Is CO_2 trading always beneficial?
A CGE-model analysis on secondary environmental benefits[♦]

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Abstract

The paper analyzes the cost-efficiency of trading CO_2 emissions by focusing on the overall environmental impacts of active climate policy measures. When reducing CO_2 emissions, other emissions, also related to the consumption of fossil fuels, decrease with no additional cost. These secondary benefits must be taken into consideration when analyzing gains from international emissions trading. The Swedish environmental target to comply with the Kyoto Protocol by reducing greenhouse gases, and two national goals to alleviate acidification and eutrofication effects by reducing SO_2 and NO_x pollutants are simultaneously studied in a CGE-modeling framework. The results indicate that when secondary benefits are taken into account, it may still be in the government's interest to decrease CO_2 nationally, instead of engaging in seemingly low-cost trading.

Key words: emissions trading, secondary benefits, climate policy.

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1. Introduction

In several studies, it has been shown that countries with high marginal costs to reduce their greenhouse gas emissions would benefit from international emissions trading. Trading would guarantee economic efficiency by minimizing costs to achieve national emission reduction targets agreed upon in Kyoto. (Bohm, 1998; Matsuo, 1998; Mullins and Baron, 1997; Parry et al. 1998; UNCTAD, 1998)

However, there are factors that may reduce the expected total cost saving of trading CO_2 permits. The efficiency gains could be decreased because of the potential of governments to exercise market power (e.g. Burniaux, 1998). The possibility of high transaction costs may also decrease the efficiency gains (Liski, 1998). Furthermore, trade does not necessarily benefit all countries equally. As pointed out by Böhringer et al. (1998), the final outcome depends on the domestic substitution effect vs. the terms of trade effects. Permit buyers face lower marginal abatement costs after trade on the one hand, but their terms of trade worsen on the other hand. In addition, Böhringer et al. (1998) warn against too optimistic estimates of total cost savings from CO_2 trading. According to their model simulations, trade would produce efficiency gains of only around 10% of EU-wide total abatement costs.

We study an additional interesting aspect of the cost-efficiency of trading CO_2 emissions: the overall environmental impacts of active climate policy measures. Since there are no technological possibilities to “clean up” CO_2 emissions, the measures to reduce emissions are mainly related to the use of energy. Energy efficiency can be enhanced and less carbon-intensive patterns of consumption and production can be promoted. Consequently, when tackling the energy system as a whole, there are other harmful emissions that will reduce along with adoption of measures to save energy. Typical examples of these emissions are sulfur and nitrous oxides (SO_2, NO_x). The other emissions are not necessarily global, but it may still be in the national interest to reduce negative regional and local environmental impacts of air pollutants. If there are considerable secondary benefits associated with active climate policy, the benefits should be taken into account in cost-efficiency considerations.

Neglecting the secondary environmental benefits of measures limiting greenhouse gas emissions brings into mind the well-known criticism that has earlier been directed against environmental policy. A successful policy should not be “medium-specific”, i.e., one should not control only one emission at a time. Otherwise, the regulated emission load may reduce only at the expense of an increase in other emissions; in other words, the residuals only alter their form (Ayres and Kneese, 1969). Our point here is a mirror image of this discussion. Because of the lack of cleaning mechanisms for greenhouse gases, the focus is, quite correctly, on the energy use as a whole. As a result, there will be other emission reductions that come with no additional cost, gratis. Purchasing tradable CO_2 permits seems to be the most favorable, cost-minimizing policy option, but the reductions in other emissions, or local and regional secondary benefits should also be considered when evaluating net costs of policy measures. The costs per a unit of CO_2 reduction become lower, if simultaneous reductions in other emissions are acknowledged.

