

# National Climate Policy within an International Emission Trading System

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## Abstract

In this paper a CGE model is used to analyse the optimal national climate policy in Sweden before and after the introduction of the Emission Trading System (ETS) for CO<sub>2</sub> emissions in the European Union. The optimal distribution of domestic energy tax rates are derived for different actors. It is shown that the tax rates should be equal for all actors in the economy. This holds even after the introduction of the ETS. The study gives no support to the common belief that ETS industries should have lower tax rate than non ETS industries. Before the introduction of ETS the low tax rates for electricity induced substantial carbon emissions in neighbouring countries through the common Nordic market for electricity. This effect however is not present after the introduction of ETS. It is also shown that the socially efficient amount of allowances allocated to domestic firms is zero if we want to reduce global emissions of CO<sub>2</sub> in a cost efficient way.

Keywords: CO<sub>2</sub> taxation; Energy taxation; Climate Policy; Computable General Equilibrium; Carbon Leakage; Emission Trading.

## **1 Introduction**

This paper investigates optimal domestic climate policies in Sweden. The main focus is upon energy taxes but optimal distribution of emission allowances to domestic firms is also derived. Policies for reducing carbon emission in one country may increase emissions in other countries. This effect has, in the literature, been called carbon leakage and has been divided into two kinds, direct and indirect carbon leakages.<sup>1</sup> The direct leakage is due to that a decrease in domestic demand for fossil fuel can reduce the world market price and thereby increase the use in other countries. The indirect leakage arises if domestic production of goods that are intense in the use of fossil fuels is reallocated to other country or if domestic use of fossil fuel is substituted by imported electricity that gives high carbon emission in exporting countries.

The introduction of emission trading in EU has created a new kind of carbon leakage at the member states. When domestic emissions are reduced in a plant that is part of ETS, the firm that owns the plant will sell permits to another firm within the European Union. That firm will increase its emission with the same amount. ETS thus creates a new channel for carbon leakage where the leakage effect is 100 percent.

Hoel (2001) has shown that in a small open economy, carbon-intensive tradable sectors should face a lower carbon tax than other sectors of the economy if import and export tariffs cannot be used on all traded goods. Sweden introduced general exemptions on the energy taxes for manufacturing in 1993. Before that exemptions were only granted on a case by case basis. After 1993 the exemptions have been even larger since the tax increases in energy mostly have been on households and services. One motivation for the tax exemptions was the carbon leakage effect.

Differentiated tax rates between industries were previously assumed to violate the rules of the inner market. If a member country wants to reduce carbon taxes for some industries it has to reduce them for all.<sup>2</sup> Sweden got in the negotiations of membership in the European Union a

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<sup>1</sup> Direct and indirect carbon leakage is the vocabulary of Hoel (2001). Burniaux and Martins (2000) uses carbon leakages related to non energy market and related to energy markets to describe the same features.

<sup>2</sup> See the interpretation of the EU legislation in SGOR 2003:38.

temporary exception from these rules.<sup>3</sup> In an important case in the European court (C-143/99) the similar exemptions in Austria was judged as violating the rules of the inner market if not all industries were included. The governmental report thus proposed that the exemptions should be extended to all industries not only manufacturing (SGOR 2003:38). This proposal was never passed through the parliament and in 2005 the European court accepted the Swedish tax exemptions (N 588/2005 and N 595/2005).

Due to the tax exemptions there are large differences in tax rates on fossil fuels for different kind of users. The tax rates are low in manufacturing and high in services and final consumption. While carbon leakage is an argument for tax exemptions in manufacturing there are also arguments against such exemptions. The most important argument against is that cost efficiency requires that all actors meet the same tax rate on CO<sub>2</sub> emissions. However even if the external effects are not taken into account it could be argued that an efficient allocation of available energy requires that all actors meet the same prices on energy. Otherwise the available energy will not be allocated to its most valuable use.

Whether tax exemptions are efficient or not is an empirical question. Several studies have found that tax exemptions for manufacturing are inefficient if carbon leakages are not taken into account. (Bye & Nyborg 2003, Böhringer & Rutherford 1996, Hill 2001). An exception is Söderholm & Hammar (2005) who do not find any positive welfare effect from removing the tax exemptions. Harrison & Kriström (1997) found in their CGE analysis that increasing taxes for manufacturing would not lower global emission of CO<sub>2</sub> due to the carbon leakage effect. Nilsson (1999) finds in the multi-country model GEM-E3 that tax exemptions are not reducing costs for reducing CO<sub>2</sub> emissions even if carbon leakages are taken into account. The conclusion from our study is, however, that the tax exemptions increase costs significantly.

Broberg et al, (2008) find it more cost efficient to increase taxes for industry than increasing them for households and services. (Broberg et al 2008). In their simulation they increase the CO<sub>2</sub> tax in manufacturing from 25 % to 30 % of the household's tax rate. They do not however simulate the effects of a total equalisation of the tax rates on energy. In their analysis only the GDP effect is reported and not the impact on welfare measures, such as

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<sup>3</sup>Swedish governmental report 2003:38 page 442

Equivalent Variation and National Income. Therefore they do not take terms of trade effects or effects from net capital income to other countries into account and therefore they probably underestimate the national benefits from increases in energy taxes for manufacturing.

There seems to be considerable divergences in the results from different models. Thus more research is needed to find out what specific feature of the models that is crucial for these divergences.

The purpose of this paper is to analyse the efficiency of the energy taxes in Sweden, specifically whether it is cost efficient to have tax exemptions for manufacturing. The analysis is based upon data from 2001. It is analysed whether it would have been possible for Sweden to reduce global emissions at a lower cost by taxing industry as heavily as households and services and by higher tax rates on electricity. The situations before as well as after the introduction of the emission trading system in EU are analysed. Moreover the effect from the introduction of ETS as such is analysed, since a dataset is needed equal to the dataset of 2001 in all aspects but for the presence of an international trading system in CO<sub>2</sub>. Moreover, increasing CO<sub>2</sub> taxes is compared with decrease domestic supply of allowances as a mean to reduce global CO<sub>2</sub> emissions from a cost efficiency perspective.

A country can indirectly levy a tax on emissions in other countries through a tax on commodities that are intense in the use of fossil fuels in production. Such a tax has an effect on the foreign countries if net trade is affected. For instance, a national tax on the use of electricity in Sweden would be a way to tax carbon emissions in other countries belonging to the Nordpool electricity market.

The effect of the electricity tax on carbon emission has changed completely after the introduction of ETS. Every reduction in CO<sub>2</sub> emissions from electricity generation will be offset by an increase in emissions from the firm that the electricity producer sells its allowances to.

Beside the environmental effect a tax on electricity could also reduce the distortion on international trade from the tax on fuel oil if it makes the relative price between electricity and fuel oil closer to their relative price in the world market.

Burniaux and Martins (2000) have studied carbon leakage from the Kyoto protocol in a global model with two regions i.e., participating and non-participating countries. They study how the size of carbon leakages depends on the values of different parameters in the model. They found that with a supply elasticity of coal between 0 and 2 the direct carbon leakage effect varies between 20 % and 100 % of the domestic emission reduction.

In the analysis of carbon leakage in this paper direct leakage is ignored since the reallocation of production that the tax exemptions are supposed to prevent has an impact on indirect leakages only. The impact on world market prices of fossil fuels from an increase in the production of energy intense goods would be the same regardless of in what part of the world the production is increased.

One contribution of the paper is the way of modelling trade margins that makes it possible to calibrate the model with physical quantities even when different actors meet different unit prices. This makes it possible to report unit tax rates in physical units, and the results would be much more reliable since the price structure in the model comes closer to the price structure in reality.

Section two describes some important features of the model. In section three we use an applied CGE model to analyse whether the Swedish structure of carbon and energy taxes in year 2001 was efficient or not. Three hypotheses are evaluated. The first hypothesis is that all actors should meet the same tax rate on fossil fuels, the second that all actors should meet the same tax rate on electricity and the third that the relation between the tax rate on fossil fuels and the tax rate on electricity was not optimal in 2001. One argument for using higher taxes on electricity is to avoid carbon leakage. Another argument comes from trade theory. Since electricity and fossil fuels are close substitute the relative prices between them should reflect their relative price on the world market if we should use our comparative advantage optimally. Simulations of different tax schemes with more equal tax rates for different users and a different relative taxation of electricity and fossil fuels are carried out. We show that these different tax schemes would have been welfare improving, i.e. raising domestic income at a given global emission level.

In section four we introduce emission trading into the model to simulate the effect of ETS to the Swedish economy. We compare the effects of ETS with an alternative more stringent

trading system, a system where the price of the allowances is higher. We also analyse the effects of altering domestic supply of allowances. In section five we return to the tax exemptions to examine whether the introduction of ETS has changed the conclusions from section three. Section six analyses the optimal supply of allowances to domestic firms and section seven concludes.

## **2 The model**

The model used in this study is a static small open economy computable general equilibrium (CGE) called SAINT<sup>4</sup> calibrated with Swedish data from 2001 (Bohlin 2009c). The dataset has 15 industries producing 24 commodities. For details about calibration and data see appendix 1 and Bohlin 2009c. In this section some of the key features in SAINT that are important for this kind of study are described. For a complete mathematical formulation of the model see Bohlin 2009b.

### **2.1 Modelling a small open economy with carbon leakage**

SAINT is based upon the small open economy assumptions. That is world market prices are assumed to be unaffected of what happens within the country so that the domestic economy will be able to import and export unlimited amounts to the fixed world market prices. International trade is modelled with the Armington/CET assumptions (Armington 1969), i.e. imports are assumed to be imperfect substitutes to domestic production and exporting is assumed to be an imperfect substitute for selling domestically. The elasticities in the trade equations are found in appendix 1

In the balance of payments, factor income from abroad is assumed to be unaffected of the domestic policy while factor payments to other countries depend on the domestic capital return and wage levels.

To calculate indirect carbon leakages through international trade it is assumed that foreign consumption of different commodities is not affected by developments in Sweden. Therefore the changes in net trade of different commodities are used as a measure of the imposed change in foreign production. The measure used in this study could be considered as an upper bound of the carbon leakages effect under the assumptions that all adjustments in foreign countries are on the production side.

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<sup>4</sup> SAINT is a development of the IFPRI Standard model (Lofgren et al 2002).

By making assumptions about technologies abroad the change in emissions because of to a change in foreign production can be calculated. In our study, Swedish technology is assumed for all commodities except for electricity where marginal Danish technology is assumed. The CO<sub>2</sub> content of marginal production is equal to 835 kg / MWh<sup>5</sup>. This corresponds to about 80 percent of the carbon content in coal condensing power plants (Werner 2001), which almost always is the short run marginal production in Denmark and Germany. For details about the calculation of carbon emissions see appendix 2.

After the introduction of ETS it becomes a little bit more difficult to calculate carbon leakage. In this paper we assume that carbon leakage for commodities included in the in ETS is equal to 100 percent. That would for example be the case if reduced production in Sweden lead to an equally high increase within the European Union from firms that by the allowances that the Swedish firms can sell. Since the carbon leakage from ETS sectors would be equal but with the opposite sign as domestic emission in ETS sectors these sectors are not included in the calculation of emissions. Total emissions are calculated as the sum of domestic emissions in non ETS sectors, carbon leakage from non ETS sectors and the domestic supply of allowances.

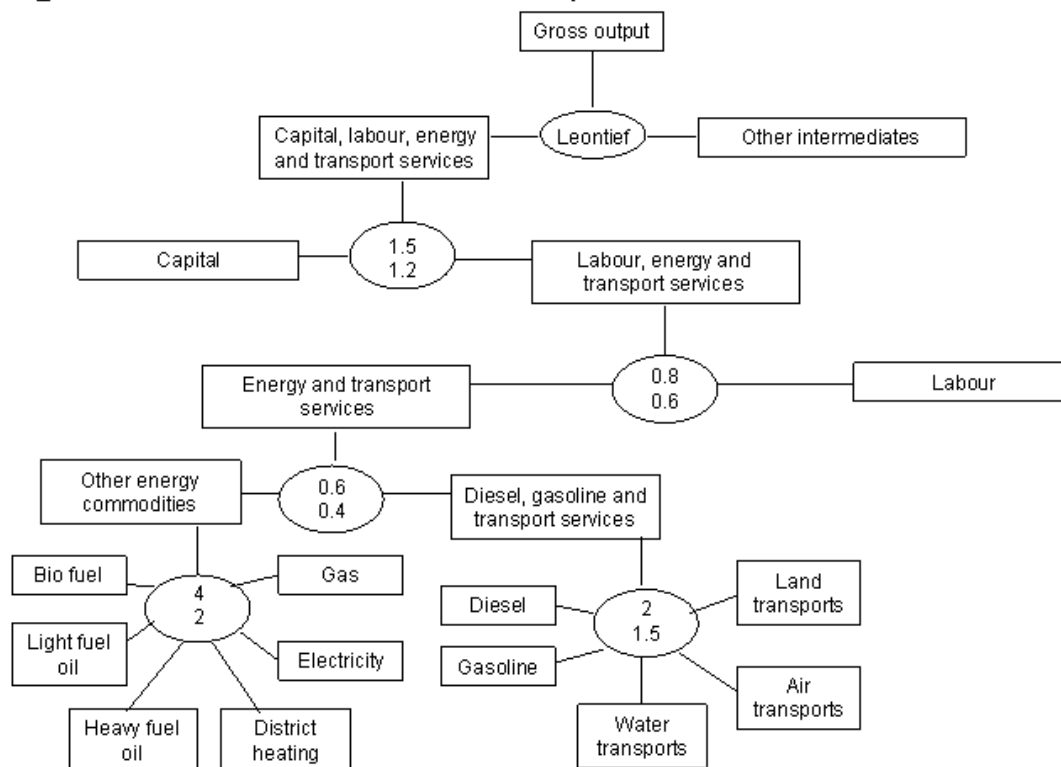
## 2.2 Production functions

The production functions in the model are nested CES functions. Figure 2.1 shows their structure. The numbers within the circles refer to the elasticities of substitution and are assumed to be the same in all industries at the referred level. Other intermediates consist of all intermediate goods except energy and transport services and are assumed to be used in fixed proportions to output, i.e., under Leontief technology. Transports and energy commodities are divided into two commodity groups. One first group consists of *diesel, gasoline and transport services* and the second of *other energy commodities*.

