Swedish Industry and Kyoto*

An Assessment of the Effects of the European CO_2 Emission Permit Trading System

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Abstract

We assess the effects on Swedish industry input and output demands of different climate policy scenarios connected to energy policy induced by the Kyoto protocol. A unique data set containing firm level data on outputs and inputs during the years 1991 – 2001 is used to estimate a factor demand model, which is then simulated for different policy scenarios. Sector specific estimation suggests that the proposed quadratic profit function specification exhibit properties and robustness that are consistent with economic theory; that is, all own-price elasticities are negative and all output elasticities are positive. Furthermore, the elasticities show that the input demands are, in most cases, relatively inelastic. Simulation of the model for 6 different policy scenarios reveal that the effects on Swedish base industry of a EU level permit trade system is dependent on (i) removal or no removal of current CO_2 tax, (ii) the established price of permits, and (iii) what will happen to the electricity price. Our analysis show that changes in electricity price may be more important than the price of permits for some sectors. +

Keywords: CO_2- emissions, factor demand, fossil fuels, tradable permit market

* We acknowledge financial support from The Swedish Institute for Growth Policy Studies (ITPS), and Stiftelsen Riksbankens Jubiléumsfond, Kulturvetenskapliga donationen (The Research Foundation of the Bank of Sweden).

1. Introduction

The objective with this study is to evaluate the potential effects on CO_2 emissions as well as the effects on the Swedish industry of the newly started system with CO_2 emission trading within the EU (ETS). In order to achieve our objective we develop an econometric partial equilibrium model for the Swedish industrial sector. The data set we use is a panel data set covering all firms within the industrial sector for the time period 1990-2001. The employed methodology implies that we obtain estimates of supply as well as demand elasticities. These elasticities are then used in a second step to simulate a system of emission trading under various assumptions.

Already here it should be emphasized that the model is embedded within a number of assumptions that will have effects on the results. These assumptions may be criticized for various reasons, and we will discuss some of them in the concluding section.

The background to our study can be traced back to the Kyoto protocol article concerning flexible mechanisms in greenhouse gas policies. According to this article one of the options available to fulfill the obligations within the protocol is to make use of emission trading among the Annex I countries. As of January 1, 2005 such an Emission Trading Scheme (ETS) has been launched within the European Union. During the first trading period, 2005 to 2007, the ETS covers only CO2 emissions from large emitters in the power and heat generation industry, and in selected energy intensive industrial sectors such as combustion plants, oil refineries, coke ovens, iron and steel plants, and factories making cement, glass, lime, bricks, ceramics, pulp and paper. A size threshold based on production capacity or output determines which plants in these sectors are included in the scheme. Within this first phase more than 12 000 installations in the 25 Member States are covered, accounting for approximately 45 % of the EU's total CO2 emissions. Due to the fact that the Swedish industry is relative energy intensive it is of interest, for at least two reasons, to study the effects on the Swedish industry. Firstly, the ETS will imply an explicit price on CO2, which directly affects the industry in the form of a price increase in fuels that emit CO2 (fossil fuels mainly). Secondly, and perhaps more important is the indirect effect on the market for electricity. A probable scenario is that the ETS will impose additional costs on electricity generation in Europe, which in turn may put an upward pressure on the price of electricity. Since the electricity markets have become more integrated this effect may spill over also on the Swedish electricity market in terms of higher prices. This in turn may have significant effects on the Swedish industry. We discuss this further below.

When writing this, in October 2005, the emission trading market has been in operation for 10 months. Trading has been fairly low and the price has peaked at about 30 EURO/ton CO_2, and is right now between 20 and 25 EURO/ton. This is a significantly higher price than the predictions, which were in the range of 5 to 10 EURO/ton CO_2. Also, the electricity price has risen about 30% in the same period (see www.nordpool.com), indicating that the introduction of an emission permit trade market could have impacted the electricity price, but this is not verified in any robust statistical way.

The rest of the paper is structured as follows. The theoretical model underlying the empirical analysis is presented in section 2, whereas the data used and the final empirical specification is presented in section 3. The empirical results along with the resulting price elasticities are presented in section 4. In section 5 we present a number of simulations, given different assumptions about the permit market. Section 6, finally, is devoted to some concluding comments and a discussion.

2. The model

In this section we derive the model that will be used subsequently in the empirical analysis. The model that will be used is based on standard micro economic foundations. More specifically this means that we assume that (a) each individual firm's objective is to maximize profits, (b) each individual firm operates in a competitive environment, (c) each individual firm has a technology that transform inputs to a single output (and a byproduct) in an efficient way. Assumption (a) implies, among other things, that given an output decision, each firm will choose a bundle of inputs that minimize costs. Furthermore assumption (b) implies that all input and output prices are exogenous to the firm. Assumption (c) implies that we can describe the technology with a production function. [1]

More specifically we assume that the firms are using an input vector $\mathbf{x} = [x_1,\ldots, x_n]$ to produce a single output q. Denote the corresponding input price vector as $\mathbf{w} = [w_1,\ldots, w_n]$, and the corresponding output price p. Then, given the assumptions above we can write the profit function for a representative firm as:

$$\pi = pq^* - \mathbf{w}'x^* = \pi(\mathbf{w}, p) \qquad (1)$$

,

where q^* and $\mathbf{x}^*$ are the profit maximizing output and input choice.

The profit function in (1) have the usual properties, i.e. increasing in p, non-increasing in $\mathbf{w}$, homogenous of degree 1 in p and $\mathbf{w}$, and convex in p. Then, by applying Hotelling's lemma to equation (1) we obtain supply and demand as functions of all prices, i.e.:

$$\nabla_p\left[\pi(\mathbf{w}, p)\right] = q(\underset{+}{p}, \underset{-}{\mathbf{w}}) \qquad (2)$$

$$-\nabla_{\mathbf{w}}\left[\pi(\mathbf{w}, p)\right] = \mathbf{x}(\underset{-(?)}{\mathbf{w}}, \underset{+}{p}) \qquad (3)$$

[1] As a by-product to q we also assume that the firm produces a bad output, in this particular case CO_2. However, a reasonable assumption is that CO_2 is produced in a fixed proportion to the input of fuel. Thus, any reduction of CO_2 production can only be accomplished by a reduction in fuel input. An increase of the CO_2 tax, for example, will then affect firm profit through a higher price of fossil fuels. This property of a fixed proportion between q and CO_2 also implies that we do not have to consider the "multi-output" property explicitly.

The sign under the argument denote the expected sign. That is, from theory it follows that the own price supply effect is positive, whereas the effect on supply from an increase in any input price is negative. The negative sign under **w** in equation (3) denotes the own price demand effect, whereas the question mark denote the cross-price effects that can't be signed a priori. The sign of the cross price effect will depend on the technology, whether inputs are gross substitutes or gross complements in production. The reason for using the term gross is that a price change will lead to two different effects. A substitution effect and a scale, or production, effect; the latter due to a change in the profit maximizing level of production, which then may reinforce, or weaken, the pure substitution effect. That is, even if energy and labor are substitutes from a pure technological point of view, the scale effect from an increase in the energy price may lead to a decrease in labor input, i.e., energy and labor may be net substitutes and gross complements at the same time.[2] Which measure to be used, net or gross, is a matter of the objective with the study. In this case, where the main objective is to analyze gross effects on input demand and profits, the gross effects seems most attractive.[3]

It should be noted that equation (1) – (3) are derived under the assumption that all inputs are flexible. Among other things, this implies that the capital stock is allowed to adjust immediately as a result of price changes. Thus the model may be viewed as a long run model.

To summarize; given data on input and output quantities and their respective price, and an explicit form of the profit function, we can estimate equations (2) – (3).