In the previous literature, Ekins (1996) has reviewed estimates of secondary benefits from several international studies and presents a possible range of SO_2 related secondary benefits in the UK.[1] In our paper, the importance of secondary environmental benefits is related to emissions trading by using the Swedish case as an illustrative example. An interesting feature of the Swedish climate policy is that Sweden has already implemented a tax on CO_2 emissions, and is one of the European countries that have relatively high marginal costs to reduce CO_2 emissions. Sweden would be an obvious candidate for buying tradable CO_2 permits. However, by launching trade in CO_2 permits the government's tax revenues would necessarily be transferred to factor payments abroad to finance "import of carbon dioxide". Therefore, imposing new taxes or charges should be considered as an alternative to balance the government budget and to finance domestic transfer payments, which are currently financed by a CO_2 tax.

We use a Swedish static computable general equilibrium (CGE) model, which incorporates other noxious emissions (SO_2, NO_x) than CO_2 only to analyze the expected secondary environmental gains resulting from active policy measures, motivated by climate policy. To take into account the secondary benefits we assume that the present environmental taxes on sulfur and nitrogen emissions reflect the politically determined willingness to pay for a marginal reduction (avoided damage) of these emissions.

[1] See Kverndokk and Rosendahl (2000) for other studies, which have used same background information on benefit/damage estimates as Ekins.

The next section briefly reviews those aspects of the emissions trading literature, which are relevant for our analysis. Thereafter a short description of the model and the reference scenario ("business as usual") is given. Numerical simulations of meeting the requirements of the Kyoto Protocol with and without emissions trading are presented. Finally, the potential gains from trade in CO_2 permits are discussed with special emphasis on secondary benefits.

2. Emissions trading

The Kyoto Protocol requires that industrialized countries reduce their emissions of greenhouse gases by 5.2 % of 1990 levels by the period 2008-2012.[2] The Protocol allows the use of the so-called flexibility mechanisms to lower the implementation costs of the treaty. Emissions trading is one of these mechanisms.

The underlying idea of emissions trading is to allow more abatement to be undertaken where the marginal cost of abatement, at the given quota allocation, is the lowest. The purpose is to combine an administrative instrument (amount of permits; regulation target) with efficiency features of market-based instruments (emissions have a market price in terms of permit prices; taxes). In other words, the total amount of permits is determined by a quota in order to set an upper limit to the emissions level, but the system of trading itself guarantees cost-efficiency --- in a similar way as taxes do --- such that emissions reduction is reached at the lowest possible cost. Those who have relatively low (high) costs of reducing emissions can benefit from selling (purchasing) permits. There will be no incentive for further trade in permits once the marginal cost of abatement from each emission is equal to the price of permit.

Consequently, a fundamental incentive for launching CO_2 trading domestically or internationally is that the costs of reducing greenhouse gases differ among the sources that generate CO_2 emissions. The marginal abatement costs may differ for two reasons: either the marginal cost of *abatement functions* or the emission *reduction targets* are different. For example, even if two countries have the same marginal cost of abatement functions, a cost differential arises if they have different emission reduction requirement placing them at different points on the function. Furthermore, differences in both marginal and total

[2] For a critical evaluation of the Protocol, see, e.g., Barrett (1998).

abatement cost stem from differences in the projected population growth, the rate and nature of production growth, economic trade relations with other countries, the efficiency of the current energy technology stock, and the availability of alternative energy sources.
The European Union has committed itself to a reduction of greenhouse gases by 8 per cent from the 1990 level to the period 2008-2012, but the member countries have agreed on differentiated targets within the European "bubble". To some extent the abatement cost differences were taken into account when the member countries pledged to "burden sharing" within the EU. However, the target levels agreed upon within Europe do not necessarily harmonize the marginal abatement costs from country to country. On the contrary, recent analyses indicate that countries do not face equal conditions when reducing their energy-related CO_2 emissions to meet the Kyoto targets. However, a comprehensive comparison of cost estimates is difficult because of the different assumptions underlying different models and estimation techniques used in the analyses. Cost estimates depend crucially on the baseline scenarios assumed and technologies included in the analyses.[3]

The International Energy Agency has estimated CO_2 mitigating costs by using the energy model MARKAL (Kram 1998; Schmid and Schaumann, 1998). The marginal cost range for EU member states was estimated to be US $ 0 to US$ 252 per ton of CO_2 equivalent if all countries cut emissions by 8% from 1990 level. When comparing the costs between the individual EU member countries, it was found that Sweden would bear a cost burden well above average. In the US, the Clinton administration has reported that if emissions were stabilized at 1990 levels in 2010, the implicit marginal cost would be (in terms of 1995 dollars) US $ 145 per ton of carbon, or approximately 1995 US$ 60 per ton of CO_2 (Interagency Analytical Team, 1997).