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<sup>5</sup> This number is used by Statistics Denmark.

**Figure 2.1 Nest structure of the production functions**



The numbers in the ellipses refers to the elasticity of substitution between each aggregate. The top number in the long run elasticity and the bottom number is the short run elasticity.

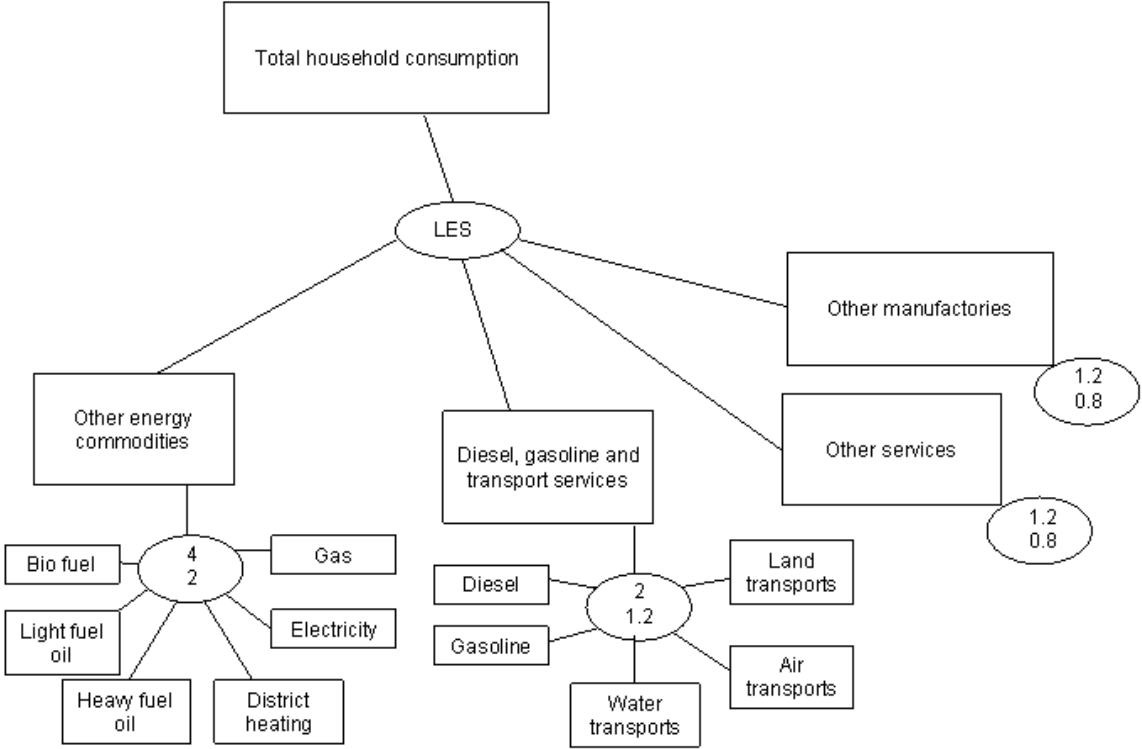
Choosing a set of reasonable elasticities for the a CGE model cannot be based solely on econometric estimates, as these are derived from historical data and specific contexts so that estimates from different sources may not be consistent with each other. The motives for the choice of the elasticities for the reference case are the following. Labour and energy are assumed to be easy to substitute with capital in the long run, which is reflected by the 1.5 in that nest. Also, in the long run it should be even easier to substitute between different kinds of heating system thus the 4 for other energy. However, it is assumed to be more difficult to substitute between labour and energy. For the elasticity of substitution between different transports, a compromise of 2 is made between, on the one hand, the easiness of substituting in-house transport (consumption of diesel) and purchased transport services, on the other hand, the difficulty of substituting sea transport for land transport.

Some industries are producing more than one commodity. In these cases the output of an industry always consists of the same shares of different commodities produced in the industry. However this is in quantity terms so changes in relative prices may have an impact on the income share from different outputs in an industry.

### 2.3 Household consumption and labour supply

On the consumption side there is just one representative household in the model. Consumer behaviour is described in figure 2.2. It is modelled as a LES-CES nested system with a LES system at the top aggregating together four commodity groups. One commodity group consists of *diesel gasoline and transport services* and the other three are *other energy commodities*, *other manufactories* and *other services*. Within these four aggregates there are CES equations.

Figure 2.2 Nest structure of the consumption functions



The numbers in the ellipses refers to the elasticity of substitution between each commodity. The top number is the long run elasticity and the bottom number is the short run elasticity.

Since the elasticity of substitution between the four different commodity groups probably is fairly low, the Frisch parameter in the LES system is -2 giving a rather high proportion of subsidiary consumption.<sup>6</sup> The elasticity of substitution within the heat and transports aggregates follows the reasoning in the production functions whereas the elasticity of

<sup>6</sup> In a LES system some parts of the consumption of every commodity is fixed, the so called habit or subsidiary consumption, while the rest of the consumption have fixed proportions of the part of the expenditure that is not used for subsidiary consumption. The Frisch parameter determines the share of subsidiary consumption.

substitution with the other two aggregates are assumed to be lower since they are more heterogeneous.

Labour supply is assumed constant regardless of the real wage. The double dividend hypothesis is thus ruled out by assumption. If real wages have an impact on labour supply the model will thus underestimate welfare gains in simulations where the tax rate on labour is reduced.

## **2.4 Modelling trade margins and commodity taxation**

SAINT is developed with the purpose of being as consistent as possible with the system of national accounts. In national accounts the payments in the economy is reported both in purchaser prices, i.e. the amount of money paid by the final user, and divided into trade margins that goes to the retail sector, taxes that go to the governmental sector and payments at basic prices i.e. the part of the price that ends up with the producer. This structure is also followed in SAINT and this feature is the main difference between SAINT and other environmental CGE models.

Keeping track of trade margins in an appropriate way is important in a study of unit taxes since the size of the trade margins will determine the percentage cost increase from a specific unit tax rate. Moreover, an appropriate modelling of trade margins will improve the possibilities to calibrate the model from data over physical quantities and not only from monetary payments, a feature that is very important in environmental models where physical quantities are as important as monetary payments.

To understand the importance of trade margins consider the data over the use of electricity in the pulp and paper industry and the household sector presented in table 2.1. From the third row in table 2.1 we can see that average prices differ quite a lot between households and the pulp and paper industry. In most CGE models prices are assumed to be equal for all users and are normalised to 1, i.e. the quantity unit would be equal to the quantity that is purchased for one million SEK. From the fourth row of table 2.1 we can see that such a procedure would make very large difference in the quantity units for different actors in terms of GWh.

Using the technique of normalising prices to one we would not be sure that supply would equal demand in physical terms but only in money terms. It would be difficult to calculate the total use of electricity in physical terms. It would also be difficult to define an equal unit tax rate per GWh since that tax rate must differ between different users.

Table 2.1 Electricity prices and use 2001

	Sector	
	Pulp and paper	households
Use of electricity in GWh	21 662	41 127
Amount of money spent (million SEK)	4 591	37 991
Taxes (million SEK)	106	14 991
Amount of money spent less taxes (million SEK)	4 485	22 950
Average price less taxes (SEK per kWh)	0.21	0.56
Amount of electricity purchased by 1 million SEK (GWh)	4.8	1.8

To deal with this problem SAINT is constructed to allow price differences between different actors not explained by tax differences. This is done by including a trade margin that may differ for different users. To illustrate the role of the different kinds of taxes and the trade margins in the determination of purchaser prices consider equation (1). This equation is the household demand equation for a specific commodity.

$$(1 + tv_{c,h}) (PQ_c + tq_{c,h} + TM_{c,h}) = QCGH_{h,cgh} \cdot PCGH_{h,cgh} \cdot \left( \sum_{c' \in C'} \delta_{h,c',cgh}^{cgh} \cdot QH_{h,c',cgh}^{-\rho_{h,cgh}^{cgh}} \right)^{-1} \cdot \sum_{c \in C} \delta_{h,c,cgh}^{cgh} \cdot QH_{h,c,cgh}^{-\rho_{h,cgh}^{cgh} - 1} \quad (1)$$

Where:

- $EH_h$  = household consumption expenditure in household  $h$
- $PQ_c$  = basic price for commodity  $c$
- $tq_{c,h}$  = the unit tax rate for commodity  $c$  and household  $h$
- $TM_{c,h}$  = the Marginal Trade Margin for commodity  $c$  and household  $h$
- $tv_{c,h}$  = the ad valorem tax rate for commodity  $c$  and household  $h$
- $QH_{h,c,cgh}$  = the quantity demanded for com.  $c$  and household  $h$  in commodity group  $cgh$

$QCGH_{h,cgh}$  = the quantity of commodity group  $cgh$  consumed by household  $h$

$PCGH_{h,cgh}$  = the price of aggregate  $cgh$  consumed by household  $h$

$\delta_{h,c,cgh}^{cgh}$  = share parameter in the CES utility function within the commodity group  $cgh$  for household  $h$

$\rho_{h,cgh}^{cgh}$  = exponent in the in the CES utility function within the commodity group  $cgh$  for household  $h$

The left hand side of equation (1) is the purchaser price of the commodity. It is determined from the basic price that is the same for all users and from the user specific tax rates and trade margins. The benefit of this way of modelling is that the model can be calibrated from data over physical energy use in different sectors and that statutory tax rates can be used.

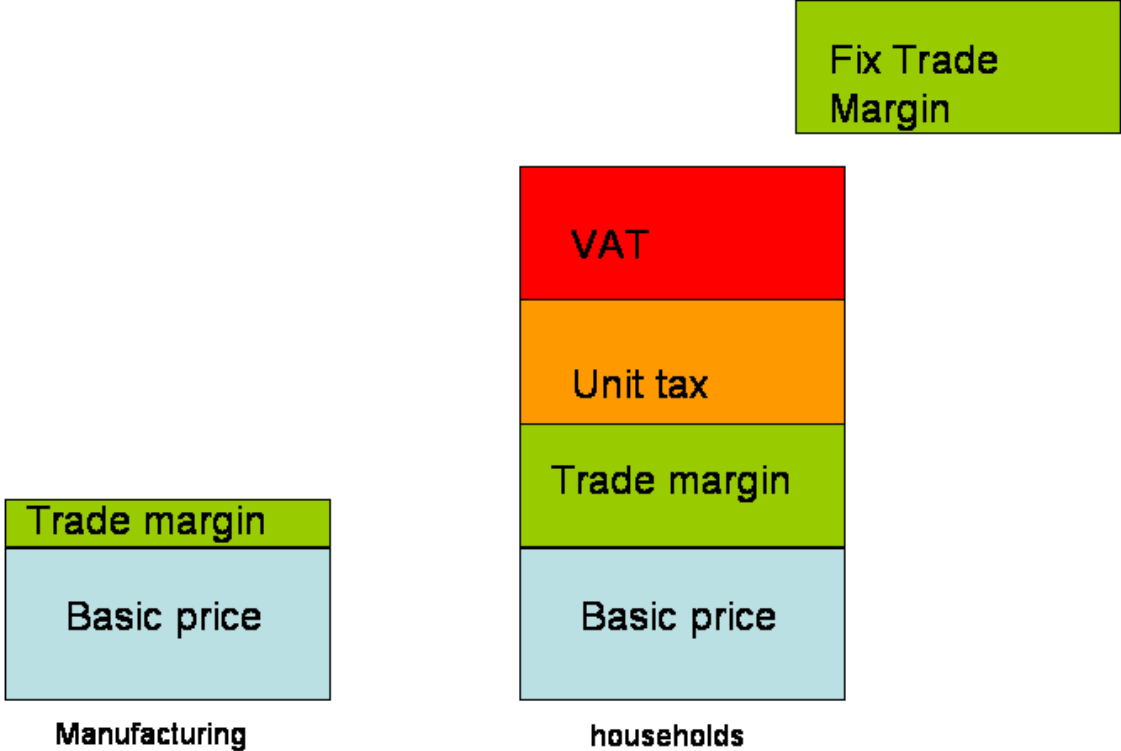
Equation (1) is calibrated in two different ways for different kinds of commodities. For commodities with known physical units, which are most of the energy commodities, the procedure is the following: Starting from the matrix of unit taxes and the known tax rates, the used quantity of each user is calculated as the tax payment divided by the tax rate. Multiplying this with an assumed basic price gives the new rows in the use matrix at basic prices. Trade margins are calculated by subtracting the matrices of taxes and the new use table at basic prices from the original use matrices at purchaser prices.

For fossil fuels the basic price is chosen in a compromise between getting a small difference in total trade margins on fossil fuels from original data and minimizing the number of sectors with negative trade margins. In the original data there are no trade margins on electricity, probably due to that retail sellers of electricity are classified in the same industry code as the producers. For electricity the basic price is chosen in order to minimizing the number of sectors with negative trade margins. For industry 40, supply of electricity, gas, steam and hot water, the supply of electricity is reduced and the supply of trade margins (retail services) is increases to get balance in the supply and use of trade margins. For the rest of the commodities trade margins from national accounts are used.

