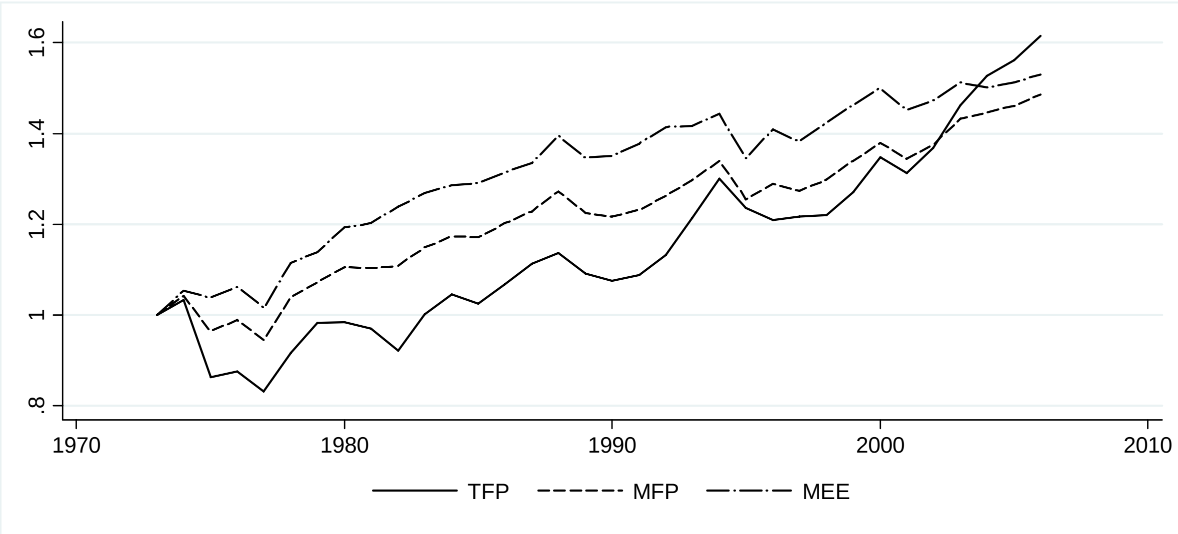
It is worth noticing that the physical energy efficiency was roughly constant over the period while the economic energy efficiency improved from the late 1970s. We may accordingly conclude that measures taken within the industry aiming for substitution implied real cost reductions while thermal energy efficiency did not improve. From the perspective of the firm, improved energy efficiency is only motivated if it reduces total costs. Energy constituted a smaller cost share (around 10 percent) than both capital and labour (roughly 15 percent each) during most of the period and was far less important than materials (roughly 50 percent).

It is possible that the improved economic energy efficiency undermined the material input efficiency. As previously shown internal bio fuels substituted for oil. At least in theory it could be assumed that the increased bio fuel inputs at the same time reduced the amount of available fibre for the making of cellulose pulp. It is also evident that the pulp wood productivity fell slightly during the period. This deterioration was, however, not large enough to be explained by the increased use of internal bio fuels. It is furthermore worth to notice that even though pulp wood productivity to some extent caused by increased combustion of bio fuels it may still have made sense to the industry if the combined energy and material inputs experienced productivity growth.

In order to evaluate the importance of improved energy efficiency we will therefore compare the productivity of (i) the combined energy and material inputs material and energy productivity (MEE), (ii) Total Factor Productivity (TFP) measuring the combined labour and capital inputs and (iii) Multi Factor Productivity (MFP) measuring the productivity of all inputs.

The productivity performance in the pulp and paper industry is shown in figure 3. Over the full period 1973 to 2006 the productivity increased by close to 1.3 per cent annually on average across the three measures. The productivity growth has not however been constant or similar across the different measures. After the oil price crises in 1973, output fell dramatically causing excess capacity and reduced total and multifactor productivity. The energy and material productivity remained fairly constant due to a rapid adjustment to the lower output measures. As the market improved and investment in new technology came into place, the productivity performance improved rapidly. During the period 1977 and 1988 the productivity increased by close to 3 per cent annually. In the following period, the productivity growth was somewhat slower and fluctuated more between years and measures applied. In both cases however improvement in energy efficiency did not take place at the expense of any other of the combined input efficiencies. The growth in energy and material productivity took place at the same time as productivity on labour and capital improved. The investment in new technology shows that firms not only cut down on the input of oil, but also on energy and material.

Figure 3. Productivity performance in the pulp and paper industry, by total factor productivity (TFP), multifactor productivity (MFP) and material and energy productivity (MEE), 1973-2006.



Source: Calculations based on Swedish Official Manufacturing Industry Statistics (*SOS Industri*)

Reduction of CO_2 emissions was the combined effect of substitution and reduced energy intensity. Increasing oil prices, due to taxes and world market prices, may help to explain how firms substituted and saved on energy. To account for this potential price effect, we have tested the elasticity of changes in relative price across energy carriers on energy mix.