Böhringer et al. (1998) have used a CGE-model covering seven EU member countries to consider burden sharing within the European "bubble". A model run illustrating a case where each country would reduce CO_2 emissions by 8 % from 1990 resulted in an estimate of a marginal cost range of 1995 US $ 28 to US $134. If trade were allowed, the market price of a CO_2 permit would be 1995 US $ 50 in 2010. Again, to make a comparison with the US, another CGE-model result shows that the marginal cost is US $ 240 per ton of carbon

[3] The literature on the economic aspects of climate change is considerable. Here we have considered models that simulate the implementation of the Kyoto target levels. See, e.g., OECD (1998) for other CO2 targets simulated for the US, Europe and Japan.

(US$100 per ton of CO_2) if the US must satisfy its reduction target within its own geographical boundaries. The cost would drop to US$100 per ton of carbon (US$42 per ton of CO_2) with Annex I trading *and* the Clean Development Mechanism. (Manne&Richels, 1998) It is important to highlight the tentative nature of the cost projections presented in various modeling studies. A general conclusion to be drawn is that for similar reduction objectives, marginal costs of greenhouse gas reductions differ widely. This supports the argument that CO_2 trading would lead to efficiency gains.

3. The model and the baseline calibration

In the following analyses, we will use a Swedish general equilibrium model, EMEC[4], which has been developed to analyze environmental policy measures and their economic impacts. The model is currently calibrated for the economic and environmental accounts of 1993. The Swedish economy illustrated by the model consists of a public sector and 17 production sectors. These sectors use four inputs: capital, energy, material, and labor, where labor is divided into three groups: unskilled, technicians and skilled non-technicians. The total supply of labor is exogenous, while capital is supplied at a given international interest rate. All production factors are mobile between sectors in the economy. The production technology is captured by CES functions, and the nesting structure of input choices in production is illustrated in Figure 1. Production results in output of 20 composite commodities, which are allocated to intermediate goods, investments and final demand. In line with the Armington assumption, domestic and foreign goods are differentiated such that non-traded and traded goods are separated. The model is closed by an exogenous Current Account ratio and the foreign price level is the numeraire. A detailed model description is given in Östblom (1999).

Energy sector, emissions and taxes

A considerable share of air pollution is emitted from combustion of fossil fuels: energy use and transports are emission intense economic activities. That is why households play an important environmental role in energy political decisions. Still, heavy industries such as iron, steel and metal as well as pulp and paper, traditionally have the highest energy uses per value added, as compared to other production branches in Sweden. (Statistics Sweden 1998:11)

[4] Environmental medium term economic model

In the model, five energy sources are specified: electricity, coal, oil, gas, and biofuels. There are three atmospheric emissions (CO_2, SO_2, NO_x) linked to the production sectors, the public sector and the households. It is noteworthy that the links between sectors and emissions have been established via the use of energy in these sectors; the different emission contents of each type of fuel are identified using fuel specific coefficients. Therefore, fuel substitution possibilities as a measure to minimize emissions are relatively realistically described.[5]