For commodities where the trade margins are more then 30 percent of the basic price the individual trade margin divided into a marginal trade margin equal to 30 percent of the basic price and a fixed trade margin treated as pure transfer not dependent on the quantity

purchased.<sup>7</sup> A fixed trade margin could for example be interpreted as the fixed cost in an electricity contract.

**Figure 2.3 Prices in SAINT**

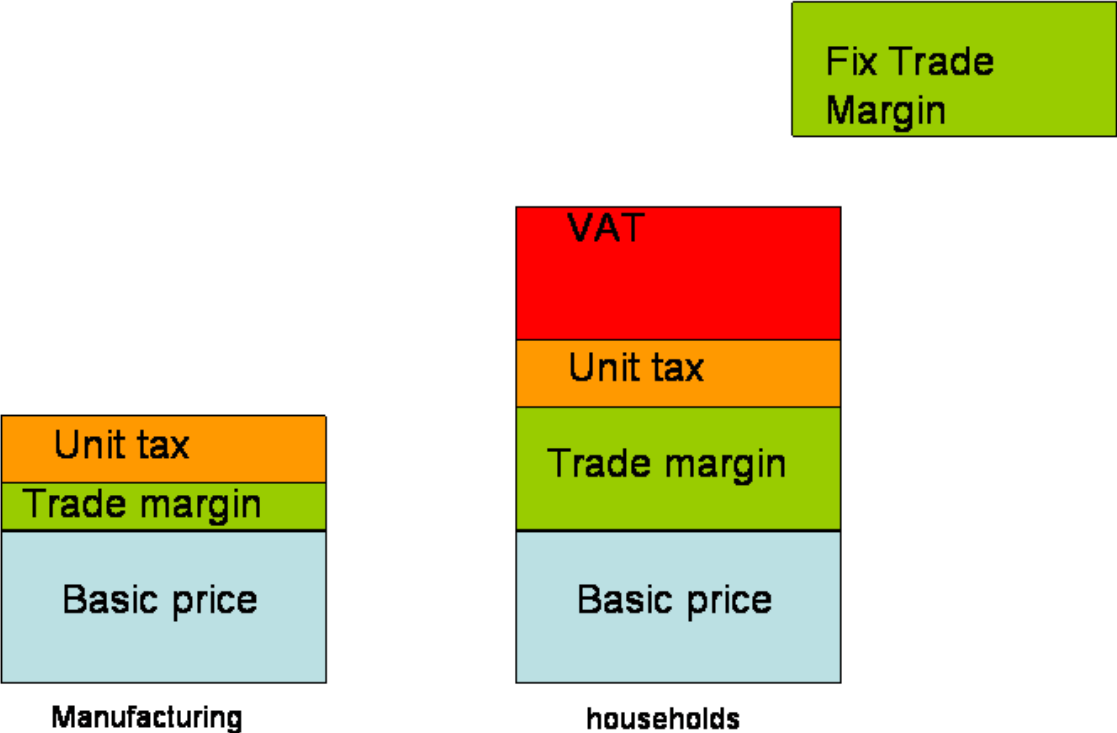


The price structure of SAINT is illustrated in figure 2.3. The price consists of four parts, the basic price, the trade margin, the unit tax and the value added tax. The taxes do not appear in the stable for the pulp and paper industry since their tax payments are almost zero. The trade margins are divided into a fix part and a part that is related to the purchased quantity. The Fix trade margins are not a part of the stable illustrating that it does not have an impact on the marginal cost of electricity.

<sup>7</sup> There is also a sensitivity analysis made where the marginal trade margin are reduced to maximum 10 percent of the basic price.

Figure 2.4 illustrates the equalization of energy taxes. It can be seen that even after the equalization there is large price differences between households and industry. It can also be seen that even if the unit tax on electricity is equal for manufacturing and household in terms of SEK per kWh it makes up a much larger percentage share of the price in manufacturing. Thus the results in this study cannot be compared with the result from studies where an ad valorem tax on energy is equalized. Since the trade margin have the same effect on household behaviour as a pigovian tax, households have still higher incentives to cut down on the use of electricity than manufacturing even after the tax equalization. This is important to keep in mind when the result of this study is compared with analyses that ignore the impact from trade margins.

**Figure 2.4 Tax equalization**



## 2.5 Modelling emission trading

Following the small open economy assumption the domestic economy cannot influence the price of the permits that are exogenously given. To simplify the model the permits is modelled as an increase in the unit tax on fossil fuel. Since emission trading does not give any income to the government a transfer is made from the government to the capital owners in the industries included in the emission trading system. (In the following these industries will be referred to as the ETS industries.) The size of the transfer to each industry is equal to the price of the permits times the amount of permits each industry receives. The difference between total emissions in the ETS industries and domestic supply of permits gives the net export in permits. This net export gives a payment to the government from the rest of the world. Thus the government revenue from the extra tax is exactly equal to its cost for the transfer to the capital owners and to the rest of the world and the governmental budget is unaffected from emission trading.

There are several limitations of the model due to the simplifications made. This way of modelling assumes that there are no political economic causes from changes in the price of the permits. If cost efficiency is an issue when designing climate policy politicians would be more willing to decrease the total quota if the price of the permits decreases compared to the Pigovian taxes used in other sectors. Thus this assumption may not hold in reality. The model also assumes that the initial distribution of permits is made in a way that does not influence behaviour. This is certainly not the case in the real ETS system, since exiting plants does not keep their permits and entrants may receive permits. In the model an industry must be classified as either an ETS industry or a non ETS industry. In reality most industries consists of both ETS plants and non ETS plants. For this reasons the results of this study cannot be interpreted as the impact of the ETS system that was actually introduced, but the results can give qualitative results about how to design tax rules when some parts of the economy take part in an emission trading system and some parts do not.

### **3 Domestic climate policy before ETS**

In this section we consider the situation before the introduction of ETS. In the simulations presented here the impact of the tax exemptions on energy and carbon taxes on fossil fuels for manufactories is evaluated. Actual tax rates are used as base and the impact from changing them are reported for different tax levels. The tax rates reported in the table are the total unit tax rates on different kind of energy, i.e. both the part that is called energy tax and the part that is called carbon tax. The tax rates on fossil fuels are equal for all users in all simulations.<sup>8</sup> Simulations 3 and 5 are also based on equal tax rates on electricity for all users while the other simulations assume actual tax rates on electricity.

In all experiments government consumption is held constant in quantities while labour taxes are adjusted in order to hold government budget surplus unaffected, i.e. taxes are shifted between energy and labour. In the balance of payments foreign saving is fixed. Investments are also fixed in quantities meaning that household savings are adjusted as much as needed to finance investments when prices of investments goods are changing. Internal and external equilibrium is achieved by changing the household's marginal propensity to save. The governmental budget is balanced through changes in the tax rate on labour income. Using labour taxation for the revenue recycling of carbon taxes is very common in the literature (Bye and Nyborg 2003).

The main motivation for holding foreign savings, government consumption and domestic investment fixed is to simplify evaluation of welfare effects. If the accumulation of foreign and domestic assets as well as government consumption is constant all welfare effects will come through changes in household consumption and emissions. A drawback of this is that we cannot analyse the ability of the Swedish economy to attract foreign capital. A sensitivity analysis over this macro closure is therefore made in section 3.2. The simulations are made both in the long and the short run. In the long run elasticities in the production and household demand functions are high and capital can move between industries. In the short run elasticities are lower and capital stocks fixed at the industry level.

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<sup>8</sup> It should be noted here that an equal unit tax rate does not imply an equal ad valorem tax rate if different users meet different prices. In this study the unit tax rates are equalized implying that the tax paid of households, that typically meet higher prices than large industries, makes up a smaller percentage share of the total cost. The result can thus not be totally compared to studies where the ad valorem tax rates are equalized for different actors.

In Table 3.1 the tax rates in five simulations are reported. The tax schemes are chosen in order to evaluate our three hypotheses. Hypothesis 1 that all actors should meet the same tax rate on fossil fuels is evaluated with simulation 1, 2 and 4. Simulation 3 and 5 are chosen in order to evaluate the other two hypotheses, that all actors should meet the same tax rate on electricity and that the relation between electricity taxes and taxes on fossil fuels were not optimal at this time.

The tax rates of simulation 1 are chosen in order to hold national income constant in the long run simulation. In simulations 2 and 3, household consumption valued as equivalent variation is held constant. In simulations 4 and 5 global emissions of CO<sub>2</sub> are held constant and the potential increase in household consumption from a more efficient tax structure is measured. In simulation 3 and 5 also the tax rates on electricity is equalized for all users. The level of the electricity tax is chosen in an effort to maximize the global emission reduction for a specific level of consumption. In simulation 3, the tax on electricity is higher than the base rate for all users. In simulation 5, the electricity tax is reduced for households and services and increased for manufactories.

Table 3.1 Tax rates in simulations

Tax item	Tax rates in base model*	Simulations				
	Households & services / most manufacturing	(1)	(2)	(3)	(4)	(5)
gasoline	4.50 / 4.50	4.39	4.29	4.12	3.70	3.71
diesel	3.39 / 3.39	3.29	3.19	3.02	2.60	2.61
light fuel oil	2.21 / 0.38	2.09	1.99	1.82	1.40	1.41
heavy fuel oil	2.28 / 0.42	2.19	2.09	1.92	1.50	1.51
gas	1.37 / 0.29	1.46	1.39	1.27	0.98	0.99
electricity	0.18 / 0.00	b	b	0.33	b	0.10

\*Tax rates for other users in base model see table A3.1 in appendix 3.

b = the same tax rates as in the base model.

The results are reported in table 3.2. The top number in each cell refers to the long run effect and the bottom number refers to the short run effect. The changes in CO<sub>2</sub> emissions are reported as global change, national change, impact through international trade in electricity, and, finally, impact from international trade in non-energy commodities. The changes in national emissions are calculated from the changes in the use of diesel, gasoline, fuel oil and gas. Other sources of CO<sub>2</sub> are ignored.

Total domestic emissions of CO<sub>2</sub> are in the base model equal to 34 millions tonnes. That is roughly half of total emissions in reality. The divergence could be explained from the fact that not all sources of CO<sub>2</sub> are taken into account and errors in data. Since emission of CO<sub>2</sub> is calculated from taxes actually paid, tax evasion and some tax reductions not taken into account may also explain part of the divergence<sup>9</sup>.

In all simulations, the carbon leakage from trade in non-energy commodities is small. The carbon leakage through trade in electricity is more important for the impact on global emissions. In simulations 1 and 2 the high CO<sub>2</sub> taxes increase the use of electricity and thus CO<sub>2</sub> emissions in foreign electricity production. Simulation 2 shows that it would have been possible to reduce global CO<sub>2</sub> emissions with 9 million tonnes without any loss in welfare if the tax rates between manufacturing and households were equalized. In simulation 3, carbon leakage through electricity trade decreases significantly from the increase in the electricity tax. In simulation 3 the costless reduction is 13 million tonnes, more than one third of total domestic emissions in the model.

GDP is deflated both with the GDP deflator and with CPI. The reason for including a measure of GDP deflated with another deflator than the GDP deflator is to make it possible to decompose the difference between national income and domestic production into the effect that comes from net factor income from abroad and the effect that comes from changes in relative prices, the “terms of trade” effect.<sup>10</sup> GDP deflated with the GDP deflator is almost not influenced at all while GDP deflated by CPI increases nearly as much as national income. This gives an illustration of the fact that the difference between national income and domestic product is to a large extent caused by different deflators, i.e., more than by net factor income from abroad. Net factor income from abroad decreases since a part of the increase in capital income falls on foreign capital owners. But national income increases much more than GDP since the terms of trade improve. With a more efficient tax structure Sweden would produce almost the same quantity but would be better paid for it and would be able to import a larger

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<sup>9</sup> We study the industry specific reductions of energy taxes, within each industry there are also some firms getting even higher reductions due to extra energy intensity in their production.

<sup>10</sup> It may come as a surprise that it is possible to get terms of trade effects in a small open economy model with fixed world market prices. But the price development of domestic production plus export may differ from the price development of domestic production and import since the Armington assumption changes the quantity units when we move away or towards the optimal mix of imports and domestic production. If one unit of an imported commodity doesn't add as much to the quantity of the composite good as before the price of the composite good may change even if the world market price is unchanged.

quantity of goods so that household consumption could increase. With less disturbed relative prices the country would make better use of its comparative advantages.

Table 3.2 Results

Variable	Simulations				
	(1)	(2)	(3)	(4)	(5)
<b>CO<sub>2</sub> emissions</b>					
Changes in thousand tonnes					
Domestic	-12 363 -8 491	-11 247 -7 723	591 -2 677	-2 477 -2 279	-3 900 -2 483
trade in electricity	1 602 5 198	1 648 4 973	-16 540 -20 096	1 958 3 413	2 821 3 274
other trade	283 454	294 411	2 716 1992	485 131	1 065 702
global	-10 478 -2 840	-9 304 -2 338	-13 234 -20 781	-33 1 266	-15 1 493
<b>Economic variables</b>					
Percentage changes					
National income	0.00 0.12	0.44 0.50	0.87 0.51	3.15 2.80	3.00 2.76
GDP, deflated by CPI	0.02 0.15	0.50 0.57	0.90 0.51	3.50 3.12	3.33 3.08
GDP, GDP-deflator	-0.14 -0.12	-0.07 -0.07	-0.13 -0.27	0.45 0.26	0.54 0.35
Private Consumption	-0.02 0.22	0.55 0.70	1.44 1.05	4.16 3.65	4.02 3.63
Equivalent Variation*	-0.25 -0.16	0.00 0.03	0.00 -0.16	1.54 1.13	1.87 1.50
Exchange rate**	0.29 0.44	0.73 0.83	1.38 1.26	3.50 3.26	3.71 3.67
Gross real wage	-0.09 -0.14	0.40 0.32	-0.19 -0.78	3.54 3.19	3.37 3.15
Disposable Real wage	-0.12 1.20	0.94 2.35	3.07 6.49	7.49 6.52	7.28 1.20
Labour tax	0.02 -0.34	-0.39 -0.63	-2.36 -2.29	-2.76 -2.31	-2.74 -2.37
Capital return	0.17 0.25	0.64 0.68	0.26 -0.14	3.62 3.34	3.37 3.24

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect. All variables are deflated with CPI if not else specified.