3. Empirical specification and data

In order to obtain an operational form of the demand system we need to specify a functional form for the profit function. The functional form should be chosen in such a way that it puts as few restrictions as possible on the technology, but still is operational from an econometric point of view. Furthermore, for suitable parameter values it should satisfy the properties associated with a profit function, i.e. non-decreasing in p, non-decreasing in **w**, homogenous in p and **w**, and convex in (p, **w**). The most common specifications used are the translog, generalized Leontief, and the normalized quadratic. All of these are second order approximations of any arbitrary profit function (see for example Chambers, 1988, for a discussion about flexible profit functions).

[2] It can be shown under what conditions inputs can be net substitutes and gross complements, or vice versa, at the same time. The interested reader is referred to Chambers (1988).

[3] It should be noted that gross effect can be decomposed into the two sub effects. Furthermore, an alternative is to use the cost function instead of the profit function, which means that the demand functions would be conditioned on the production level, which in turn means that the substitution effects are net effects.

In this study we have chosen the normalized quadratic profit function (see Lau, 1972, 1974, 1976a-b, 1978, for background and derivation of the normalized quadratic profit function and elasticity formulas)[4] which can be written as:

$$\pi = \beta_0 p + \beta_1 p^2 + \beta_{1i} \sum_{i=1}^{n} p w_i \sum_{i=1}^{n} \alpha_i w_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} w_i w_j , \quad i, j = 1,...,n \tag{4}$$

Linear homogeneity implies that we can normalize profits by dividing through both sides of equation (4) with one of the prices. In this case we normalize with the output price, which gives us the normalized profit function as:

$$\frac{\pi}{p} = \alpha_0 + \sum_{i=1}^{n} \alpha_i \frac{w_i}{p} + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \frac{w_i}{p} \cdot \frac{w_j}{p}, \quad i, j = 1,...,n \tag{5}$$

where $\alpha_0 = \beta_0 + \beta_1$. Furthermore we impose the symmetry restriction by setting $\alpha_{ij} = \alpha_{ji}$.

Applying Hotelling's lemma gives us then the supply and demand functions as:[5]

$$q^* = \alpha_0 - \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \frac{w_i}{p} \cdot \frac{w_j}{p}, \quad i, j = 1,...,n \tag{6}$$

$$x_i^* = -\left(\alpha_i + \sum_{j=1}^{n} \alpha_{ij} \frac{w_j}{p} \right), \quad i = 1,...,n \tag{7}$$

Thus by adding a stochastic term to equations (5) – (7), we have a system that can be estimated with standard techniques such as Seemingly Unrelated Regression Equations (SURE), Full Information Maximum Likelihood (FIML), or some instrumental variable technique such as Generalized Methods of Moments (GMM).[6]

Now it is straightforward to derive the elasticities associated with normalized price changes.

$\varepsilon_{ij} = -\alpha_{ij}(w_j/p)/x_i, \quad i, j = 1, \ldots, n$

which denotes the own-price demand elasticity when $i = j$, and the cross price elasticity when $i \neq j$. The supply elasticities are defined as:

$$\varepsilon_{ip} = -\sum_{j=1}^{n} \varepsilon_{ij}$$

$\varepsilon_{pi} = \varepsilon_{ip}(w_i/p)(x_i/q),$

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[4] The selection procedure was "trial-and-error" until finding the most adequate specification in terms of the cost function being well behaved.

[5] $\partial\pi/\partial w_i = -x_i^*$, and $\partial\pi/\partial p = q^*$. This implies that $\partial(\pi/p)/\partial(w_i/p) = -x_i^*$, and that $q^* = \pi/p + (\mathbf{w}/p)\cdot\mathbf{x}^*$.

[6] See, for example, Green, 1993, or any standard text book in econometrics.

$$\varepsilon_{pp} = -\sum_{i=1}^{n} \varepsilon_{pi}$$

for $i = 1,..., n$

The data set we use is a firm level unbalanced panel covering the period 1990-2001. It includes data on output and input data on quantity and value of labor, electricity, all types of fuels used, and capital investment. Fuels are aggregated into a single variable. For the firms analyzed here, the fossil fuel content in relation to total fuel use is 70-80%. The data set contains all industry plants with more than 5 employees (86 000 rows of data) and is classified according to the SNI industry standard (see www.scb.se for a description of the SNI classification system). Due to the panel data structure several approaches are possible in the estimations of the demand and supply functions. One possible approach is a panel data approach by just pooling the data or include fixed effects in some form. A pure pooling approach means, however, that we impose very restrictive assumptions on the model. One such restriction is that every plant, independent of its type activity, are assumed to have the same technology. This means, for example, that a price change will have the same marginal effect on all plants in the industry. The advantage with the pooling approach is of course that the degrees of freedom will be large since the number of observations equals the number plants times the number of years.

An alternative, and less restrictive, in terms of differences in technology, approach is to allow plants to be heterogeneous on a certain levels of aggregation. That means that the parameters are sector specific for the chosen level of aggregation. In practice this means that we separately estimate sector specific demand systems. The advantage with this approach is that we allow all parameters to vary between the different sectors. The disadvantage is that the chosen level of aggregation does not correspond to differences and similarities in the actual technology. However, this is a general problem in this kind of analysis. In this paper we have chosen this second approach.

Given this approach we can write the normalized profit for a representative firm in sector m as:

$$\frac{\pi_m}{p_m} = \alpha_{0m} + \sum_{i=1}^{n} \alpha_{ik} \frac{w_{im}}{p_m} + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ijm} \frac{w_{im}}{p_m} \cdot \frac{w_{jm}}{p_m}, \quad i, j = 1,...,n \quad m = 1,...,M , \quad (11)$$

where M is the number of sectors, i.e. the aggregation level. The corresponding supply and demand system is then:

$$q_m^* = \alpha_{0m} - \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ijm} \frac{w_{im}}{p_m} \cdot \frac{w_{jm}}{p_m}, \quad i, j = 1,...,n \quad m = 1,...,M \quad (12)$$

$$x_{im}^* = -\left(\alpha_{im} + \sum_{j=1}^{n} \alpha_{ijm} \frac{w_{jm}}{p_m} \right), \quad i = 1,...,n \quad m = 1,...M \quad (13)$$

The econometric specification includes error terms in the profit, supply, and demand functions described above (assumed to have white noise properties). In the final empirical specification we allow for technological progress by adding a trend variable that interacts with all prices in the profit function. This implies that derived demand and supply equations will include a time trend. Also, we introduce "fixed effects" by dividing each industry studied into size groups (by quartiles from employee data), meaning that we also, to a limited degree admittedly, allow for different technologies within sectors.

Given (11) – (13) it is now straightforward to define the price elasticities as:

$$\varepsilon_{ijm} = -\alpha_{ijm}(w_{jm}/p_m)/x_{im}, \tag{14}$$

$$\varepsilon_{ipm} = -\sum_{j=1}^{n} \varepsilon_{ijm} , \tag{15}$$

$$\varepsilon_{pim} = \varepsilon_{ipm}(w_{im}/p_m)(x_{im}/q_m), \tag{16}$$

$$\varepsilon_{ppm} = -\sum_{i=1}^{n} \varepsilon_{pim} , \tag{17}$$

for

$i, j = 1, \ldots, n \quad m = 1, \ldots, M$

Equations (14) - (17) defines the demand elasticities, the supply elasticity with respect to input prices, and the own price supply elasticity.

In table 1 we present the sectors of the data set. Note that in this study, we focus on the base industry which includes the pulp & paper industry, mining, chemistry, and iron and steel sectors.

As discussed above the estimation approach implies a classification of plants into *M* different sectors. The classification system used here follows the SNI classification system at the 2, 3 and 4 digit levels, which means that we classify plants into 17 different industries, or sectors (see table 1). To limit the amount of results presented, in this paper we only focus on the so called base industry, which is also the most relevant part of the manufacturing industry to investigate in terms of CO_2 emissions.[7] All trading firms within the ETC can be found in this category. This means we are left with the following industry sectors: trading sector (1), mining industry, except iron ore, (2), mining industry, iron ore, (3), pulp and paper (4), chemical (5), rubber and plastic (6), stone and non-metal mineral (7), and iron and steel (8).