The use of energy by households and firms has mainly been taxed for fiscal rather than environmental reasons. However, in addition to direct taxation of energy, Sweden has imposed taxes on carbon dioxide and sulfur emissions: tax rates are 370 SEK per ton of CO_2 and 30 000 SEK per ton of SO_2 [6]. When calibrating the tax rates in the model, today's reduced tax rates and exemptions for certain industries, such as the manufacturing industry, have been taken into account. There is also a charge on nitrogen oxides; large combustion plants with annual production of 25 GWh or more pay SEK 40 000 per ton emitted. However, the nitrogen charge is neutral to the national budget, since repayments are made to operators of plants with the lowest nitrogen emissions. Furthermore, private consumption is subject to value-added tax and other indirect commodity taxes. The government receives income also in payroll taxes paid by employers. Consequently, firms and households maximize their profit/utility by using the relatively lowest priced production factors/consumption goods, given the prevailing prices including taxes and substitution possibilities/preferences.

Reference scenario

The model reference scenario up to year 2015 has been developed at the National Institute of Economic Research for the medium term survey of the Swedish economy (National Institute of Economic Research, 2000), and rests upon the following assumptions:

- The number of employed grows by 0,4 % per year.
- The average workweek is shortened from 36,9 hours/week to 35,5 hours/week.
- The labor productivity increases by 1,8 % per year.
- Government expenditures increase by 1,2 % per year.
- The Current Account surplus is slightly below one % in 2015 and has thereby decreased from today's high levels.

[5] In many CGE-models emissions are still related to aggregate output/consumption levels.

- The world market grows by 4 % per year.
- The world market prices increase on average by 1,5 % per year. More specifically the world market annual price increases are for: oil – 1,1 %; coal – 0,6 %; gas – 2 %; electricity – 1,9 %. The world market price for biofuels is assumed to be constant during the simulation period.

Changes in the macroeconomic key variables over time, captured in the baseline scenario are summarized in Tables 1 and 2.

Table 1 Key figures for the Swedish economy 1980-2015
Annual % change

	1980-1989	1990-1997	1980-1997	1997-2015
GDP	2,1	0,8	1,5	1,9
Private consumption	1,7	0,3	1,0	2,4
Government consumption	1,5	-0,1	0,9	1,2
Investments	3,5	-3,8	0,3	3,0
Exports	4,4	7,5	5,5	3,7
Imports	3,9	4,4	3,9	4,2
Employment [1)]	1,0	-1,1	0,1	0,2
- Private sector, total [1)]	0,9	-1,0	0,1	-0,2
- Government sector [1)]	1,5	-1,5	0,2	1,1
Current account [2)]	0,6	9,2	9,2	0,8

[1)] Hours worked
[2)] In percent of GDP in the final year
Source: SCB and EMEC

Table 2 Value added and employment 1997 - 2015
Annual percent change

Branch	Value added [1)]	Hours worked
Agriculture, fishery and forestry	0,2	-2,4
Mining	0,6	-1,9
Pulp and paper mills	1,4	-0,9
Chemical industries	1,8	-1,1
Basic metal industries	1,6	-1,4
Engineering	3,3	-0,1
Other industries	0,4	-1,7
Electricity, gas and heat supply, Water and sewage	0,9	-1,7
Petroleum refineries	0,3	-2,6
Construction	1,2	-0,2
Transportation	1,4	-0,7
Services	2,2	0,3
Real estate	0,8	0,5
Private sector, total	1,9	-0,2
Government services	1,2	1,1

[1)] Factor prices
Source: EMEC

As indicated in Tables 1 and 3, *total energy demand* is supposed to increase annually by 0,8 %, i.e., at a lower rate than the growth of GDP, 1,9 %. Reduced energy demand is partly

[6] Tax rates of 1997, US$ = SEK 7.64 in 1997.

achieved by enhancing energy efficiency in the private sector. Industry and services account for almost one half of total energy consumption.

Table 3 Energy demand and emissions 1997-2015
Percent, %

	Energy demand, Annual change	Share of total energy consumption year 2015
Industry and services	0,7	48
Transportation (exclusive household transports)	-0,1	11
Energy supply	1,3	13
Households	1,1	29
Total	0,8	100

Table 4 reports two alternative scenarios with a lower (1,3 %) and a higher (2,5 %) annual growth of GDP and corresponding growth of emissions. It is worth pointing out that no major development or breakthrough in cleaning mechanisms to reduce SO_2 and NO_X has been assumed, but the growth of emissions represents today's technological abatement possibilities.