\*Calculated as EV / household consumption in the base model.

\*\*SEK / Foreign currency

From simulation 5, we see that the cost of the inefficient structure of energy and CO<sub>2</sub> taxes is about 1.9 percent of household consumption measured as equivalent variation. The loss in National income is equal to 3 percent. The welfare differences between simulation 4 and 5 are small and differ between different measures. Evaluated with national income, the electricity

tax rates that were actually used in 2001 is preferred while instead using equivalent variation as criterion implies that the tax rate of simulation 5 is preferred.

Both wages and capital return increases with more than three percent in simulation 4 and 5. The tax cut on labour give higher increase in disposable wage than in gross wage. If we instead chose to decrease taxes on capital the outcome would be the opposite. Note that labour supply is constant in the model. If real wages have an impact on labour demand the positive welfare effects in Simulation 3, 4 and 5 are underestimated.

The short run effects are in most cases smaller than the long run effects. One exception is carbon leakages from trade in electricity that are higher in the short run. The reason for this is that in the long run, when domestic capital stock is reallocated, the change in the use of electricity changes domestic electricity production more than net export.

### **3.1 Winners and losers**

In the long run analysis when capital is reallocated the return to capital is equal in all industries. In the short run it may differ though and we can use the short run operating surplus in different industries to see how the overall gains for capital owners are distributed. The short run operating surpluses in different industries are reported in table 3.3. In simulation 4 and 5 all industries except distribution of natural gas will benefit from the tax reform. Noteworthy is that this industry is the industry that has the largest benefit in the simulation 3 with highly increased taxes on electricity.

Disaggregating the wage effect to different industries is not possible in the model since the model assumes an equal wage throughout the economy. It is however possible to distinguish winner from losers from the reallocation of the fixed labour supply between different industries in the long run simulation. Those industries that increase their use of labour would in reality probably need to pay higher wages than those that reduce their labour use. Note though that even industries in the latter category may pay higher wages in simulations 4 and 5 than they do in the base model since the overall wage level increases. The long run percentage change in the use of labour is reported in table 3.4.

Table 3.3 Short run percentage change in operating surplus

Industries	Simulations				
	(1)	(2)	(3)	(4)	(5)
A01 Agriculture, forestry, fishing	-0.28	0.17	-1.42	2.97	2.62
A10 Mining	-3.63	-2.63	-0.94	3.95	2.76
A15 Manufacture of food textile and wearing apparel	0.28	0.81	1.89	4.04	4.83
A20 Manufacture of wood, paper, publishing	0.05	0.49	-0.47	3.22	2.70
A23 Manufacture of coke & refined petroleum products	-7.60	-4.68	15.60	15.52	11.41
A24 Manufacture of chemicals metals and metal products	-0.10	0.28	-0.94	2.65	2.64
A30 Manufacture of machinery and furniture	1.77	2.02	5.80	3.52	5.78
A40 Electricity, steam and hot water supply	9.49	9.30	-5.58	7.70	4.44
A402 Supply of gas	-32.12	-29.21	18.37	-9.94	-6.21
A41 Distribution of water. Construction	-0.10	0.29	-0.72	2.64	2.51
A50 Retail trade, Hotels and restaurants, financial services	0.15	0.61	-0.38	3.46	3.24
A60 Transports	-0.36	-0.26	-2.78	0.32	0.24
A70 Real estate activities, Renting of equipment, R&D	0.07	0.53	0.37	3.40	3.55
A75 Public services	-0.06	0.39	-0.36	3.18	2.97
A90 Other service activities	-0.03	0.47	0.13	3.53	3.21

For a more complete description of the industries in each aggregate see appendix 1

Table 3.4 Long run percentage change in employment

Industries	Simulations				
	(1)	(2)	(3)	(4)	(5)
A01 Agriculture, forestry, fishing	-1.30	-1.01	-2.75	0.84	-0.34
A10 Mining	-12.58	-9.66	17.86	14.94	2.68
A15 Manufacture of food textile and wearing apparel	-0.58	-0.38	0.30	0.83	1.03
A20 Manufacture of wood, paper, publishing	-0.52	-0.50	-4.25	-0.34	-2.60
A23 Manufacture of coke & refined petroleum products	-12.86	-8.99	30.87	23.30	6.75
A24 Manufacture of chemicals metals and metal products	-0.95	-0.99	-4.40	-1.26	-2.35
A30 Manufacture of machinery and furniture	1.93	1.69	7.96	-0.02	3.77
A40 Electricity, steam and hot water supply	9.93	9.15	-24.57	2.80	1.27
A402 Supply of gas	-57.77	-54.60	44.17	-29.13	-20.70
A41 Distribution of water. Construction	0.06	0.02	-0.03	-0.22	-0.27
A50 Retail trade, Hotels and restaurants, financial services	0.08	0.13	-0.02	0.47	0.37
A60 Transports	-1.63	-2.12	-5.66	-5.05	-5.47
A70 Real estate activities, Renting of equipment, R&D	0.13	0.17	0.61	0.37	0.63
A75 Public services	0.03	0.03	0.35	0.02	-0.08
A90 Other service activities	-0.02	0.08	0.58	0.68	0.68

For a more complete description of the industries in each aggregate see appendix 1

In table 3.5 the production, use and net export of electricity is reported. The changes are small in all simulations but simulation 3. Here it can be seen that simulation 3 both decreases global carbon emission at no cost and at the same time reduces domestic production of electricity with 31 TWh, or nearly half of the nuclear power. Simulation 3 also shows a strange feature of the Armington model of international trade. Net export of electricity is not equal to the difference between import and export in simulation 3. When we move away from the optimal mix between domestically produced power and imported power more power is needed to satisfy the same need. The net export of 24 TWh (55 – 31) therefore diminishes to 20.

Table 3.5 Change in production and use of electricity, TWh

	Simulations				
	(1)	(2)	(3)	(4)	(5)
Domestic electricity use	16 7	15 7	-55 -38	7 5	5 4
Domestic electricity production	14 1	13 1	-31 -10	4 1	2 0
Net export in electricity	-2 -6	-2 -6	20 24	-2 -4	-3 -4

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect.

These simulations indicate that the tax exemptions for industry were inefficient. But would it have been a good idea to have smaller tax exemptions? In table 3.6 and 3.7 simulation 3 and 5 are compared with simulations with small tax reductions in industry. Here the tax reductions cover all industries and not only manufacturing.

Table 3.6 Tax rates in simulations

Tax item	Tax rates in base model*	Simulations			
		(3)	(3b)	(5)	(5b)
	Households & services / manufacturing	all	households / firms	all	households / firms
gasoline	4.50 / 4.50	4.12	4.18 / 4.01	3.71	3.78 / 3.63
diesel	3.39 / 3.39	3.02	3.08 / 2.91	2.61	2.68 / 2.53
light fuel oil	2.21 / 0.38	1.82	1.88 / 1.71	1.41	1.48 / 1.33
heavy fuel oil	2.28 / 0.42	1.92	1.98 / 1.81	1.51	1.58 / 1.43
gas	1.37 / 0.29	1.27	1.32 / 1.20	0.99	1.04 / 0.93
electricity	0.18 / 0.00	0.33	0.35 / 0.31	0.10	0.12 / 0.08

\*Tax rates for other users in base model see table A3.1 in appendix 3.

Table 3.7 Results

Variable	Simulations			
	(3)	(3b)	(5)	(5b)
<b>CO<sub>2</sub> emissions</b>				
Changes in thousand tonnes				
domestic	591 -2 677	1 175 -2 299	-3 900 -2 483	-3 762 -2 318
trade in electricity	-16 540 -20 096	-16 425 -20 013	2 821 3 274	2 792 3 514
other trade	2 716 1 992	2 633 1 887	1 065 702	928 581
global	-13 234 -20 781	-12 617 -20 425	-15 1 493	-42 1 777
<b>Economic variables</b>				
Percentage changes				
National income	0.87 0.51	0.72 0.35	3.00 2.76	2.81 2.56
GDP, deflated by CPI	0.90 0.51	0.73 0.33	3.33 3.08	3.12 2.85
GDP, GDP-deflator	-0.13 -0.27	-0.10 -0.24	0.54 0.35	0.53 0.34
Private Consumption	1.44 1.05	1.29 0.87	4.02 3.63	3.81 3.40
Equivalent Variation*	0.00 -0.16	0.00 -0.19	1.87 1.50	1.81 1.42
Exchange rate**	1.38 1.26	1.12 0.93	3.71 3.67	3.40 3.33

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect. All variables are deflated with CPI if not else specified.

\*Calculated as EV / household consumption in the base model.

\*\*SEK / Foreign currency

Simulation 3b reduces CO<sub>2</sub> less than simulation 3 at the same level of consumption and simulation 5b has lower consumption than simulation 5 at the same level of emissions indicating that even these small tax exemptions are inefficient. The tax exemptions are even more inefficient if we only evaluate domestic emissions.

## 3.2 Sensitivity analyses

In the first sensitivity analysis we evaluate the impact from the choice of macro closure. The marginal propensity to save is held constant and foreign saving are allowed to vary in order to keep saving equal to the sum of domestic investment and foreign saving. Since foreign savings are allowed to vary also the current account may vary.

The effects on emissions and national income are on almost the same level and are thus not very sensitive to the choice of macro closure. Private consumption decreases in simulation 3. But since foreign saving increases foreign assets will accumulate and future consumption possibilities will increase. The effects on wages and capital return are the same as well as the industry specific effects on operating surplus and employment. The conclusion about small tax exemptions is unchanged as well. Simulation 3b has lower national income and lower reductions in emissions than simulation. Simulation 5b has almost the same reduction of emissions as simulation 5 and lower national income. For detailed numbers of this sensitivity analysis see tables A3.1.1 to A3.1.8 in the web appendix 1.<sup>11</sup>

In the second sensitivity analysis we evaluate the impact from different kind of modelling electricity trade. The specification of the trade equations for electricity is changed so that the elasticity of substitution in the Armington and CET equations are increased while the trade elasticities are left unchanged. By increasing substitutability a TWh will become a TWh. Thus the export supply and import demand is no longer the first order condition to the Armington and CET equations respectively, but has to be considered as a reduced form of a complicated model describing the limitations in the electricity net. In the Armington equation the elasticity of substitution is increased from 3 to 15 and in the CET equation it is increased from 4.5 to 22.5.

In this analysis simulation 1, 2, 4 and 5 are almost unchanged since net export of electricity in those simulations were almost unchanged compared to the base case. In simulation 3 the reduction in global emissions are reduced with 17 million tonne instead of 13 million tonne. Production and use of electricity is almost unchanged but the net export has increased and

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<sup>11</sup> The web appendix could be downloaded at [www.....](http://www.....)

gives a larger reduction in global emissions. For details see tables A3.2.1 to A3.2.8 in web appendix 1.

The third sensitivity analysis evaluate the impact from a reduction of all trade elasticities. The elasticities used are found in appendix 1. This time the elasticities of Armington and import demand equations are equal just as in the main simulation. With lower trade elasticities carbon leakages will become smaller. Thus the tax on electricity will be less efficient in reducing global carbon emission and simulation 3 is not the most efficient policy with respect to reduction of CO<sub>2</sub> emissions. On the other hand it will give a higher reduction in the domestic production of electricity and a larger reduction in the production of nuclear waste.

Equalizing taxes on electricity for different users have positive welfare effects even with lower trade elasticities. The high tax exemptions for manufacturing is inefficient even in this case since simulation 2 and 3 reduces emissions under constant consumption and 4 and 5 increases consumptions at constant emissions. Even the small tax exemptions are inefficient since simulation 3b gives lower reductions in emissions than simulation 3 at the same level of consumption and simulation 5b gives lower consumption than simulation 5 under almost the same level of emissions. For detailed numbers of this sensitivity analysis see tables A3.3.1 to A3.3.8 in web appendix 1.

In the fourth sensitivity analysis all assumptions are the same as in the main simulation except the assumptions about technology. It is assumed that all intermediate goods are used under Leontief technology, i.e. in fixed proportions to output. The implication of that is that the only possibility for industry to cut down on the use of fossil fuels and electricity is to reduce its output. Households have the same behavioural functions as before meaning that the households still have a possibility to change between different kinds of energy.

Under these assumptions shifting the tax burden from households to manufacturing reduces the incentives to save energy for the actors with a possibility economize their use of energy and increase the incentives for actors that have no such possibility. Not surprisingly this leads to higher emissions. In this analysis it is only simulation three that reduces global emissions. On the other hand all simulations give increases in consumption, probably due to the positive welfare effect from equalizing taxes on final consumption and intermediate use. As shown in

Bohlin (2009a) under Leontief technology fiscal taxes on a subset of the commodities should be higher on intermediate use than in final consumption. Thus emission three shows that even under the Leontief assumption it is possible to reduce emission and increase consumption at the same time.