[7] Also, the base industry is the most electricity intensive part of manufacturing, and electricity price is likely to be influenced by the trading system (more on this below in the simulation section).

Table 1. Industry branch codes classification of Swedish manufacturing according to Statistics Sweden (SNI). Base industry includes the following sectors: pulp & paper industry, mining, chemistry, iron and steel (the 8 sectors specified in 3rd column).

SNI (branch code)	Description	Base industry
composite sector	1. Trading sector (ETS)	1
10+11+14	2. Mining industry, not iron ore	2
131+132	3. Mining industry, iron ore	3
15+16	4. Food industry	
17+18+19	5. Textile industry	
201+202+203+204+205	6. Wood industry	
2111+2112+2121+…+2124	7. Pulp and paper industry	4
22	8. Printing and other paper related industry	
231+232+233+24	9. Chemical industry	5
251+252	10. Rubber and plastic industry	6
261+…+268	11. Stone and non-metal mineral industry	7
27+28	12. Iron and steel industry	8
29	13. Machinery industry	
30+…+33	14. Electro industry	
34	15. Motor vehicle industry	
35+361+…+366	16. Other manufacturing industry	
37	17. Recycling industry	

Within in each industry it is assumed that the representative plant produces a scalar output (q), using labor (x_1), gross capital investments (Δx_2), electricity (x_3), and fuel (x_4)[8]. The associated prices are p, and $w_1 - w_4$, respectively. Input prices are calculated from data on quantity and value for electricity, fuel and labor, which means that these prices are firm specific. The price of investments is an investment good price index taken from *Statistics Sweden's* (www.scb.se) online data base, and is the same for all firms. Furthermore, it is assumed that the representative firm adjusts output and all inputs instantaneously to the desired level, i.e., there are no adjustment costs in the model.[9] Hence, the model can be considered a long-run model. Note that in the empirical analysis, gross investment, which we here denote Δx_2, replace the capital

[8] The fuel variable is a composite variable consisting of all fuels used where 80-90% can be categorized as fossil fuels.

[9] An alternative specification is of course to allow for sluggish adjustment of some of the inputs, for example capital, by assuming that there are costs of adjustment. Such a specification would imply a dynamic model where the magnitude of the adjustment costs determines the path towards a steady state. See Hamermesh and Pfann (1996) for an overview of such models, and Lundgren and Sjöström (1999 and 2001) for applications on Swedish data. Lundgren and Sjöström find no evidence of capital stock sluggishness in Swedish industry as a whole.

stock, x_2. Gross capital investment is defined as $\Delta x_2 = x_2 - (1 - \delta)\ \Delta x_{2,-1}$ where δ is depreciation (-1 indicate lagged value). This, we assume, does not alter the parameter interpretations, since Δx_2 is basically x_2 differentiated. The elasticities, however, become somewhat different in magnitude since $(d\Delta x_2/dw_2)(w_2/\Delta x_2)$ is not equal to $(dx_2/dw_2)(w_2/x_2)$ unless $d\Delta x_2/dx_2 = \Delta x_2/x_2$. Since we lack data on the capital stocks, and have no adequate procedure to approximate them, we have chosen to specify the empirical model in terms of gross investment instead of a proxy for capital stock.

Descriptive statistics for the trading sector and the rest of the industry are provided in table 2a-b and figure 1a-b. From table 2a and 2b we can see that, not surprisingly, the variance across firms is significantly higher looking at the whole industry compared to the trading sector, indicating that the trading sector is relatively homogenous. Further, the cost share of fuel and electricity is considerably higher in the trading sector compared to the industry as a whole.

Table 2a. Descriptive statistics, the trading sector. Average across plants 1990-2001.

	Mean	Std. deviation	Cost share	Std. deviation
Fuel (GWh)	200 496	420 624	0.11	0.11
Electricity (GWh)	218 299	333 076	0.15	0.10
Labor (# of employees)	478	564	0.56	0.16
Real investment value (TSEK)	56 763	113 276	0.18	0.16
Real output value (TSEK)	1 330 722	1 860 594		
Nobs	1 439			

Table 2b. Descriptive statistics, total industry. Average across all plants 1990-2001.

	Mean	Std. deviation	Cost share	Std. deviation
Fuel (GWh)	3 698	39 844	0.03	0.04
Electricity (GWh)	4 071	31 761	0.04	0.04
Labor (# of employees)	82	253	0.82	0.13
Real investment value (TSEK)	3 769	24 818	0.11	0.12
Real output value (TSEK)	131 898	705 774		
Nobs	69 791			

Figure 1a and b displays the development of the cost shares over time for the trading and non-trading sector respectively. Two main conclusions can be drawn from the figures. The first one is that the cost shares have been fairly stable over time for both the trading and the non-trading sector. Secondly, a comparison of the trading and non-trading sector reveals large differences in the sense that that the trading sector on average is significantly more energy and capital intensive than the non-trading sector.

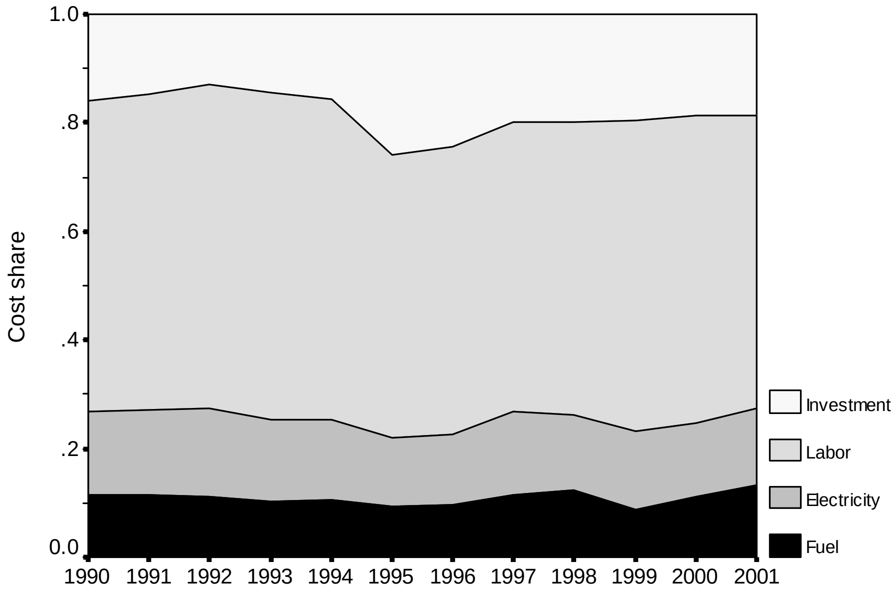

Figure 1a. Cost shares for the trading sector, 1990-2001.

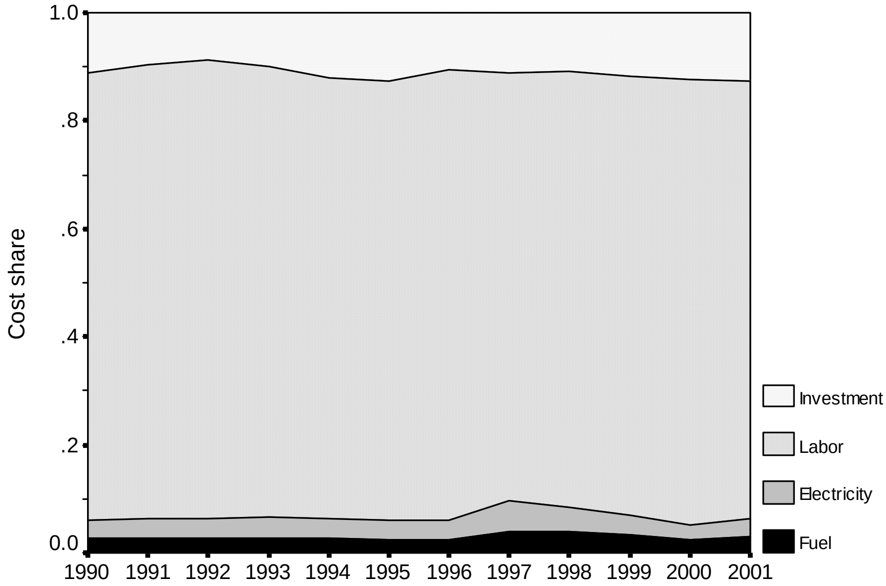

Figure 1b. Cost shares for the non-trading sector, 1990-2001.