Table 4 Alternative scenarios
Annual growth rates (%) and emission levels 2015 (ton)

	GDP %	CO_2 % / mill.ton	SO_2 % / 1000 ton	NO_X % / 1000 ton
Alternative, low	1,3	0,3 / 60	0,0 / 100	0,9 / 410
Baseline	1,9	0,9 / 67	0,7 / 110	1,8 / 460
Alternative, high	2,5	1,5 / 74	1,3 / 120	2,2 / 510

One conclusion to be drawn from Table 4 is the relatively strong positive correlation between emissions and economic growth. Consequently, the general economic development behind the scenarios should be kept in mind when comparisons between the reference and policy scenarios are made. In the following analyses, we use the *baseline* GDP growth as our reference scenario.

4. Kyoto simulations

Within the European "bubble" Sweden has negotiated a target of not exceeding the greenhouse gas emissions level of 1990 by more than 4 % in 2008-2012.[7] The following simulations illustrate the effects of fulfillment of the Swedish CO_2 target such that all simulation results are related to the reference scenario described above in Section 3. The difference between the reference scenario and the alternative policy scenario ("Kyoto scenario") is thereby interpretable as the consequence of implementing the climate policy that Sweden has agreed upon internationally. It should be noted that we assume that world market prices do not change due to the implementation of the Kyoto Protocol. This can be interpreted as a simulation of a unilateral action or an action that does not have any effect on the world markets.

The measurement reference for reduction of greenhouse gas emissions within the Kyoto Protocol is the average of emissions during the period 2008-2012. It should be pointed out that the simulations here have 2015 as the final year, because the reference scenario was initially prepared for the medium term survey of the Swedish Department of Finance.

Compliance with the Kyoto Protocol by reducing CO_2 emissions within Sweden

The Kyoto Protocol can be implemented in Sweden by increasing the current carbon dioxide tax such that the energy use in the economy decreases to a level where the carbon dioxide emissions conform to the level agreed upon. When the tax rate is increased, the economic agents have several options in the long run to adopt to the new price levels. Substitution between fuels and between fuels and other inputs make it possible to reduce emissions without decreasing output. Our simulations show that the carbon dioxide tax must be increased approximately 2,5 times from the 1998 level. This corresponds to a tax of US $ 119/ton of CO_2 (or 0,91 SEK/kg CO_2)[8]. However, one reason for the high tax rate is the many exemptions applied in practice. The manufacturing industry has a reduction of 50 % from the common carbon dioxide tax level and carbon dioxide emissions from industry processes are not taxed at all.

The difference in GDP in 2015 between the reference scenario and the Kyoto scenario (see Table 5) is 0,3 %, or almost US $ 1 billion (slightly above seven billion Swedish crowns). This may seem as a relatively small economic effect, but it should also be recalled that a static CGE model estimates the long term cost estimate. It pertains to a situation where the economy has totally adjusted to the changes that conforming to the emission goal requires, and has

[7] The possibility to increase emissions was motivated by the Swedish decision to phase out nuclear power.
[8] Using the exchange rate of US$ = SEK 7,64 and 1997 prices.

reached a new equilibrium. Despite the high marginal costs, a moderate impact on GDP is corroborated by other international studies.[9]

Table 5 Macroeconomic effects of the policy scenario, compliance with the Kyoto Protocol in 2015

	Percentage change compared to the reference scenario	Billion SEK compared to the reference scenario
GDP	-0,3	- 7,0
Private consumption	-0,1	-0,7
Government consumption	0,0	-0,0
Investments incl. storage	-0,5	-1,9
Exports	-0,7	-10,5
Imports	-0,5	-6,1
Real income[1)]	-0,3	-5,7

[1)] Adjusted for terms of trade effects

Since the supply of labor is exogenously given in the model, the level of employment is not affected by the wage changes. However, the adjustment to an increased carbon tax results in modest wage reductions (less than 0,1 % annually), which affect the allocation of labor between sectors. Moreover, since real wages decrease in the Kyoto scenario, households' labor income decreases as well. On the other hand, the increased tax revenues from the carbon dioxide tax are redistributed to the households by lump-sum transfers. This can be interpreted as for example a flat rate decrease in the income tax.