This time it is fairly difficult to compare simulations 3 with 3b and 5 with 5b since they differ in both welfare and emissions. To simplify the evaluation of small tax reduction two more simulations are added. Simulation 3c and 5c have the same level of consumption evaluated with equivalent variation as simulation 3 and 5 respectively. These simulations show that small tax exemptions for industry are justified in this case. The tax exemptions reduce carbon leakages without disturbing the choice of energy used in intermediate use since there is no such choice by assumption. The reduction in carbon leakages makes it possible to reach the same level of emissions at lower tax rates. These lower tax rates give higher welfare and this effect dominates over the negative impact on welfare from using lower taxes on intermediate use under Leontief technology. If we compare simulation 3 with 3b we can see that tax exemptions give lower welfare if the tax rates are on about the same level as the compared common tax rate.

This result is contradictory to the common understanding that fiscal taxes should rely heavily on final consumption and pigovian taxes should be equal on intermediate use and final consumption. If we do not take emissions into account welfare is higher with equal tax rates on households and industry. If we take emissions into account small tax exemptions for industry is justified. For detailed numbers of this sensitivity analysis see tables A3.4.1 to A3.4.10 in the web appendix 1.

In the fifth sensitivity analysis the elasticities of substitutions in the production function were multiplied with 0.3. In this case even the small tax exemptions were inefficient. Compare 3 with 3d and 5 with 5 d in table A.3.4.27. The conclusion here is that tax exemptions are inefficient even with very small possibilities for industries to switch between different kinds of energy carriers or to substitute energy for capital, i.e. invest in energy saving equipment.

We argue that it is important to keep track of differences in trade margins between different users in studies over energy tax rates since these trade margins will determine the marginal cost of energy for different users. This argument is the main motivation beyond the

development of SAINT. To check for the importance of marginal trade margins a sensitivity analysis where made were the maximum size of them where changed from 30 percent to 10 percent of the basic price. This means that price differences between large and small purchasers are reduced. The result of this sensitivity analysis is shown in tables A 3.5.1.

The qualitative result was unchanged. Tax exemptions are still inefficient. For most of the simulations also the numerical results were similar. The exemption is simulation three where the numbers differ quite a lot. The reason for this is probably that this is the simulation where the changes in electricity taxes are the largest and trade margins are an important part of the price of electricity. In analyses of the electricity market it seems to be important to model how the price contracts are made. To get reliable results we need to know if there are large fix costs in electricity contracts or if more most of the trade margins have in impact on the marginal cost of increasing the use of electricity.

## **4 Introduction of ETS**

ETS was introduced in January 2005 based on Directive 2003/87/EC. The Directive stipulates three phases:

- (i) Phase 1: 2005-2007, Learning by Doing phase;
- (ii) Phase 2: 2008-2012, Kyoto Period; and
- (iii) Phase 3: Post 2012.

During Phase 1, 46 percent of European CO<sub>2</sub> emissions were covered. In the EU ETS, the Commission certifies a national allocation plan for each member state according to which each member state allocates allowances to each installation. During Phase 1, at least 95 percent of the permits were allocated without charge according to historic emissions. From Phase 2, the regulation states that that each member state should allocate at least 10 percent of the permits through auctioning.

After the introduction of ETS the marginal cost of emission differ even more between different actors in the Swedish economy. The tax exemptions were defined from the industry classification of the firm so that all firms in the same industry had the same tax rate. The obligation to deliver emission permits under the ETS depends upon properties of the installation. Within an industry and even within a firm there will be installations with and without obligation to deliver CO<sub>2</sub> allowances and thus with different marginal cost on CO<sub>2</sub> emission. Table 1.2 shows the distribution of CO<sub>2</sub> emission in different sectors of the Swedish economy and how much of those emissions that are covered by ETS.

Table 1.2 Emission of CO<sub>2</sub> in Sweden 2005 and 2006

	2005				2006			
	Total	ETS allow	ETS Em	ETS share	Total	ETS allow	ETS Em	ETS share
A01 Agriculture, forestry, fishing	2982	0	0	0.00	3002	0	0	0.00
A10 Mining **	502	439	439	0.87	524	439	440	0.84
A15 Manufacture of food textile and wearing apparel	771	212	188	0.24	739	213	151	0.20
A20 Manufacture of wood, paper, publishing**	2058	2012	1573	0.76	2092	2057	1576	0.75
A23 Manufacture of coke & refined petroleum products	2532	592	534	0.21	2772	592	524	0.19
A24 Manufacture of chemicals metals and metal products **	10808	9437	6095	0.56	10657	11086	7469	0.70
A30 Manufacture of machinery and furniture	540	78	73	0.14	535	79	69	0.13
A40 Electricity, steam and hot water supply **	8050	3308	5366	0.67	7552	3066	5288	0.70
A41 Distribution of water. Construction	2053	57	6	0.00	2124	57	6	0.00
A50 Retail trade, Hotels and restaurants, financial services	2294	19	20	0.01	2391	19	21	0.01
A60 Transports	12931	0	0	0.00	13450	0	0	0.00
A70 Real estate activities, Renting of equipment, R&D	645	85	83	0.13	707	87	84	0.12
A75 Public services	713	0	0	0.00	777	0	0	0.00
A90 Other service activities	172	0	0	0.00	11	0	0	0.00
OFF Government consumption	1027	0	0	0.00	1080	0	0	0.00
PK households	11951	0	0	0.00	11093	0	0	0.00
ETS-installations not distributed to industries	0	2656	2042		0	2656	2523	
<b>Total</b>	<b>60213</b>	<b>18920</b>	<b>16439</b>	<b>0.27</b>	<b>59915</b>	<b>20376</b>	<b>18177</b>	<b>0.30</b>

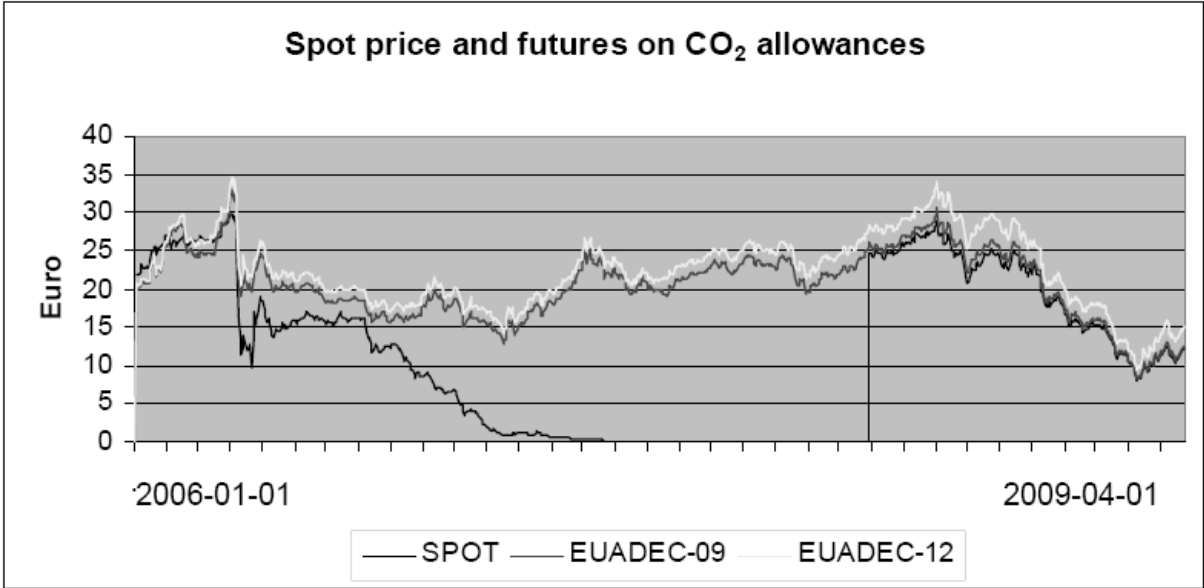
Source: Own calculations based upon data from statistics Sweden and Swedish Energy Agency.

From table 1.2 it can be seen that only about 30 percent of the Swedish emissions of CO<sub>2</sub> were covered by ETS. The industries with the highest share of their emissions covered by ETS are mines, pulp and paper, non metallic mineral products, steel and metals and electricity, gas, heat and water distribution.

In the model an industry must either be classified as an ETS industry or a non ETS industry. The industries A10, A20, A24 and A 40 are treated as if all their installations were covered by ETS while the rest of the industries are treated as if none of their installations were covered.

The divergence of the marginal cost of CO<sub>2</sub> between ETS and non ETS installations will depend upon the price of the allowances. The development of the price and future prices is shown in figure 1.2.

Figure 1.2 The Price of Allowances, phase 2 and 3



Source: Nordpool.

In phase 1, banking was not allowed. Prices of allowances fell in spring 2006 after the release of the first emission report, since the oversupply of allowances could not be saved to the second phase. Futures on the price in the second phase were still high. In the second phase banking is allowed and the divergence between future price and spot price will only reflect expected future interest rate. In the beginning of phase two the market expected a more restrictive allocation of allowances and the price was almost as high as in the beginning of phase 1. However as in phase one the price falls back. The reason for this may be expectations of less restrictive allocation of permits, expectations of a decreases in the cost of emission reductions or expectations of that the current crisis will result in a long lasting depression with low demand of energy.

Emission trading is often assumed to have almost the same impact on efficiency as a pigovian tax at the same level as the price of the permits. This is only true for a pure grandfathered emission trading system, where the behaviour of firms do not have any impact on how many permits they will receive, or if the permits are auctioned. Sterner and Muller (2006) explain the impact of different distribution methods of permits on the incentives for different kinds of decisions in firms. The ETS is not a pure grandfathered system since firms are not allowed to keep their allowances upon exit. Moreover new entrants can, under some circumstances, get permits even though they didn't have any emissions in the reference year.

These features of the ETS makes it equivalent to a pigovian tax combined with a tax on shutting down polluting plants and a subsidy for investments in polluting industries. This does clearly impose inefficiencies. Suppose one firm owns two different coal power plants of equal size. If they decide to shut down one of them they will lose half of their permits. If they decide to reduce the production by half on both plants they will keep all their permits. ETS gives incentives to low capacity use and higher fixed costs. Moreover a new investment in coal power plants will give the investor permits with a high economic value that he will not receive if he instead invests in sun or wind power.

The cost of CO<sub>2</sub> emissions implied by ETS considering investments in abatement and adjustment of production levels at existing plants will differ from the cost it implies for Greenfield investment and shutting downs. The marginal cost of reducing CO<sub>2</sub> emission will not be equal to the price of the permits and the cheapest ways of reducing emissions will not be used. ETS will thus not give cost efficient reductions of CO<sub>2</sub>. These features are not possible to implement in the CGE model used in this thesis and ETS will for simplicity be treated as if it was a pure grandfathered system. It is important to remember though, that the ETS of the real world for these reasons probably are more costly than what is shown in this analysis.

When their marginal cost increases firms under the ETS can increase their prices and thus their revenue. Since permits are allocated for free their total cost does not increase. Thus industries with a lot of plants that is covered by the ETS are expected to get increased profits. For ETS to have a negative impact on the profits of a firm, the net purchase of allowances must make up a higher share of the firms emissions than the share of the increased marginal cost that is passed over to the customers, if scale effects is ignored.

This increase in output prices will also benefit non ETS firms in these industries. For example wind, water and nuclear power stations gains from the increase in electricity prices. As expected we find in the CGE-analysis that all industries covered by ETS get increased profits.

Since emission trading significantly increases the marginal cost in electricity generation in neighbouring countries the export and import prices of electricity are increased. This would give rise to a significant increase in the net export of electricity that wouldn't be realistic due to the limitations in transmission capacity and the limited possibilities to increase electricity

production from waterpower in Sweden. The limited supply of rivers would probably give rise to increases in the resource rents from water power and therefore the return to capital is exogenous increased in industry 40, production of electricity and heat. The increase in required return to capital reduces the increase in capital stock in that industry and thus the increase in electricity production becomes more realistic. Note that in the short run analysis this has no impact since the return to the fixed capital stock is determined on the market.

The changes in national emissions are calculated from the changes in the use of diesel, gasoline, fuel oil and gas. Other sources of CO<sub>2</sub> are ignored. The changes in CO<sub>2</sub> emissions are only reported as national change. Since this is not a national policy measure it doesn't make sense to calculate carbon leakage. The meaningful measure of carbon leakage would be the leakage out of the European Union and that cannot be analysed in a Swedish model.

In Table 4.1 the experiment parameters in three simulations are reported. These are the exogenous permit price, the price increases on exported and imported electricity, the domestic distribution of permits and the capital return difference in electricity production (percentage difference between the return in electricity generation and the return to capital in other industries)<sup>12</sup>. Simulation A and B has a low permit price close to the lowest expectations about future prices during spring 2009. Simulation c and d has a high permit price close to the highest expectations about future prices during spring 2009 and thus higher increases in electricity prices. For each price we both have one simulation with a low, and one with a high domestic supply of permits. The increase in electricity prices is calculated as 30 %<sup>13</sup> of the increase in marginal cost of production. The increase in marginal cost of production of electricity is calculated as 0.835<sup>14</sup> times the permit price. The results are reported in table 4.2.

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<sup>12</sup> This parameter only have an impact on the long run analysis since in the short run analysis capital is industry specific and changes in return between industries are endogenous in the model.

<sup>13</sup> This number is fairly arbitrary. The impact of electricity prices from the increased cost of production in carbon power plants would not only depend upon elasticities of demand and supply but also on the share of hours that carbon power sets the price on Nordpool. This share may differ between the hours when Sweden is an exporter and the hours when Sweden is an importer of electricity and thus the price increase may be different on export and import prices. Econometric estimations on actual price data wouldn't help us to get a reliable number since the interesting price increase is the long run price increase. Sijm et al (2005) estimates the pass through rate of permit prices on electricity prices to be between 40 and 100 % in Germany and Netherlands. In the long run when the price increased have spurred investments in carbon free electricity generation the pass through rate would be lower. It should also be lower in Sweden since the common price only affects Sweden for a part of the time.