The development of the mean and the variation within the trading sector is displayed in figure 2. Here we can see that the mean as well as the variation has been stable over time.

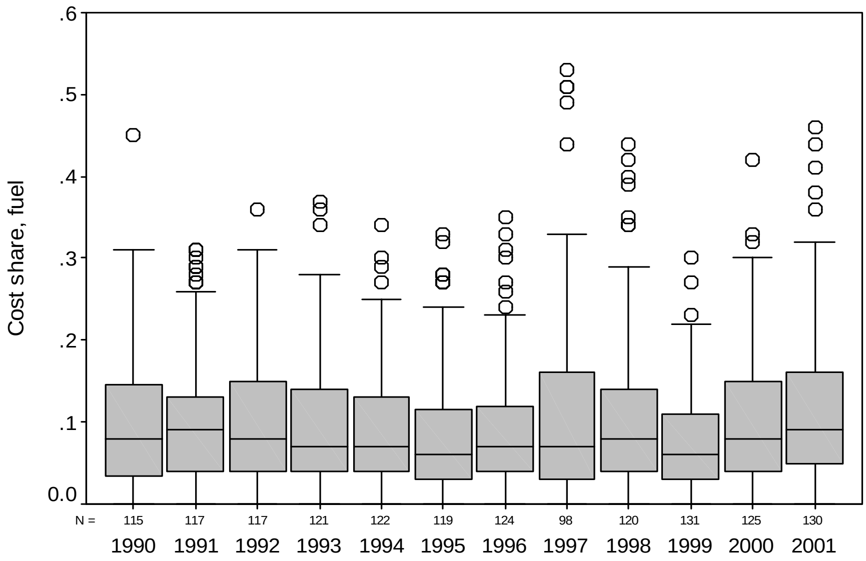

Figure 2. Cost share for fuel within the trading sector, 1990-2001.

4. Results

The equation system (11), (12), and (13) was initially estimated simultaneously with Full Information Maximum Likelihood (FIML).[10] However, when including the supply equation, (12), the system estimation did not converge, or produced nonsense results. Therefore, we only estimated equation (11) and (13), still obtaining all parameters of the system. The left-hand side variable of equation (11), profits, was approximated by taking revenues and subtracting the cost of investment, labor, electricity, and fuels (cost of materials was not included since we lack data on this variable). We also included size dummys specifically for each sector based on quartiles for the labor variable (amount of employees), and a time trend accounting for technical progress. Both the size dummys and the time trend possibly co-vary with input prices. The obtained parameter estimates was then used to calculate the elasticities according to equations (14) to (17). The parameter estimates for each sector are presented in Appendix 1 (Note that parameters associated with dummys or time trends are not presented. These can be obtained from authors upon request). For compactness, we only present the results for the trading sector (sector 1), in the form of an elasticity matrix, Table 3, in this section. The elasticity matrices for the rest of the industry (sector 2-8) can be found in Appendix 2. However, we offer some comments on both trading and non-trading sector results below.

[10] FIML is a standard method in this type of multiple equations model. System of equations and estimation of the type performed in this paper can for example be found in Berndt (1991). See also Kriström and Lundgren (2003) or Brännlund and Lundgren (2004) for similar system equation estimations.

The first column of the matrices denote which input/output the elasticity is associated to; labor (x_1), gross capital investment (Δx_2), electricity (x_3), fuel (x_4), and production (q). The first row indicate which price the elasticity relates to; the hourly wage (w_1), investment good price index (w_2), price of electricity (w_3), price of fuel (w_4), and price of the output (p). The second column show cost shares for the inputs. This means that the second column-second row denote labor cost share, s, while third column-second row denote the own-price elasticity for labor (-0.71).

Table 3. Own-price and cross-price elasticities for the trading sector and cost shares, s. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

	s	w_1	w_2	w_3	w_4	P
x_1	0,56	-0,71	0,07	-0,11	-0,30	1,05
Δx_2	0,18	0,13	-0,51	0,19	-0,20	0,39
x_3	0,14	-0,30	0,28	-0,97	-0,47	1,45
x_4	0,11	-1,20	-0,44	-0,69	-0,72	3,05
q		-0,12	-0,02	-0,06	-0,09	0,31

Before proceeding to comment the elasticities for the specific sectors, it is convenient commenting on the elasticities in Table 3.

All own-price elasticities have the expected sign stipulated by theory; that is, a price increase in any of the inputs will decrease demand for that specific input. For output, the opposite relation holds, i.e., a price increase will increase demand for the product. We can also conclude that demand is inelastic for all inputs but electricity, for which the own price elasticity is close to unity. The own-price elasticity for fuel is -0.72, which would suggest that an increase in fuel price would induce an increase in the cost share of fuel. This implies that the firms cannot fully substitute away from fuel to another input in case of a fuel price increase. Furthermore, the results suggest that an output price increase will increase production (0.31).

Looking at the cross-price elasticities, it is worth noting that a higher fuel price leads to lower production and lower use of all other inputs. This would imply that fuel is a gross complement to the other inputs. If it is also a complement in a technical sense is, however, not possible to deduce from table 3a.

The results in Table 3 can now be used to analyze possible effects of different policies affecting the price of fuel or the other inputs. For example, we are able to investigate the effects of introducing an emission permit market for CO_2, which is the case for Europe since the beginning of 2005. Assume, for example, that the current CO_2 tax is replaced by a trading system. The effect of such a shift in policy instrument is utterly dependent upon what price that will be established for emission rights (when writing this the price is about 25 euros per ton CO_2). If the emission price right is less than the current tax, the use of fuel, and thus CO_2 emissions, will decrease, and vice versa. We also see that production, employment, and the use of electricity will increase. In the next section a more in depth simulation of different policy change scenarios will be conducted.

In tables A2a-g (see Appendix 2), we show elasticities, and cost shares, for each sector (2-8). The cost shares differ considerable across sectors for the variables of interest here. The electricity cost share range between 4 and 16%. The lowest cost share for electricity is found in the iron and steel industry, while mining of iron ore has the highest. The implication is that an increase in the electricity price, as a consequence of a policy change, will have very different effects on the different sectors. It should be noted that there is probably also a considerable variation within sectors. The cost shares for fuel have about the same range as for electricity. The rubber and plastic sector has the lowest, 2%, while mining industry has the highest, 12%. This suggests that if fuel price goes up, the mining industry will be the sector that is relatively most negatively affected.

The price elasticities have the expected sign; that is, all own-price elasticities are negative, and the output elasticities are positive. The reader should, however, note that the elasticities vary in magnitude, and in case of cross-price elasticities also in sign, across sectors. This suggests that the various sectors will adapt differently to price changes.