In a model with total employment given and with totally flexible wages, no employment effects can be studied. However, to test the sensitivity of employment to an increase in a carbon tax, we made an additional simulation experiment. Therefore, we assumed that wages are rigid at the reference scenario level, and it will be the total employment that has to adjust such that demand equals supply on the labor market. This will induce a total employment effect that will decrease total employment by 0,6 % compared to the reference case in 2015. The sectoral impacts of climate policy on the Swedish economy are illustrated in Figures 2 and 3 in both cases, i.e., with rigid and flexible wages.

[9] Initially, before the agreement achieved in Kyoto, the total European costs were estimated to be 15-35 bn ECU annually by 2010 for a 15 % reduction in CO2 emissions compared to 1990 (COM(97)481). This corresponds to 0.2 – 0.4 % of GDP produced in the EU member countries. MARKAL-MACRO model has been used for post-Kyoto calculations, and the estimated total costs for EU13 proved to be 0.24% of GDP. (ETSAP; Schmid&Schaumann 1998). See also Kverndokk and Rosendahl (2000) for a survey on mitigation costs for Nordic countries.

Emissions trading

EMEC is a single country model and is therefore only capable of analyzing effects on the Swedish economy. In order to analyze emissions trading, the price of emission permits has to be taken as given. This is probably also true in reality, because Sweden is a small open economy and can hardly affect the world markets, or prices of tradable permits. Since Sweden already has a carbon dioxide tax and the tax revenues are used to finance government expenditures, the government has to take into account its budget constraint. In our policy scenario, the budget constraint corresponds to the one in the reference scenario.

Technically, the emission permits are modeled as imported goods that are bought by the government. The government in turn collects taxes to finance the trade on emission permits. The implementation of the Kyoto Protocol increases the tax rate in Sweden so that it matches the international price of emission permits. When the tax rate is higher than the price of permits, it is cheaper to buy emission permits from abroad. However, the present tax system with exemptions to certain industries, means implicit subsidies for the exempted industries whenever the price of internationally tradable CO_2 permit is higher than the reduced (exempted) domestic tax. In this case the government has to finance its increase in expenditure by decreasing the households' consumption possibilities. This can be interpreted as an increase in the income tax or as a decrease in transfers from the government to the households.

There is a considerable uncertainty about what the international price level of CO_2 permits will be. We have chosen to illustrate the effects of emissions trading with two ad hoc price levels for the international emission permits, US$ 100/ton of CO_2 and US$ 50/ton of CO_2, the latter of which approximately corresponds to the current Swedish carbon tax rate.

Table 6 Effects of the implementation of the Kyoto Protocol compared to the reference scenario in 2015
Macroeconomic effects (rows 1-8) in *billions of Swedish crowns*

	No International Trade	Trade with Emission Permits Price: $50	Trade with Emission Permits Price: $100
GDP	- 7,0	-3,9	-6,8
Private consumption	-0,7	-0,4	-0,5
Government consumption	-0,0	0,0	0,0
Investments incl. inventories	-1,9	-0,1	-1,4
Exports	-10,5	-0,1	-7,9
Imports[1)]	-6,1	-0,3	-4,6
Real income[2)]	-5,7	-0,5	-4,1
Total costs of emission permits	0,0	3,6	1,7
CO_2 –emissions *in million tons* compared to the reference scenario	-9,1	-1,2	-7,1
Percent of total CO_2-reduction that is bought from abroad.	0,0	97,2	22,8
Carbon dioxide tax within Sweden, *US$/ton*	119	50	100

1) Does not include imports of emission permits.