<sup>14</sup> 0.835 is a number used of statistic Denmark for the carbon intensity in Danish electricity production.

Table 4.1 Experiment parameters

Experiment parameter	Unit	Simulations			
		(a)	(b)	(c)	(d)
Permit Price	SEK / kg	0,16	0,16	0,35	0,35
Export Price increase	%	22	22	49	49
Import Price increase	%	22	22	49	49
Capital return difference in A40*	%	5	5	13	13
<b>Distributed permits:</b>					
A10	1 000 tonnes	286	357	286	357
A20	1 000 tonnes	1640	2050	1640	2050
A24	1 000 tonnes	1952	2440	1952	2440
A40	1 000 tonnes	1416	1770	1416	1770
SUMMA		5294	6617	5294	6617

\* This parameter will only have an impact on the long run simulations.

Table 4.2 Results

Variable	Simulations			
	(a)	(b)	(c)	(d)
<b>CO<sub>2</sub> emissions</b>				
Changes in thousand tonnes				
Domestic	-2350	-2347	-3409	-3402
	-928	-926	-1371	-1365
<b>Economic variables</b>				
Percentage changes				
National income	-0.08	-0.08	-0.09	-0.09
	-0.07	-0.06	-0.12	-0.12
GDP, deflated by CPI	-0.07	-0.07	-0.05	-0.05
	-0.05	-0.05	-0.08	-0.08
GDP, GDP-deflator	-0.06	-0.06	-0.14	-0.14
	-0.05	-0.05	-0.11	-0.11
Private Consumption	-0.11	-0.09	-0.05	-0.02
	-0.08	-0.06	-0.10	-0.07
Equivalent Variation	-0.09	-0.07	-0.01	0.02
EV / household consumption	-0.11	-0.09	-0.16	-0.13
Exchange rate	-0.02	-0.02	-0.04	-0.04
SEK / Foreign currency	0.00	-0.01	-0.03	-0.04
Net export of permits	1510	2833	2986	4309
thousand tonnes	110	1433	1093	2417
Gross real wage	-0.17	-0.17	-0.32	-0.32
	-0.19	-0.20	-0.41	-0.41
Disposable Real wage	-0.43	-0.42	-0.67	-0.65
	-0.40	-0.39	-0.78	-0.76
Labour tax	0.19	0.18	0.26	0.24
	0.15	0.14	0.27	0.25
Capital return	0.27	0.30	0.80	0.87
	0.30	0.33	0.71	0.78

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect. All variables are deflated with CPI if not else specified.

The macroeconomic effects of this reform are very small, could almost be ignored. Net factor income from abroad decreases since a part of the increase in capital income falls on foreign capital owners. That explains why national income, in simulation **c** and **d**, decreases more than GDP deflated with CPI. In simulation **c** and **d**, GDP deflated by CPI decreases less than GDP deflated by the GDP deflator, i.e. we have a positive change in the terms of trade. The main reason for that is the increase in the price of electricity in the north European markets.

The increase in resource rents in electricity generation together with the revenue from permit trading increases the share of value added that goes to capital owners. Capital return increases while real wages decreases. Disposable wage decreases even more. Due to the decrease in real wages the tax rate on labour must be increased in order to balance the government budget.

The short run effects on emissions are smaller than in the long run since it takes some time to reallocate capital from polluting sectors and since elasticities of substitution is higher in the long run.

## Winners and losers

In the long run analysis when capital is reallocated the return to capital is equal in all industries except electricity generation. In the short run it may differ though and we can use the short run operating surplus in different industries to see how the overall gains for capital owners are distributed. The short run operating surpluses in different industries are reported in table 4.3.

Table 4.3 Short run percentage change in operating surplus

Industries	Simulations			
	(a)	(b)	(c)	(d)
A01 Agriculture, forestry, fishing	-0.32	-0.32	-0.68	-0.68
A10 Mining *	0.68 (-0.82)	1.05 (-0.83)	1.73 (-1.56)	2.54 (-1.57)
A15 Manufacture of food textile and wearing apparel	0.04	0.05	0.09	0.10
A20 Manufacture of wood, paper, publishing*	0.58 (-0.14)	0.76 (-0.15)	1.30 (-0.29)	1.68 (-0.31)
A23 Manufacture of coke & refined petroleum products	-0.75	-0.74	-0.71	-0.70
A24 Manufacture of chemicals metals and metal products *	0.15 (-0.40)	0.28 (-0.41)	0.30 (-0.92)	0.58 (-0.94)
A30 Manufacture of machinery and furniture	0.45	0.43	0.76	0.72
A40 Electricity, steam and hot water supply *	13.1 (12.0)	13.4 (12.0)	30.3 (27.8)	30.9 (27.8)
A402 Supply of gas	-0.76	-0.76	-0.28	-0.27
A41 Distribution of water. Construction	-0.14	-0.14	-0.29	-0.29
A50 Retail trade, Hotels and restaurants, financial services	-0.23	-0.23	-0.48	-0.47
A60 Transports	-0.41	-0.41	-0.86	-0.87
A70 Real estate activities, Renting of equipment, R&D	-0.15	-0.14	-0.31	-0.30
A75 Public services	-0.15	-0.15	-0.32	-0.32
A90 Other service activities	-0.14	-0.13	-0.26	-0.24

For a more complete description of the industries in each aggregate see appendix 1.

\*For the industries included in ETS, the number in parenthesis refers to the change in operating surplus with the value of distributed permits excluded.

The winners of the reform are the industries included in the ETS plus manufacturing. For industries 10, 20 and 24 the gain comes from the value of the permits they receive for free. For the big winner of the reform, the electricity producers, the increased profitability comes also from the increased price of electricity.

Disaggregating the wage effect to different industries is not possible in the model since the model assumes an equal wage throughout the economy. It is however possible to distinguish winner from losers among workers in different industries from the reallocation of the labour supply between different industries in the long run simulation. Those industries that increase their use of labour would in reality probably need to pay higher wages than those that reduce

their labour use. The long run percentage change in the use of labour is reported in table 4.4. The highest reductions in employment are found in mining, refineries and supply of gas.

**Table 4.4 Long run percentage change in employment**

Industries	Simulations			
	(a)	(b)	(c)	(d)
A01 Agriculture, forestry, fishing	-0.13	-0.13	-0.24	-0.23
A10 Mining	-3.70	-3.70	-5.87	-5.87
A15 Manufacture of food textile and wearing apparel	0.05	0.06	0.13	0.16
A20 Manufacture of wood, paper, publishing	-0.47	-0.47	-1.00	-1.01
A23 Manufacture of coke & refined petroleum products	-3.31	-3.30	-4.93	-4.92
A24 Manufacture of chemicals metals and metal products	-0.91	-0.92	-2.05	-2.08
A30 Manufacture of machinery and furniture	0.60	0.58	0.52	0.49
A40 Electricity, steam and hot water supply	15.39	15.40	42.73	42.75
A402 Supply of gas	-9.21	-9.21	-15.45	-15.44
A41 Distribution of water. Construction	0.09	0.09	0.23	0.23
A50 Retail trade, Hotels and restaurants, financial services	-0.10	-0.10	-0.24	-0.23
A60 Transports	-0.19	-0.19	-0.44	-0.43
A70 Real estate activities, Renting of equipment, R&D	0.05	0.05	0.11	0.12
A75 Public services	0.02	0.02	0.06	0.06
A90 Other service activities	0.01	0.02	0.10	0.12

For a more complete description of the industries in each aggregate see appendix 1.

In table 4.5 the production, use and net export of electricity is reported. The increase in the price of electricity gives higher production and decreases use. The net export of electricity thus increases significantly. The increase in production is higher in the long run after investments in new plants.

**Table 4.5 Change in production and use of electricity, TWh**

	Simulations			
	(a)	(b)	(c)	(d)
Domestic electricity use	-3	-3	-8	-8
	-5	-5	-11	-11
Domestic electricity production	14	14	37	37
	5	5	10	10
Net export in electricity	16	16	39	39
	9	9	19	19

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect.

## 5 Domestic climate policy after the introduction of ETS

In this section the interaction between energy taxes and the introduction of ETS is investigated. Has the introduction of ETS changed the conclusion from section 3 that the energy tax exemptions for industry are inefficient? There is a literature about the arguments for combining taxes with emission trading. See for example Mandel (2008). Mandel assumes that the same policymaker controls both instrument. That is not the case in EU since ETS is controlled by the commission and the taxes of the member states. This study considers the decision at the member state, taken the design of the emission trading as exogenously given.

In the simulations we start with the outcome from the long run simulation c above. The reported changes for the different variables are the difference from the long run outcome in simulation c. First similar simulations as in section 3 are made in order to see in what way the introduction of ETS has changed the conclusions about tax exemptions for manufacturing. Thereafter a couple of simulations are made to evaluate whether taxes should be lower for industries participating in the ETS.

In table 5.1 and 5.2 the outcome from similar tax schemes as in table 3.2 is shown.

Table 5.1 Tax rates in simulations

Tax item	Tax rates in base model*	Simulations				
	Households & services / most manufacturing	(1a)	(2a)	(3a)	(4a)	(5a)
gasoline	4.50 / 4.50	4.39	4.33	4.53	3.84	3.54
diesel	3.39 / 3.39	3.29	3.23	3.43	2.74	2.44
light fuel oil	2.21 / 0.38	2.09	2.03	2.23	1.54	1.24
heavy fuel oil	2.28 / 0.42	2.19	2.13	2.33	1.64	1.34
gas	1.37 / 0.29	1.46	1.42	1.56	1.08	0.87
electricity	0.18 / 0.00	b	b	0.005	b	0.005

\*Tax rates for other users in base model see table A3.1 in appendix 3.

b = the same tax rates as in the base model.

The introduction of permit trading doesn't have very big impact on the main conclusions about tax exemptions. The biggest difference is probably the impact on the electricity market. After the introduction of permit trading net export in electricity doesn't have any impact on global emissions of CO<sub>2</sub>. If the production of electricity in Danish and German coal power

plants is reduced they just sell permits to some other firms and emission increases elsewhere in the union. Thus the optimal tax on electricity, after the introduction of ETS, is zero if CO<sub>2</sub> emission is the only externality considered. Since a zero tax rate would violate the rules of EU the minimum tax rate of 0.005 is chosen, in simulation 3 and 5, for all actors of the economy.

**Table 5.2 Results**

Variable	Simulations				
	(1a)	(2a)	(3a)	(4a)	(5a)
<b>CO<sub>2</sub> emissions</b>					
Changes in thousand tonnes					
Domestic emissions	-9631	-8788	-14447	-541	-229
	-6770	-6198	-9445	-964	936
Domestic quota					
other trade	108	145	-282	535	237
	131	140	5	210	136
global	-9523	-8643	-14729	-5	8
	-6639	-6058	-9440	-754	1072
<b>Economic variables</b>					
Percentage changes					
National income	0.00	0.26	-0.58	2.49	3.76
	0.08	0.31	-0.27	2.20	3.53
GDP, deflated by CPI	0.01	0.31	-0.55	2.76	4.24
	0.09	0.34	-0.23	2.44	3.99
GDP, GDP-deflator	-0.11	-0.06	0.05	0.35	0.79
	-0.09	-0.06	0.05	0.20	0.57
Private Consumption	0.03	0.38	-0.97	3.33	4.81
	0.18	0.47	-0.49	2.89	4.40
Equivalent Variation	-0.15	0.00	0.00	1.26	2.40
EV / household consumption	-0.09	0.02	0.15	0.91	1.93
Exchange rate	0.18	0.45	0.21	2.73	4.63
SEK / Foreign currency	0.27	0.51	0.53	2.52	4.55
Net export of permits	4620	4591	4842	4282	4305
thousand tonnes	3998	3976	4080	3761	3627
Gross real wage	-0.10	0.20	0.13	2.77	5.09
	-0.12	0.16	0.23	2.49	4.92
Disposable Real wage	0.01	0.66	-2.14	6.05	8.42
	0.33	0.86	-1.15	5.20	7.65
Labour tax	-0.08	-0.33	1.63	-2.30	-2.28
	-0.32	-0.50	1.00	-1.90	-1.87
Capital return	0.14	0.42	0.11	2.82	4.82
	0.11	0.37	0.25	2.56	4.63

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect. All variables are deflated with CPI if not else specified.

Comparing the costless reduction of CO<sub>2</sub> in table 5.2 with the equivalent simulation in table 3.2 the qualitative conclusions are almost the same. Even after the introduction of ETS, it is beneficial to remove the tax exemptions for manufacturing.

### 3.1 Winners and losers

The short run operating surpluses in different industries are reported in table 5.3 and the long run percentage change in the use of labour is reported in table 5.4. Considering return to capital the only loser in simulation 4 and 5 is suppliers of gas while the largest gainer is refineries. The reform seems to decrease demand for gas and increase demand for other fossil fuels. In simulations 1, 2 and 3 with a more restrictive climate policy refineries will be a loser and the losses in supply of gas will be even higher.