5. Simulations

In this section we will simulate the introduction of a permit market for CO_2. Using the elasticity matrices presented in the previous section we assess the partial effects of a policy change on a given sector. Before describing the different scenarios and the results from the simulations, we wish to alert the reader to some crucial assumptions. The first important assumption is that all firms in every sector are price takers. Second, a policy change does not induce general equilibrium effects. That is, policy changes only have effects on the prices of those inputs directly affected by a specific policy. For example, an increased CO_2 tax translates directly and fully into an upward price change of those inputs that produce CO_2 emissions. No other prices are assumed to change. This may be realistic in some cases, and less realistic in other cases. It is, for example, realistic to assume that significant changes in the energy and/or the CO_2 taxation system will have repercussions in the labor market. We can see from the elasticity measures that increased energy costs has a negative effect on labor demand, which may have effects on the labor market by reducing wage rates. This in turn dampens the overall cost increase, and thereby also has a dampening effect on the energy and employment decrease. The model we use here cannot track these types of general equilibrium effects, but the reader should be aware that they exist to some degree. To account for all interactive effects between all sectors and markets, a computable general equilibrium model (CGE) would be more suitable.[11] However, these type of models are not without flaws, and the modeling approach we have chosen to use in this analysis certainly has some benefits compared to CGE:s. For example, the parameters used in the simulation have been estimated using a very detailed micro-panel data, and the massive amount of information which it contains is important to consider when choosing between different modeling approaches. It should, however, be stressed that even though we have the

[11] Recent CGE analysis of the impact on the Swedish economy due to the emission trading program can be found in Hill and Kriström (2005).

data, we cannot study each company separately. The effects from, for example, price changes are to be interpreted as effects for a group of firms, or as a mean effect for a specific group of firms.

As in the previous section we have chosen to present simulation results from the trading sector in this section, and the rest of the base industry simulation results are presented in an appendix (Appendix 3). However, we comment on simulation results from both sectors in the text below.

The scenarios are presented in table 4.

Table 4. Policy scenarios.

Scenario/simulation	Emission permit price (Euro/ton)	Electricity price increase (Euro/ GWh)	CO_2 tax removed for trading sector
1	5	2	yes
2	5	2	no
3	10	4	yes
4	10	4	no
5	25	8	yes
6	25	8	no

Note: The original analysis was conducted using SEK as monetary measure with the price of an emission permit set to 50, 100, and 250 SEK/ton, and the electricity price increase set to 0.02, 0.04, and 0.08 SEK/kWh. Here we have used the exchange rate 1 Euro = 10 SEK.

The introduction of a permit market and removed CO_2 tax will have effect on the price of fuel which the firms use as input in production. In the sectors we have chosen there is always a fraction of trading firms. It is also assumed that a fuel price increase will make the production of electricity more costly, and therefore, as a second step, electricity price will increase causing additional burden on the firms.

The simulation procedure is as follows.

1. First, a CO_2 emission permit market is introduced. The price of a permit is 5, 10, or 25 Euro/ton CO_2. The CO_2 tax is removed for the trading sector or not. The permit price is translated into a price change in fuel, which is dependent on the fuel mix and production technology used by each sector (the fuel variable is a composite of all kinds of fuels, but mainly fossil fuels).

2. When the industry has adapted the input mix and the output level to the initial policy change, the price of electricity is assumed to increase by 2, 4 or 8 Euro/GWh. This leads to further substitution and adaptation.

The simulation is thus a two-step procedure, and the results are presented for a number of variables for both steps. All changes are in percent. If, for example, the change in the fuel input variable is -0.054, it means that fuel use is down 5.4%.[12]

We use the following notation for the simulation results:

D_X = percentage change in variable X.

Step 1

D_$x_1$1 = change in labor, step 1.

D_$\Delta x_2$1 = change in investment, step 1.

D_$x_3$1 = change in electricity, step 1.

D_$x_4$1 = change in fuel, step 1.

Step 2

D_$x_1$2 = change in labor, step 2.

D_$\Delta x_2$2 = change in investment, step 2.

D_$x_3$2 = change in electricity, step 2.

D_$x_4$2 = change in fuel, step 2.

Total effect

D_x_1 = total change in labor.

D_Δx_2 = total change in investment.

D_x_3 = total change in electricity.

D_x_4 = total change in fuel.

D_q = total change in output level.

D_CO_2 = total change in CO_2 emissions.

D_π = total change in profits.

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[12] The simulation technique used here is the same as in Brännlund and Lundgren (2004); that is, we calculate the effect that the policy change has on actual prices, and then use the relevant elasticity to assess the effect on input factor and output demand. For example, to obtain the "policy-to-fuel price-translation coefficient" we relate total emissions of CO_2 (in kilos) to total use of fuels (GWh) for each sector by a simple regression.

All simulations are based on sector specific CO_2 tax rates as benchmark values. These benchmark values are calculated as the mean tax rate for that specific sector in 2001. The benchmark tax rate varies quite a lot across sectors. For example, the stone and non-metal mineral industry pays about 2.3 Euro/ton, while the pulp and paper industry pays 17.6 Euro/ton. These differences are of significant importance for the effects of the policy changes considered here, especially in the case when the CO_2 tax is removed. Also, all other benchmark values, such as prices and quantities, are calculated as mean values specific for each sector in 2001. The sector specific benchmark CO_2 tax rates are (Euro/ton): trading = 5.2; mining (iron ore excluded) = 8.0; iron ore mining = 12.5; pulp and paper = 17.8; chemical = 13.5; rubber and plastic = 17.6; stone and non-metal mineral = 2.3; iron and steel = 9.5.

The simulation results for the trading sector are presented in Table 5. The results from the other sectors are presented in Appendix 3 (Table A3a-g).

In Step 1 – in scenarios 1, 3, and 5 – a permit market is introduced and current CO_2 tax is removed. This would, for the trading sector, mean an actual "tax reduction" compared to today's level.[13] In sim3 and sim5 the price of a permit exceeds current level of the CO_2 tax, and which can be interpreted as a "tax increase". In sim2, sim4, and sim6, the CO_2 tax is not removed, which simply means that CO_2 permit trading can be viewed as a "tax increase". The effects in step 1 of sim1 are that the trading sector increases the use of all inputs marginally; employment and investments increases both by 0.1%, and the use of electricity and fuel by 0.2 and 0.3% respectively. However, if the permit price becomes 10 or 25 euro, and the current CO_2 tax remains, then trading firms will experience a cost increase, which decreases the use of all inputs (sim3 and sim5). In sim2, sim4, and sim6 the results indicate a lower use of all input, since the CO_2 tax is not removed. Employment reduces by 3.7 to 18.3%, and fuel use goes down by 8.7 to 43.6% depending on the permit price. This suggests that the effects are quite large in these scenarios, and we can expect significant structural change since firms with large cost shares for fuel probably will exit out of business. A positive effect, however, is that domestic CO_2 emissions will decrease considerably.

Step 2 assesses the effect of an electricity price increase. This price increase is assumed to occur due to increased fuel costs in certain types of electricity production; the increased fuel price being a result of introducing a permit market at EU level. As expected, the increase in electricity price decreases the use of electricity. The reduction is in the range 10 to 40%, depending on the size of the price increase. The electricity price increase leads to further lowering of fuel use, which leads to further decrease in CO_2 emissions. Note that investments tend to increase as a result of a higher electricity price. This suggests that electricity and capital are gross substitutes in production.

[13] Note that in the second step we are only considering an electricity price increase, and thus sim1=sim2, sim3=sim4, and sim5=sim6.

Table 5. Effects of policy on labor input, investments, electricity input, fuel input, output, emissions, and profits (percentage change) in the **Trading sector**. All benchmark values from 2001 (specific mean values for each sector).