Table 1 shows the result of model 1, where the share of oil is the dependent variable (see details in equation 5). As is evident from the R^2 value (0.9), the regression seems to be a good fit for the data under investigation. Consistent with the expectations, the relative price of oil (Price) have a significant and negative effect on the oil input. The estimated price coefficient shows that a 10 per cent increase of the price gives an reduction of 2.2 in the oil share. Among the sectors, it can be established that sulphate consumes less oil compared with paper pacing and sulphite and paper.

Table 1. Regression estimate of relative price effect on share of oil in total energy 1970-1985

Variable	Coefficient	Std. Err.	P-value
Price	-0.228	0.020	0.000
D1	(dropped)	0.000	0.000
D2	-0.176	0.028	0.000
D 3	0.204	0.028	0.000
D 4	0.189	0.028	0.000
D 5	0.402	0.028	0.000
_cons	0.459	0.024	0.000

Notice: D1 Mechanical pulp =1, D2 Chemical pulp, sulphate =1 D3 Chemical pulp sulphite=1, D4 Paper = 1, D5 Paper, packing =1. Adj R-squared = 0.9040. Number of observations = 80

In order to fully capture the reduction of oil consumption and CO2 emissions, it is however necessary to estimate improved energy intensity resulting from price induced technical change. In order to test for the factors effecting energy intensity, a model based on the priced induced hypothesis have been estimated (see equation 6).

Table 2 shows the results of model 2. The model gives a fairly god fit for the data under investigation as indicated by the high R^2 value (0.94). Consistent with the expectations, the relative price of oil (Price) have a significant and negative effect on the oil input. The estimated elasticity of price shows that a 10 per cent increase in price gives 2 per cent reduction of energy intensity.

Table 2. Regression estimate of price induced effect on energy intensity

Variable	Coefficient	Std. Err.	P-value
Price	-0,208	0,027	0,000
D1	0,015	0,060	0,803
D 2	0,780	0,069	0,000
D3	(dropped)	0,000	0,000
D 4	-0,646	0,057	0,000
Constant	-4,099	0,078	0,000

Notice: D1 Mechanical pulp =1, D2 Chemical pulp, sulphate =1 D3 Chemical pulp sulphite=1, D4 Paper = 1. Adj R-squared= 0.9373. Number of observations = 64

To account for the impact of change in substitution and improvement in energy efficiency, we have applied a decomposition method which allows us to separate the contribution to CO2 reduction between energy substitution, energy efficiency and structural change (see details in equation 1, 2, 3 and 4). The structural component is motivated by the changes in output share between the sub sectors pulp and paper industries during the period.

Table 3 shows the decomposition of the CO_2 intensity in the pulp and paper industry and reveals that energy substitution explains the lion's part of the reduction supplemented by energy efficiency. Structural changes had a limited effect on the CO_2 intensity.

The CO2 intensity was reduced by 71 per cent during the period 1973 to 1985. Most of the reduction was achieved by substituting form oil to internal fuels (62 %), while energy efficiency contributed with 9 per cent. The impact of structural change within the pulp and paper industry contributed to an increase in CO2 emission with 1 per cent. The effect is explained by the growth of paper relative to pulp. Although the decline in sulphite industry reduced the emissions in pulp, growth of paper industries counteracted this effect.

Table 3. Decomposition of CO_2 intensity by components 1973-1985.

	Component	Total contribution	Market price	Tax
1	Energy efficiency	-9%	-7%	-2%
2	Energy substitution	-62%	-34%	-28%
3	Shift effect	1%		
1 – 2	Total	-71%	-41%	-30%

Applying the parameters of model 1 and 2 allows us to further decompose the energy efficiency and oil substitution on effects caused by market prices and subsidies and taxes respectively. This is done by excluding tax and or subvention from the market price index. As shown in table 3, the oil and energy taxes explain slightly less than half of the reduced CO2 intensity, with a higher effect on substitution than on efficiency both in absolute and relative terms. Although the active climate policy was not at hand, the energy policy had an unintended but still significant impact on the CO2 emissions in the Swedish pulp and paper industry during the 1970s and 1980s.

Conclusion

This study shows that the Swedish pulp and paper industry achieved an 80 per cent reduction of CO2 emissions. The study shows that the energy mix changed substantially in the wake of the oil price crises during the 1970s. The substitution from oil to other fuel demanded investment in new technology embedded in the real capital investments. These investments also improved the energy and material productivity as well as total factor productivity. The growing energy productivity also helps to explain the reduction of CO2 emissions. By decomposing the change in CO2 intensity (CO2/output), we can establish that 9 per cent was due to improved efficiency and 62 per cent was due to substitution. Changing composition in the pulp and paper industry structure explain a less significant part. The substitution between energy carriers was a matter of price. Higher prices of oil, due to the combined effect of market prices and taxes, help to explain most of the efficiency and substitution. Market price changes explain 60 per cent of the reduction and taxes 40 per cent of the total reduction of CO_2 intensity. Most of the reduction took place before the implementation of active climate policy in 1991.

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