Table 5.3 Short run percentage change in operating surplus

Industries	Simulations				
	(1)	(2)	(3)	(4)	(5)
A01 Agriculture, forestry, fishing	-0.19	0.08	-0.13	2.34	4.41
A10 Mining	-2.20	-1.63	-4.70	3.35	5.32
A15 Manufacture of food textile and wearing apparel	0.02	0.34	0.24	3.03	5.64
A20 Manufacture of wood, paper, publishing	0.04	0.30	-0.27	2.49	4.16
A23 Manufacture of coke & refined petroleum products	-4.30	-2.51	-19.16	13.79	12.09
A24 Manufacture of chemicals metals and metal products	0.12	0.35	0.57	2.22	4.33
A30 Manufacture of machinery and furniture	0.95	1.12	2.35	2.50	5.06
A40 Electricity, steam and hot water supply	2.88	2.95	5.94	3.41	6.86
A402 Supply of gas	-32.21	-30.35	-52.42	-13.83	-21.07
A41 Distribution of water. Construction	-0.09	0.15	0.09	2.06	3.94
A50 Retail trade, Hotels and restaurants, financial services	0.18	0.46	0.25	2.78	4.91
A60 Transports	-0.06	0.00	1.10	0.40	1.85
A70 Real estate activities, Renting of equipment, R&D	0.01	0.30	0.04	2.64	4.76
A75 Public services	-0.06	0.21	-0.13	2.48	4.44
A90 Other service activities	-0.03	0.27	-0.66	2.77	4.36

For a more complete description of the industries in each aggregate see appendix 1

The long run impact on employment follows somewhat the same pattern as the short run impact on operating surplus. It may be a surprise that the transport sector gets hurt when their tax rate on fuels is reduced. This must be explained from a reduced demand of transport services. When fuels get cheaper for households more people will choose to travel with their own car.

Table 5.4 Long run percentage change in employment

Industries	Simulations				
	(1)	(2)	(3)	(4)	(5)
A01 Agriculture, forestry, fishing	-0.24	-0.22	-0.48	-0.11	-0.24
A10 Mining	-6.45	-4.65	-22.55	14.11	3.42
A15 Manufacture of food textile and wearing apparel	-0.25	-0.13	-0.43	0.85	1.42
A20 Manufacture of wood, paper, publishing	-0.15	-0.14	-1.32	-0.07	-0.90
A23 Manufacture of coke & refined petroleum products	-6.07	-3.62	-29.27	21.92	5.81
A24 Manufacture of chemicals metals and metal products	-0.46	-0.48	-0.01	-0.60	-0.36
A30 Manufacture of machinery and furniture	0.68	0.56	2.67	-0.46	0.55
A40 Electricity, steam and hot water supply	7.44	6.90	13.52	1.50	7.23
A402 Supply of gas	-52.40	-50.36	-80.07	-29.80	-51.64
A41 Distribution of water. Construction	-0.28	-0.31	-0.24	-0.63	-0.86
A50 Retail trade, Hotels and restaurants, financial services	-0.07	-0.03	-0.23	0.26	0.24
A60 Transports	-0.31	-0.71	1.57	-4.04	-5.23
A70 Real estate activities, Renting of equipment, R&D	-0.21	-0.18	-0.37	0.05	0.04
A75 Public services	-0.30	-0.28	-0.63	-0.11	-0.36
A90 Other service activities	-0.30	-0.24	-1.32	0.27	-0.36

For a more complete description of the industries in each aggregate see appendix 1

## Impacts in the electricity market

Table 5.5 gives the changes in the electricity market. It could be seen that the cost of the high decrease in CO2 emissions in simulation 3 and the high increase in income in simulation 5 is a drastic increase in domestic electricity generation. It may be doubtful whether this increase would be possible without other kinds of external effects.

Table 5.5 Change in production and use of electricity, TWh

	Simulations				
	(1)	(2)	(3)	(4)	(5)
Domestic electricity use	12	11	51	6	41
	7	7	34	4	29
Domestic electricity production	11	10	34	2	23
	0	0	9	0	8
Net export in electricity	-1	-1	-18	-4	-20
	-7	-7	-27	-5	-23

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect.

## Tax exemptions on ETS industries

It could be argued that the industries that are part of the emission trading system shouldn't pay any tax on the use of fuels that are included in that system since a decrease in this emission doesn't have any impact on global emissions.. Table 5.6 and 5.7 presents the results from simulations where these taxes are set to 0.

Table 5.6 Tax rates in simulations

Tax item	Tax rates in base model*		Simulations				
	Households & services / most manufacturing		(1b)	(2b)	(3b)	(4b)	(5b)
gasoline	4.50 / 4.50		4.43	4.37	4.57	4.01	3.68
diesel	3.39 / 3.39		3.33	3.27	3.47	2.91	2.58
light fuel oil	2.21 / 0.38		**2.13	**2.07	**2.27	**1.71	**1.38
heavy fuel oil	2.28 / 0.42		**2.23	**2.17	**2.37	**1.81	**1.48
gas	1.37 / 0.29		1.49	1.45	1.59	1.20	0.97
electricity	0.18 / 0.00		b	b	0.005	b	0.005

\* Tax rates for other users in base model see table A3.1 in appendix 3.

\*\* 0 in industries included in emission trading.

b = the same tax rates as in the base model.

Table 5.7 Results

Variable	Simulations				
	(1b)	(2b)	(3b)	(4b)	(5b)
<b>CO<sub>2</sub> emissions</b>					
Changes in thousand tonnes					
Domestic emissions	-6528	-5711	-11622	-315	-76
	-5399	-4849	-7961	-1380	469
Domestic quota					
other trade	17	54	-360	318	77
	85	94	-45	147	79
global	-6511	-5657	-11983	3	1
	-5314	-4756	-8006	-1233	548
<b>Economic variables</b>					
Percentage changes					
National income	0.00	0.27	-0.59	1.86	3.23
	-0.01	0.22	-0.37	1.59	3.02
GDP. deflated by CPI	0.00	0.30	-0.58	2.05	3.64
	-0.01	0.25	-0.35	1.77	3.41
GDP. GDP-deflator	-0.04	0.01	0.13	0.29	0.75
	-0.05	-0.02	0.10	0.15	0.54
Private Consumption	-0.06	0.30	-1.08	2.41	4.04
	-0.01	0.30	-0.68	2.06	3.69
Equivalent Variation	-0.15	0.00	0.00	0.89	2.10
EV / household consumption	-0.13	-0.02	0.12	0.63	1.70
Exchange rate	0.06	0.33	0.06	1.97	3.99
SEK / Foreign currency	0.08	0.33	0.32	1.79	3.93
Net export of permits	750	757	1154	794	1374
thousand tonnes	1934	1946	1893	2018	2099
Gross real wage	-0.09	0.21	0.10	2.04	4.47
	-0.19	0.09	0.16	1.77	4.30
Disposable Real wage	-0.15	0.51	-2.32	4.38	7.02
	-0.02	0.53	-1.52	3.70	6.37
Labour tax	0.04	-0.21	1.74	-1.65	-1.76
	-0.13	-0.31	1.21	-1.36	-1.43
Capital return	0.05	0.34	0.01	2.06	4.16
	0.00	0.26	0.11	1.84	4.01

Note: The top number in each cell refers to the long run effect. the bottom number to the short run effect. All variables are deflated with CPI if not else specified.

From table 5.7 it could be seen that the reduction of emission is lower in sim 1-3 than it was in table 5.2. Moreover the welfare improvements are lower in simulation 4 and 5 than it was in table 5.2. To reduce the tax rate to 0 in ETS industries was not welfare improving. But it may be the case that a smaller reduction in the tax rates for ETS industries would be welfare improving. Such simulations are reported in table 5.8 and 5.9. The tax rates in ETS industries are reduced with 25 % of the permit cost.

Table 5.8 Tax rates in simulations

Tax item	Tax rates in base model*	Simulations				
	Households & services / most manufacturing	(1c)	(2c)	(3c)	(4c)	(5c)
diesel	3.39 / 3.39	4.39	4.33	4.53	3.85	3.55
light fuel oil**	2.21 / 0.38	3.29	3.23	3.43	2.75	2.45
heavy fuel oil**	2.28 / 0.42	2.09	2.03	2.23	1.55	1.25
gas**	1.37 / 0.29	1.84	1.78	1.98	1.30	1.00
electricity	0.18 / 0.00	2.19	2.13	2.33	1.65	1.35
		1.94	1.88	2.08	1.40	1.10
		1.46	1.42	1.56	1.08	0.88
		1.28	1.24	1.38	0.90	0.69
		b	b	0.005	b	0.005

\*Tax rates for other users in base model see table A3.1 in appendix 3.

\*\* The first number refers to the general tax rate the second to the tax rates for ETS industries.

b = the same tax rates as in the base model.

Table 5.9 Results

Variable	Simulations				
	(1c)	(2c)	(3c)	(4c)	(5c)
<b>CO<sub>2</sub> emissions</b>					
Changes in thousand tonnes					
Domestic emissions	-9538	-8713	-14427	-528	-236
other trade	-6699	-6141	-9392	-957	919
global	103	138	-287	520	221
	127	135	0	204	129
	-9436	-8575	-14714	-8	-15
	-6571	-6005	-9392	-753	1048
<b>Economic variables</b>					
Percentage changes					
National income	0.00	0.26	-0.59	2.45	3.72
GDP. deflated by CPI	0.08	0.30	-0.28	2.16	3.49
GDP. GDP-deflator	0.01	0.30	-0.56	2.72	4.19
Private Consumption	0.09	0.33	-0.24	2.41	3.95
Equivalent Variation	-0.10	-0.06	0.05	0.35	0.79
EV / household consumption	-0.09	-0.06	0.06	0.20	0.57
Exchange rate	0.03	0.37	-0.99	3.29	4.74
SEK / Foreign currency	0.17	0.46	-0.50	2.84	4.34
Net export of permits	-0.15	0.00	0.00	1.24	2.38
thousand tonnes	-0.08	0.02	0.15	0.90	1.91
Gross real wage	0.17	0.44	0.20	2.68	4.58
Disposable Real wage	0.26	0.49	0.51	2.48	4.49
Labour tax	4487	4452	4751	4067	4058
Capital return	3880	3854	3968	3609	3447
	-0.10	0.19	0.11	2.73	5.04
	-0.12	0.15	0.22	2.45	4.87
	0.01	0.64	-2.17	5.97	8.31
	0.32	0.83	-1.18	5.12	7.54
	-0.08	-0.32	1.64	-2.27	-2.24
	-0.32	-0.49	1.01	-1.88	-1.84
	0.13	0.41	0.10	2.78	4.76
	0.11	0.36	0.24	2.52	4.58

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect. All variables are deflated with CPI if not else specified.

Not even this very small reduction of the tax rate in ETS industries were welfare improving. The result here is thus that all actors should meet the same tax rate regardless of if they take part in ETS or not.

## **Sensitivity analysis**

In sensitivity analysis over macro closure making foreign savings flexible and marginal propensity to save fixed does not change the conclusion in any other aspects than to the degree the welfare improvement is taken out in higher consumption or in higher savings.

Sensitivity analysis over trade elasticities does not give any large effect on the quantitative results and does not change the main conclusions about tax optimal tax rates.

In sensitivity analysis over technology the leontief technology makes tax exemptions for ETS industries welfare improving while even small elasticities of substitutions (0.3 times the elasticities in the main scenarios) makes tax exemptions welfare reducing.

The results seem pretty robust over different model specifications.

## 6 Reducing quota or increasing taxes?

The introduction of ETS gives us a new instrument to reduce global emission of CO<sub>2</sub> by reducing the domestic supply of permits. If domestic supply of permits is reduced, domestic firms need to buy permits from other European firms that need to reduce their emissions. In this section the optimal level of domestic supply of permits is derived.

In the simulations reported in table 6.1 and 6.2 the domestic supply of permits is decreased while consumption is held constant by reducing the tax rates on fossil fuel. It turns out that the most efficient size of the domestic supply of permits is zero if our goal is to reduce global emission as much as possible without any loss in consumption.

Table 6.1 Tax rates and permit supply in simulations

Tax item	Tax rates in base model*		Simulations			
	Households & services / most manufacturing	(3a)	(3d)	(3e)	(3f)	
Gasoline	4.50 / 4.50	4.53	4.50	4.48	4.47	
Diesel	3.39 / 3.39	3.43	3.40	3.38	3.37	
light fuel oil	2.21 / 0.38	2.23	2.20	2.18	2.17	
heavy fuel oil	2.28 / 0.42	2.33	2.30	2.28	2.27	
Gas	1.37 / 0.29	1.56	1.54	1.53	1.52	
electricity	0.18 / 0.00	b	b	b	b	
Permit supply		5294	2647	1059	0	

\*Tax rates for other users in base model see table A3.1 in appendix 3.

b = the same tax rates as in the base model.

Table 6.2 Results

Variable	Simulations			
	(3a)	(3d)	(3e)	(3f)
<b>CO<sub>2</sub> emissions</b>				
Changes in thousand tonnes				
Domestic emissions	-14447	-14127	-13936	-13806
	-9445	-9181	-9025	-8919
Domestic quota		-2647	-4235	-5294
		-2647	-4235	-5294
other trade	-282	-280	-279	-278
	5	3	1	0
global	-14729	-17054	-18450	-19378
	-9440	-11826	-13259	-14212
<b>Economic variables</b>				
Percentage changes				
National income	-0.58	-0.45	-0.37	-0.32
	-0.27	-0.15	-0.08	-0.03
GDP. deflated by CPI	-0.55	-0.41	-0.33	-0.27
	-0.23	-0.10	-0.02	0.03
GDP. GDP-deflator	0.05	0.07	0.08	0.08
	0.05	0.06	0.07	0.07
Private Consumption	-0.97	-0.86	-0.80	-0.75
	-0.49	-0.39	-0.34	-0.30
Equivalent Variation	0.00	0.00	0.00	0.00
EV / household consumption	0.15	0.14	0.13	0.13
Exchange rate	0.21	0.35	0.44	0.49
SEK / Foreign currency	0.53	0.67	0.75	0.80
Net export of permits	4842	2188	595	-467
thousand tonnes	4080	1422	-173	-1236
Gross real wage	0.13	0.28	0.37	0.43
	0.23	0.38	0.47	0.53
Disposable Real wage	-2.14	-1.85	-1.69	-1.58
	-1.15	-0.90	-0.76	-0.66
Labour tax	1.63	1.53	1.47	1.43
	1.00	0.92	0.88	0.85
Capital return	0.11	0.11	0.11	0.11
	0.25	0.25	0.25	0.24

Note: The top number in each cell refers to the long run effect, the bottom number to the short run effect. All variables are deflated with CPI if not else specified.