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	0.001	0.001	0.002	0.003
Sim2	-0.037	-0.024	-0.056	-0.087
Sim3	-0.035	-0.023	-0.054	-0.084
Sim4	-0.073	-0.049	-0.113	-0.174
Sim5	-0.145	-0.097	-0.223	-0.345
Sim6	-0.183	-0.123	-0.282	-0.436

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	-0.011	0.019	-0.099	-0.070
Sim2	-0.011	0.019	-0.099	-0.070
Sim3	-0.022	0.039	-0.197	-0.140
Sim4	-0.022	0.039	-0.197	-0.140
Sim5	-0.045	0.078	-0.395	-0.281
Sim6	-0.045	0.078	-0.395	-0.281

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	-0.010	0.020	-0.096	-0.067
Sim2	-0.048	-0.005	-0.155	-0.157
Sim3	-0.058	0.0155	-0.252	-0.224
Sim4	-0.096	-0.010	-0.310	-0.315
Sim5	-0.190	-0.019	-0.618	-0.626
Sim6	-0.229	-0.045	-0.677	-0.717

	D_q	D_CO_2	D_π
Sim1	-0.006	-0.067	-0.009
Sim2	-0.018	-0.157	-0.021
Sim3	-0.024	-0.224	-0.029
Sim4	-0.035	-0.315	-0.041
Sim5	-0.070	-0.626	-0.082
Sim6	-0.081	-0.717	-0.093

Looking at the total effects we find that the cost decrease from sim1 is offset by the cost increase which follows from the electricity price increase. In all scenarios, we can observe that the total effect on production and profits are modest compared to the effects on fuel and electricity use and CO_2 emissions. These results are due to the fact that the cost chares and marginal products for fuel and electricity are small. Also, there may be "invisible" substitution away from fuel and electricity to some other input which is not included in our empirical specification. For example, raw material, which in some firms is a significant input, is not a part of the production function in our analysis.

The effects on the trading sector of introducing a permit market are not surprising, and the simulation results are basically what you would expect. The effects on the trading sector are, to a large extent, dependent on whether the current CO_2 tax is removed or not. If the tax is kept at its current level, then the permit market will simply be an additional burden on the industry which drives up the cost of fuels. If combined with an electricity price increase, which is likely with an EU level permit market, this effect/burden is even more significant.

In tables A2a-g (see Appendix 2) the simulation results for the rest of the base industry sectors are presented. In general, the effects of the different scenarios on these sectors follow the same pattern as for the trading sector. However, there are significant differences in magnitude of the effects between sectors. The largest percentage changes are found in the iron ore mining, chemical, stone and non-metal mineral, and iron and steel industry. In sim5 and sim6 the use of fuel in the stone and non-mineral industry drops 100%, which indicates that the "mean" firm in this sector exits the industry. The effects on the mining sector (not iron ore) are relatively modest. Furthermore, it is clear that the energy intensive sector pulp and paper is not so much affected by step 1 (permit market only). However, the electricity price increase (step 2) has a quite severe effect on this sector.

In sum; the effects on the Swedish base industry (forest, chemical, mining, steel), including the trading sector, of the introduction of a CO_2 emission permit market on EU level are dependent on (*i*) what price is established for a permit, (*ii*) what happens to the current CO_2 tax, and (*iii*) what happens to the electricity price. The simulations show that the effects can be significant, in terms of competitiveness, when the current CO_2 tax is not removed, and these effects vary considerable across sectors. The effects probably vary a great deal within sectors too. This suggests that structural change will occur with a possibility that some firms will go out of business. In the case where the current CO_2 tax is removed the effects are not clear cut. A permit price below 10 Euro/ton will probably mean an improvement, in terms of cost level, for many firms. However, this is dependent on the electricity price increase. A price increase of more than 4 Euro/ GWh is likely to induce an overall increased cost level for many firms, even though the price of permits establishes at a fairly low level.

6. Conclusions

The purpose of this paper is to shed light on the effects of introducing a permit market for CO_2 emissions on the Swedish base industry in general and on the permit trading sector in particular. By "effects" we mean changes in factor demand, output, emissions, and profits.

Sector specific estimation of factor demand and profit functions exhibit properties and robustness that are consistent with economic theory; that is, all own-price elasticities are negative and all output elasticities are positive. Furthermore, the elasticities show that the demands are, in most cases, relatively inelastic.

Simulation of the model for 6 different policy scenarios suggest that the effects on Swedish base industry of a permit trade system is dependent on (*i*) removal or no removal of current CO_2 tax, (*ii*) the established price of permits, and (*iii*) what will happen to the electricity price. Our analysis show that changes in electricity price may be more important than the price of permits for some sectors. Note, however, that the price of electricity is dependent on the price of permits, which in turn depends on how many permits that are emitted throughout the whole European trading system. The results presented in this article are basically in line with findings in recent CGE studies performed on the Swedish economy with similar scenarios. See Hill and Kriström (2002 and 2005), and Nilsson and Kriström (2002).

Finally, we would like to stress that simulations of the type performed in this paper are not without flaws. The underlying parameters should be viewed as "local approximations" and simulations that stretch beyond the price fluctuations observed historically in the data are uncertain. As a consequence sim5 and sim6, the most extreme scenarios, should be interpreted with care. Careful interpretation is also motivated by the partial equilibrium setting used here. There are reasons to believe that policy reforms of the kind simulated here will have effects on other markets. For example we can't rule out possible effects on the labor market. However, what the effects will be on wage setting and employment can't be determined a priori without further assumptions of the functioning of the labor market. This in turn implies that we can't say what the final effects on the industry will be. There are at least two problems associated with this. The first is that the simulations per se do not take into account possible interactions. The second is that the estimated parameters in our model are biased due to endogenous right hand side variables, such as the wage rate. Thus, high ranked for future research is to include the labor market explicitly into this kind of model. This would not only potentially improve the quality of the results when evaluating policy reforms like the one here, but also contribute to the understanding of how wage setting and employment is affected by energy and environmental policy.

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Appendix 1.

Table A1. Parameter estimates for all sectors (m = 1,…, 8). * indicates significance at 5%-level. Data covers years 1990-2001, and all plants with employees > 5.

Param.	**Sector 1**	**Sector 2**	**Sector 3**	**Sector 4**	**Sector 5**	**Sector 6**	**Sector 7**	**Sector 8**
α_{0m}	14838.9*	1973.81*	-573.440	8882.49*	9815.15*	2682.43*	2179.49*	6092.74*
α_{1m}	-1083.76*	-196.497*	7302.57	-665.811*	-442.313*	-336.158*	-278.753*	-443.922*
α_{2m}	-492756*	-77941.3*	-443363	-644405*	-271272*	-96831.5*	-73771.4*	-181996*
α_{3m}	-544755*	-103083*	-447189	-390719*	-87273.5*	-17795.8*	-32324.6*	-92806.9*
α_{4m}	-629004*	-18097.2*	-403439	-196823*	-107084*	-8254.55*	-141231*	-124671*
α_{11m}	117.808*	2.80321*	12.8667	14.4696*	7.64197	14.2830*	8.71173*	10.5576*
α_{22m}	.88E+08	.49E+07*	.15E+08	.68E+08*	22704.0	.40E+07	.12E+08*	.19E+08*
α_{33m}	.89E+08*	361802	.53E+08	.16E+08*	.10E+08*	766273*	478621	.44E+07*
α_{44m}	.83E+08*	.12E+07*	.46E+08	.14E+08*	.12E+08*	743347*	.15E+08*	.43E+07*
α_{12m}	-16526.9	1191.00	27487.2	79067.9*	12464.3	4083.46	-3411.40	-1704.39
α_{13m}	22397.1	425.994	-11985.1	28659.4*	-8034.90	429.079	2249.76*	3412.26
α_{14m}	83350.3*	-690.726*	5150.20	3732.43	7358.70	-217.713	1421.22	3555.17
α_{23m}	-.29E+08	.16E+07*	.52E+08	.61E+08*	-.53E+07	-424193	312559	-.30E+07
α_{24m}	.42E+08	-360511.	.89E+08	.27E+08*	.72E+07	354017	.20E+07	.34E+07
α_{34m}	.58E+08*	-22537.6	.44E+08	.10E+08	.36E+07	-163536	.26E+07*	.36E+07*
Nobs	1439	1137	145	2117	2736	2905	3333	12775

Note: sectors 1-8 are: the trading sector (1), the mining industry except iron ore (2), the iron ore mining industry (3), the pulp and paper industry (4), the chemical industry (5), the rubber and plastic industry (6), the stone and non-metal mineral industry (7), and iron, steel and metal industry (8).