## **7 Conclusions**

The main conclusion of this study is that tax exemptions for the Swedish industry are inefficient, increasing the cost to achieve a specific emission target. The indirect carbon leakage effects are shown to be fairly small and do not justify the tax exemptions. This is in line with the analysis of Burniaux and Martins (2000).

After the introduction of ETS tax exemptions are still inefficient even for those industries that take part in ETS. It may come as a surprise that it is efficient with an equally high carbon tax on ETS industries since they do not give any net increase in global emissions. To understand this result we must probably go to the findings of Newberry (1985) and Bohlin (2009) that even fiscal taxes on inputs, when deviating from their optimal levels, in some cases should be as high or higher in industries as in households. For energy to be allocated to the most favourable use in the economy it is important that energy prices are fairly equal for different users.

Another conclusion of the study is that before the introduction of ETS increases in the tax of electricity and reduction in the tax on fossil fuels reduces global emission of carbon dioxide without any loss in consumption and at the same time reduces the production of nuclear waste. After the introduction of ETS the electricity tax should be as low as possible if the only purpose is to reduce CO<sub>2</sub> emissions since reductions in emission from electricity generation only increases emissions elsewhere.

The introduction of ETS increased profits significantly in the industries that are part of the system. It is shown that the optimal level of the domestic supply of permits should be zero if the objective is to reduce global emission of CO<sub>2</sub>. Reducing the supply of permits is less costly than increases energy taxes even though export income from permits is lost.

In economics it is sometimes assumed that decision makers on average behave rational so that their preferences could be revealed from their behaviour. From that perspective a cost effective reduction of global CO<sub>2</sub> emission seem not to be preferred by national policymakers due to the oversupply of permits in ETS. Such a preference may be consistent with game theory that says that in a one shot game it is not rational for a national policy maker to reduce

emissions of CO<sub>2</sub> since the impact of national policies is negligible to domestic citizens that bear the total cost for them. On the other hand, in repeated games it may be preferable to try to achieve a cooperative strategy.

Since domestic taxes is preferred over reduction of permit supply, although they are less cost efficient in reducing global emissions, one conclusion may be that policy makers prefer to reduce emissions domestically. One rational explanation to such preference may be that domestic use of fossil fuel not only gives CO<sub>2</sub> emissions but also a lot of emissions with local effects. Another may be that the reputation impact, that is important in repeated games, may be more influenced by domestic emissions than by emissions in other countries as a result of domestic policies.

The sensitivity analysis shows that the conclusion that tax exemptions are inefficient is pretty robust for different assumptions. It is only under the unrealistic assumption of Leontief technology that tax exemptions may be justified. The conclusion that electricity taxes was too low before the introduction of ETS requires that the trade elasticities are not too small. With low trade elasticities the carbon emission increases from increased taxes on electricity but the production of nuclear waste decreases even more.

The decomposition of the potential gain from a more efficient way of achieving the same emission target shows that almost all industries would gain. This result may be sensitive to the level of aggregation. In a more disaggregated model it may be the case that more industries would be losers. The lack of losers from a removal of the tax exemptions may make it difficult to understand the political-economy motives beyond the tax exemptions. One possible explanation is that there in reality are losers that are hidden in these wide aggregates of industries. Another is that it may be easier for industries to see the cost increases from increased taxes on energy than to recognise the benefits from a more efficient economy that they would achieve indirectly from changes in other relative prices.

The methodological developments in SAINT considering the treatments of trade margins seem to be of importance for analyses of the electricity market. The sensitivity analysis over trade margins indicated that these have a significant impact on the results in simulations with large changes in the electricity market while the results in other simulations were not very sensitive to the way of modelling trade margins.

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## Appendix 1 Data and elasticities

For this simulation a SAM described in Bohlin 2009c is used. Secondary products were removed so that no commodity is produced in more than one industry. To calculate the vector of inputs that should follow the output to its main producing industry, industry specific technological coefficients were calculated with the Bohlin Widell method described in Bohlin Widell 2006. In this calculation equal weights were used for the industry and commodity technology assumptions. After the reallocation of secondary output the SAM was aggregated to reduce the number of industries and commodities in order to simplify the solution of the model. Moreover industry 40 was disaggregated into 2 different industries using the industry technology assumption. Table A1.1 shows the industries in the model and the commodities they are producing after this aggregations and disaggregation.

Table A1.1 The industries in the model and the commodities they are producing

<b>A01</b> Agriculture, hunting and related service activities, Forestry, logging and related service activities, Fishing, fish hatcheries and fish farms; service activities incidental to fishing	<b>C01</b> Products of agriculture, hunting and related services, Products of forestry, logging and related services, Fish and other fishing products; services incidental of fishing
<b>A10</b> Mining of coal, lignite, uranium and thorium; extraction of peat, crude petroleum and natural gas, Mining of metal ores, other mining and quarrying	<b>C10</b> Coal and lignite; peat ,Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying ,Uranium and thorium ores, Metal ores, Other mining and quarrying products
<b>A15</b> Manufacture of food, beverages and tobacco products, Manufacture of textiles Manufacture of wearing apparel, luggage, handbags, and footwear; dressing of leather and fur.	<b>C15</b> Food products and beverages, Tobacco products, Textiles, Wearing apparel; furs Leather and leather products
<b>A20</b> Manufacture of wood and of products of wood, cork, straw and plaiting materials except furniture; Manufacture of pulp, paper and paper products, Publishing, printing and reproduction of recorded media.	<b>C20</b> Wood and products of wood and cork (except furniture); articles of straw and plaiting materials, Pulp, paper and paper products Printed matter and recorded media
	<b>C20bio</b> Biofuel
<b>A23</b> Manufacture of coke, refined petroleum products and nuclear fuels	<b>C232A</b> Gasoline
	<b>C232D</b> Diesel
	<b>C232E</b> Light fuel oil
	<b>C2327</b> Heavy fuel oil
	<b>C230</b> Other commodities in 23 coke, refined petroleum products and nuclear fuels

<p><b>A24</b>  Manufacture of chemicals and chemical products,  Manufacture of rubber and plastic products,  Manufacture of other non-metallic mineral products,  Manufacture of basic metals  Manufacture of fabricated metal products, except  machinery and equipment. Manufacture of  machinery and equipment n.e.c.</p>	<p><b>C24</b>  Chemicals, chemical products and man-made  fibres, Rubber and plastic products, Other non-  metallic mineral products, Basic metals  Fabricated metal products, except machinery and  equipment, Machinery and equipment n.e.c.</p>
<p><b>A30</b>  Manufacture of office machinery, computers,  electrical machinery and apparatus n.e.c.  Manufacture of radio, television and communication  equipment and apparatus  Manufacture of medical, precision and optical  instruments, watches and clocks  Manufacture transport equipment  Manufacture of furniture, Recycling; manufacturing  n.e.c.</p>	<p><b>C30</b>  Office machinery and computers, Electrical  machinery and apparatus n.e.c. Radio, television  and communication equipment and apparatus,  Medical, precision and optical instruments, watches  and clocks, Motor vehicles, trailers and semi-  trailers, Other transport equipment, Furniture; other  manufactured goods n.e.c. Secondary raw materials</p>
<p><b>A40</b>  Electricity, steam and hot water supply</p>	<p><b>C401</b>  Electricity  <b>C403</b>  Steam and hot water</p>
<p><b>A402</b>  Supply of gas</p>	<p><b>C402</b>  Gas</p>
<p><b>A41</b>  Collection, purification and distribution of water.  Construction</p>	<p><b>C41</b>  Collected and purified water, distribution services of  water, Construction work</p>
<p><b>A50</b>  Sale, maintenance and repair; Wholesale and  commission trade. Retail trade,  Hotels and restaurants, Supporting and auxiliary  transport activities; activities of travel agencies, Post  and telecommunications  Financial intermediation, except compulsory social  security</p>	<p><b>C50</b>  Sale, maintenance and repair; Wholesale and  commission trade. Retail trade, Hotel and restaurant  services  <b>C63</b>  Supporting and auxiliary transport services; travel  agency services  Post and telecommunication services  Financial intermediation services, except insurance  and pension funding services  Insurance and pension funding services, except  compulsory social security services  Services auxiliary to financial intermediation</p>
<p><b>A60</b>  Land transport; transport via pipelines, Water  transport, Air transport</p>	<p><b>C60</b>  Land transport; transport via pipeline services  <b>C61</b>  Water transport services  <b>C62</b>  Air transport services</p>
<p><b>A70</b>  Real estate activities, Renting of machinery and  equipment without operator and of personal and  household goods, Computer and related activities,  Research and development  Other business activities</p>	<p><b>C70</b>  Real estate services, Renting services of machinery  and equipment without operator and of personal and  household goods  Computer and related services, Research and  development services, Other business services</p>
<p><b>A75</b>  Public administration and defence; compulsory  social security, Education, Health and social work</p>	<p><b>C75</b>  Public administration and defence services;  compulsory social security services, Education  services, Health and social work services</p>
<p><b>A90</b>  Sewage and refuse disposal, sanitation and similar  activities, Activities of membership organisation  n.e.c. Recreational, cultural and sporting activities  Other service activities, Private households with  employed persons</p>	<p><b>C90</b>  Sewage and refuse disposal services, sanitation  and similar services, Membership organisation  services n.e.c. Recreational, cultural and sporting  services, Other services</p>

In table A 1.2 the trade elasticities used in different simulations are reported.

Table A 1.2 Trade elasticities

Commodity	Most simulations		Sensitivity analysis 4.3	
	import	export	import	export
C01	1.65	3.90	1.1	2.6
C10	1.65	3.90	1.1	2.6
C15	1.65	3.90	1.1	2.6
C20	1.65	3.90	1.1	2.6
C232A	2.25	4.50	1.5	3.0
C232D	2.25	4.50	1.5	3.0
C232E	2.25	4.50	1.5	3.0
C2327	2.25	4.50	1.5	3.0
C23O	2.25	4.50	1.5	3.0
C24	1.65	3.90	1.1	2.6
C30	1.65	3.90	1.1	2.6
C401	3.00	4.50	2.0	3.0
C41	0.75	1.20	0.5	0.8
C50-52	0.75	1.20	0.5	0.8
C60	1.20	3.45	0.8	2.3
C61	1.20	3.45	0.8	2.3
C62	1.20	3.45	0.8	2.3
C63	1.20	3.45	0.8	2.3
C70	0.60	1.20	0.4	0.8
C75	0.75	1.20	0.5	0.8
C90	0.90	1.80	0.6	1.2

## **Appendix 2 Calculations of carbon emissions**

Carbon emissions from domestic production are calculated from the use of fossil fuels times the coefficient for carbon emission in table A5. Carbon leakages from net trade in electricity are calculated as the change in net trade times 0.835. Carbon leakages from trade in other commodities are calculated by multiplying the change in net trade with the sum of the technological coefficient for fossil fuels in domestic production times the coefficients in table A5 and the technological coefficients for electricity times 0.835. The implication of this calculation is that foreign production are assumed to be more carbon intense than domestic production since domestic use of electricity only adds to the carbon emission if it has an impact on net trade in electricity and not if domestic electricity production changes while all use of electricity in foreign production adds to carbon emission.

**Table A 5 Carbon emissions used in the calculations**

<b>Energy</b>	<b>carbon emission</b>	<b>source</b>
Gasolin	2.375 kg/l	calculated from tax rate
Diesel	2.855 kg/l	calculated from tax rate
Light fuel oil	2.855 ton/m <sup>3</sup>	calculated from tax rate
Heavy fuel oil	2.855 ton/m <sup>3</sup>	calculated from tax rate
Natural gas	2.136 ton/m <sup>3</sup>	calculated from tax rate
Other fossil fuels	0	Not included in the calculations.
Electricity net trade	0.835 kg/kWh	Statistics Denmark. As a comparison coal condensing plants that most often are marginal production have emissions of 1.0 (Werner, 2001)
Domestic electricity	0	

### **Appendix 3 Tax rates on energy in the base solution.**

**Table A 3.1 Tax rates on energy in base**

<b>Fuel</b>	<b>user</b>	<b>taxrate</b>	<b>motivation</b>
Gasolin liter	All	4.50	
Diesel liter	All except 05,13 and 61	3.39	
	05 fishing	0.02	All diesel used in boats are tax free
	13 mining of metal ores	0.75	diesel used in special vehicles in mining are tax free
	61 Water transports	0.01	All diesel used in boats are tax free
Light fuel oil liter	01-37	0.38	agriculture and industry pay no energy tax and just 25 % of CO2 tax
	40	0.73	no taxes in prod. of electricity, half energy tax in prod. of heat <sup>15</sup>
	41 - 95 households	2.21	
		2.21	
Heavy fuel oil liter	01-37	0.42	agriculture and industry pay no energy tax and just 25 % of CO2 tax
	40	0.76	no taxes in prod. of electricity, half energy tax in prod. of heat
	41 - 95 households	2.28	
		2.28	
electricity kWh	01-37	0	No tax in industry and agriculture
	40-55, 61-95	0.18	
	60	0.03	No tax in railways
	H	0.18	
gas liter	01-37	0.29	agriculture and industry pay no energy tax and just 25 % of CO2 tax
	40	0.63	no taxes in prod. of electricity, half energy tax in prod. of heat
	41 - 95 households	1.37	
		1.37	

<sup>15</sup> An assumption of 50% electricity and 50 % heat is used in the calculation of the tax rate.