Appendix 2

Table A2a. Own-price and cross-price elasticities for the **mining** industry **except iron ore**, and cost shares, *s*. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

	s	w_1	w_2	w_3	w_4	p
x_1	0.66	-0.41	-0.14	-0.09	0.11	0.53
Δx_2	0.14	-0.43	-1.38	-0.88	0.14	2.55
x_3	0.07	-0.46	-1.39	-0.59	0.03	2.42
x_4	0.12	0.53	0.22	0.03	-1.09	0.32
q		-0.10	-0.15	-0.09	-0.01	0.36

Table A2b. Own-price and cross-price elasticities for the **iron ore** industry, and cost shares, *s*. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

	s	w_1	w_2	w_3	w_4	p
x_1	0.56	-0.11	-0.17	0.07	-0.03	0.24
Δx_2	0.21	-0.25	-0.10	-0.34	-0.57	1.25
x_3	0.16	0.19	-0.63	-0.61	-0.49	1.55
x_4	0.08	-0.13	-1.67	-0.79	-0.81	3.39
q		-0.04	-0.17	-0.11	-0.15	0.48

Table A2c. Own-price and cross-price elasticities for the **pulp and paper** industry and cost shares, *s*. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

	s	w_1	w_2	w_3	w_4	p
X_1	0.71	-0.17	-0.73	-0.37	-0.05	1.32
Δx_2	0.16	-1.24	-0.83	-1.04	-0.44	3.56
x_3	0.09	-0.67	-1.11	-0.43	-0.26	2.47
x_4	0.05	-0.16	-0.89	-0.48	-0.62	2.15
q		-0.17	-0.26	-0.17	-0.08	0.68

Table A2d. Own-price and cross-price elasticities for the **chemical** industry and cost shares, *s*. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

	s	w_1	w_2	w_3	w_4	p
x_1	0.74	-0.17	-0.19	0.20	-0.17	0.33
Δx_2	0.15	-0.40	0.00	0.19	-0.24	0.45
x_3	0.07	0.96	0.44	-1.45	-0.46	0.50
x_4	0.04	-1.09	-0.74	-0.61	-1.90	4.34
q		-0.04	-0.02	-0.01	-0.08	0.15

Table A2e. Own-price and cross-price elasticities for the **rubber and plastic** industry, and cost shares, *s*. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

	s	w_1	w_2	w_3	w_4	p
x_1	0.79	-0.48	-0.12	-0.02	0.01	0.60
Δx_2	0.14	-0.44	-0.38	0.07	-0.06	0.82
x_3	0.05	-0.27	0.23	-0.68	0.17	0.55
x_4	0.02	0.29	-0.41	0.31	-1.63	1.45
q		-0.13	-0.05	-0.01	-0.01	0.20

Table A2f. Own-price and cross-price elasticities for the **stone and non-metal mineral** industry, and cost shares, *s*. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

		w_1	w_2	w_3	w_4	p
x_1	0.77	-0.39	0.12	-0.14	-0.07	0.48
Δx_2	0.10	0.68	-2.00	-0.09	-0.43	1.84
x_3	0.05	-1.29	-0.14	-0.40	-1.60	3.43
x_4	0.08	-0.18	-0.20	-0.48	-2.05	2.91
q		-0.12	-0.08	-0.09	-0.27	0.56

Table A2g. Own-price and cross-price elasticities for the **iron and steel** industry, and cost shares, *s*. All elasticities and cost shares evaluated at mean values for the years 1990-2001.

	s	w_1	w_2	w_3	w_4	p
x_1	0.83	-0.35	0.05	-0.17	-0.18	0.65
Δx_2	0.11	0.19	-2.00	0.52	-0.60	1.88
x_3	0.04	-0.96	0.75	-1.86	-1.57	3.63
x_4	0.03	-0.77	-0.64	-1.16	-1.45	4.02
q		-0.11	-0.08	-0.11	-0.16	0.47

Appendix 3

Table A3a. Effects of policy on labor, investments, electricity, fuel, output, emissions, and profits (percentage change). **Mining sector** except iron ore. All benchmark values from 2001 (specific mean values for each sector).

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	0.004	0.005	0.001	-0.036
Sim2	0.004	0.005	0.001	-0.036
Sim3	0.007	0.009	0.002	-0.071
Sim4	0.007	0.009	0.002	-0.072
Sim5	0.018	0.023	0.004	-0.179
Sim6	0.018	0.023	0.004	-0.179

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	-0.006	-0.056	-0.037	0.002
Sim2	-0.006	-0.056	-0.037	0.002
Sim3	-0.012	-0.111	-0.075	0.003
Sim4	-0.012	-0.111	-0.075	0.003
Sim5	-0.024	-0.222	-0.149	0.007
Sim6	-0.024	-0.222	-0.149	0.007

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	-0.002	-0.051	-0.036	-0.034
Sim2	-0.002	-0.051	-0.036	-0.034
Sim3	-0.005	-0.102	-0.073	-0.068
Sim4	-0.005	-0.102	-0.073	-0.068
Sim5	-0.005	-0.199	-0.145	-0.172
Sim6	-0.005	-0.199	-0.145	-0.173

	D_q	D_CO_2	D_π
Sim1	-0.006	-0.034	-0.005
Sim2	-0.006	-0.034	-0.005
Sim3	-0.012	-0.068	-0.011
Sim4	-0.012	-0.068	-0.011
Sim5	-0.025	-0.172	-0.024
Sim6	-0.025	-0.173	-0.024

Table A3b. Effects of policy on labor, investments, electricity, fuel, output, emissions, and profits (percentage change). **Iron ore mining sector**. All benchmark values from 2001 (specific mean values for each sector).

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	0.002	0.046	0.041	0.066
Sim2	-0.002	-0.032	-0.028	-0.045
Sim3	0.001	0.015	0.013	0.021
Sim4	-0.003	-0.064	-0.056	-0.091
Sim5	-0.004	-0.081	-0.071	-0.115
Sim6	-0.008	-0.159	-0.139	-0.227

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	0.008	-0.039	-0.071	-0.091
Sim2	0.008	-0.039	-0.071	-0.091
Sim3	0.017	-0.079	-0.142	-0.183
Sim4	0.017	-0.079	-0.142	-0.183
Sim5	0.033	-0.158	-0.284	-0.366
Sim6	0.033	-0.158	-0.284	-0.366

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	0.011	0.007	-0.030	-0.025
Sim2	0.007	-0.071	-0.099	-0.137
Sim3	0.018	-0.064	-0.129	-0.162
Sim4	0.013	-0.143	-0.197	-0.274
Sim5	0.029	-0.239	-0.354	-0.481
Sim6	0.025	-0.317	-0.422	-0.593

	D_q	D_CO_2	D_π
Sim1	0.000	-0.025	-0.006
Sim2	-0.021	-0.137	-0.009
Sim3	-0.022	-0.162	-0.015
Sim4	-0.043	-0.274	-0.018
Sim5	-0.073	-0.481	-0.034
Sim6	-0.094	-0.593	-0.037

Table A3c. Effects of policy on labor, investments, electricity, fuel, output, emissions, and profits (percentage change). **Pulp and paper** sector. All benchmark values from 2001 (specific mean values for each sector).

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	0.005	0.049	0.028	0.068
Sim2	-0.002	-0.020	-0.012	-0.028
Sim3	0.003	0.029	0.017	0.040
Sim4	-0.004	-0.040	-0.023	-0.056
Sim5	-0.003	-0.031	-0.018	-0.043
Sim6	-0.010	-0.100	-0.058	-0.139

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	-0.031	-0.088	-0.036	-0.041
Sim2	-0.031	-0.088	-0.036	-0.041
Sim3	-0.062	-0.176	-0.073	-0.081
Sim4	-0.062	-0.176	-0.073	-0.081
Sim5	-0.125	-0.352	-0.146	-0.163
Sim6	-0.125	-0.352	-0.146	-0.163

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	-0.026	-0.039	-0.008	0.027
Sim2	-0.033	-0.108	-0.048	-0.069
Sim3	-0.059	-0.147	-0.056	-0.041
Sim4	-0.067	-0.216	-0.096	-0.137
Sim5	-0.128	-0.384	-0.164	-0.206
Sim6	-0.135	-0.452	-0.203	-0.302

	D_q	D_CO_2	D_π
Sim1	-0.006	0.027	-0.002
Sim2	-0.018	-0.069	-0.004
Sim3	-0.024	-0.041	-0.006
Sim4	-0.036	-0.137	-0.008
Sim5	-0.064	-0.206	-0.015
Sim6	-0.076	-0.302	-0.016

Table A3d. Effects of policy on labor, investments, electricity, fuel, output, emissions, and profits (percentage change). **Chemical** sector. All benchmark values from 2001 (specific mean values for each sector).

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	0.002	-0.004	-0.013	-0.047
Sim2	0.003	-0.005	-0.017	-0.058
Sim3	0.005	-0.009	-0.030	-0.105
Sim4	0.006	-0.010	-0.033	-0.116
Sim5	0.013	-0.023	-0.080	-0.280
Sim6	0.014	-0.024	-0.083	-0.291

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	0.007	0.024	-0.126	-0.054
Sim2	0.007	0.024	-0.126	-0.054
Sim3	0.013	0.048	-0.253	-0.107
Sim4	0.013	0.048	-0.253	-0.107
Sim5	0.026	0.096	-0.506	-0.215
Sim6	0.026	0.096	-0.506	-0.215

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	0.009	0.020	-0.140	-0.101
Sim2	0.009	0.019	-0.143	-0.112
Sim3	0.018	0.039	-0.283	-0.213
Sim4	0.019	0.039	-0.286	-0.224
Sim5	0.040	0.073	-0.586	-0.495
Sim6	0.040	0.072	-0.589	-0.506

	D_q	D_CO_2	D_π
Sim1	-0.004	-0.101	-0.010
Sim2	-0.004	-0.112	-0.011
Sim3	-0.008	-0.213	-0.021
Sim4	-0.008	-0.224	-0.021
Sim5	-0.017	-0.495	-0.043
Sim6	-0.017	-0.506	-0.043

Table A3e. Effects of policy on labor, investments, electricity, fuel, output, emissions, and profits (percentage change). **Rubber and plastic** sector. All benchmark values from 2001 (specific mean values for each sector).

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	0.000	-0.002	0.004	-0.038
Sim2	0.000	-0.002	0.004	-0.040
Sim3	0.001	-0.003	0.008	-0.078
Sim4	0.001	-0.003	0.008	-0.080
Sim5	0.001	-0.008	0.021	-0.198
Sim6	0.001	-0.008	0.021	-0.200

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	-0.002	0.005	-0.057	0.026
Sim2	-0.002	0.005	-0.057	0.026
Sim3	-0.003	0.011	-0.113	0.051
Sim4	-0.003	0.011	-0.113	0.051
Sim5	-0.007	0.022	-0.227	0.102
Sim6	-0.007	0.022	-0.227	0.102

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	-0.001	0.004	-0.053	-0.013
Sim2	-0.001	0.004	-0.053	-0.014
Sim3	-0.003	0.008	-0.105	-0.027
Sim4	-0.003	0.008	-0.105	-0.029
Sim5	-0.005	0.014	-0.206	-0.096
Sim6	-0.005	0.014	-0.206	-0.098

	D_q	D_CO_2	D_π
Sim1	-0.001	-0.013	-0.003
Sim2	-0.001	-0.014	-0.003
Sim3	-0.002	-0.027	-0.005
Sim4	-0.002	-0.029	-0.005
Sim5	-0.005	-0.096	-0.011
Sim6	-0.005	-0.098	-0.011

Table A3f. Effects of policy on labor, investments, electricity, fuel, output, emissions, and profits (percentage change). **Stone and non-metal mineral** sector. All benchmark values from 2001 (specific mean values for each sector). * indicates changes of more than 100%.

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	-0.004	-0.027	-0.103	-0.132
Sim2	-0.008	-0.048	-0.181	-0.231
Sim3	-0.012	-0.076	-0.284	-0.363
Sim4	-0.015	-0.096	-0.361	-0.462
Sim5*	*	*	*	*
Sim6*	*	*	*	*

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	-0.010	-0.006	-0.029	-0.034
Sim2	-0.010	-0.006	-0.029	-0.034
Sim3	-0.021	-0.013	-0.057	-0.068
Sim4	-0.021	-0.013	-0.057	-0.068
Sim5	-0.042	-0.026	-0.114	-0.137
Sim6	-0.042	-0.026	-0.114	-0.137

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	-0.015	-0.034	-0.132	-0.166
Sim2	-0.018	-0.055	-0.209	-0.265
Sim3	-0.033	-0.089	-0.341	-0.432
Sim4	-0.036	-0.109	-0.418	-0.531
Sim5*	*	*	*	*
Sim6*	*	*	*	*

	D_q	D_CO_2	D_π
Sim1	-0.024	-0.166	-0.010
Sim2	-0.037	-0.265	-0.014
Sim3	-0.062	-0.432	-0.024
Sim4	-0.075	-0.531	-0.029
Sim5*	*	*	*
Sim6*	*	*	*

Table A3g. Effects of policy on labor, investments, electricity, fuel, output, emissions, and profits (percentage change). **Iron and steel** sector. All benchmark values from 2001 (specific mean values for each sector).

Step 1

	$D\_x_1 1$	$D\_\Delta x_2 1$	$D\_x_3 1$	$D\_x_4 1$
Sim1	0.005	0.018	0.047	0.043
Sim2	-0.011	-0.035	-0.091	-0.084
Sim3	-0.005	-0.017	-0.044	-0.041
Sim4	-0.021	-0.070	-0.182	-0.168
Sim5	-0.037	-0.121	-0.318	-0.293
Sim6	-0.053	-0.174	-0.456	-0.420

Step 2

	$D\_x_1 2$	$D\_\Delta x_2 2$	$D\_x_3 2$	$D\_x_4 2$
Sim1	-0.012	0.037	-0.133	-0.083
Sim2	-0.012	0.037	-0.133	-0.083
Sim3	-0.024	0.074	-0.265	-0.166
Sim4	-0.024	0.074	-0.265	-0.166
Sim5	-0.048	0.148	-0.530	-0.332
Sim6	-0.048	0.148	-0.530	-0.332

Total effect

	$D\_ x_1$	$D\_ \Delta x_2$	$D\_ x_3$	$D\_ x_4$
Sim1	-0.007	0.055	-0.086	-0.040
Sim2	-0.023	0.002	-0.224	-0.167
Sim3	-0.029	0.057	-0.310	-0.207
Sim4	-0.045	0.004	-0.447	-0.334
Sim5	-0.085	0.027	-0.848	-0.625
Sim6	-0.102	-0.026	-0.986	-0.753

	D_q	D_CO_2	D_π
Sim1	-0.003	-0.040	-0.001
Sim2	-0.017	-0.167	-0.004
Sim3	-0.020	-0.207	-0.006
Sim4	-0.035	-0.334	-0.008
Sim5	-0.065	-0.625	-0.016
Sim6	-0.079	-0.753	-0.019