2) Adjusted for terms of trade effects

By allowing international trade with emission permits at the above given prices, the macroeconomic effects of the Kyoto Protocol become even more negligible than in the case of reducing carbon dioxide emissions entirely within the Swedish borders. When the price of the emission permit is 50 dollar per ton carbon dioxide the present emission tax is only slightly increased to reach the 50 dollar level (from the present level of 48 dollar per ton of CO_2). The domestic carbon dioxide emissions do not increase very much, and the reduction needed to meet the Kyoto Protocol is bought abroad. The carbon dioxide tax revenue that was used for financing government expenditures in the reference case is now used for financing the emission permits bought from abroad. This leads to a decrease in the households' consumption possibilities.

Importing emission permits naturally affects the current account, which is exogenously given as percentage of GDP. In the long run the government can not “borrow” from abroad to finance its imports. Instead, all imports must be financed by exports and the balanced current account constraint must be satisfied in the end year of the simulation period. The permit payment is an expenditure flow out of the country. Consequently, as can also be seen from Table 6 the export is not decreased as much as the import of goods and services in the scenarios with emissions trading.

If the price of emission permits is 100 dollars per ton of CO_2, the difference in GDP is hardly noticeable compared to the scenario where the emission reduction was done completely within the country. The carbon dioxide tax is raised until it reaches 100 dollars per ton of

CO_2, which is only 19 dollars less than the tax needed to reach the Kyoto target within Sweden. The marginal cost curves in Figure 4 illustrate the effects of different emissions trading assumptions.

5. Taking into account the secondary benefits

Emissions of other environmentally harmful gases such as sulfur and nitrogen oxides are indirectly affected by the implementation of the Kyoto Protocol, because these gases are also strongly related to the burning of fuels. In particular, the Swedish parliament has defined 15 different domestic environmental targets that should be reached within a generation. Among other things, the goals aim at alleviating acidification and eutrofication. There is both environmental and political pressure to reduce air pollutants such as SO_2 and NO_X. Therefore, it is interesting to study the effects of international CO_2 trading on the reduction of other emissions. These effects can be seen in Table 7.

Table 7 Emissions in alternative scenarios
Changes in % (and mill./1000 tons) compared to the reference scenario in 2015

	CO_2 % (mill.ton)	SO_2 % (1000 ton)	NOx % (1000 ton)
No international trade	-13,6 (-9,1)	-9,3 (-10,1)	-14,5 (-69,0)
Trade with Emission Permits Price: $50	- 1,7 (-1,2)	-0,3 (-0,3)	-0,4 (-1,9)
Trade with Emission Permits Price: $100	-10,5 (-7,1)	-7,2 (-7,8)	-11,1 (-52,9)

The results show that the reductions of SO_2 and NO_X emissions are very low when the price of a tradable CO_2 emission permit is $50 per ton of CO_2 compared to the reduction in the reference scenario.[10] Furthermore, if Sweden's goal were to reduce its emissions of SO_2 and NO_X such that they correspond to the alternative scenario of "no international trade", this would imply that the emissions of SO_2 should be decreased by 9856 tons and the emissions of NO_X by 67144 tons. Given that both SO_2 and NO_X emissions increase in the reference scenario for 2015, the present Swedish tax rates for these emissions should give a lower

[10] There are two caveats that should be born in mind. Contrary to CO2, sulfur and nitrogen emissions can be abated by various cleaning mechanisms (filters etc.) and other technical solutions. However, in our simulations no explicit new avoidance mechanisms are included, but the emission contents of fuels are fixed. In addition, the Swedish sulfur and nitrogen oxide emissions to some extent affect other countries and other countries export emissions to Sweden's territory. These emission transports are not included in the analysis.

bound estimate on the marginal benefits of reducing these pollutants, or avoiding the damages they cause. The tax rates are SEK 30 000 per ton of SO_2 and SEK 40 000 per ton of NO_X so that an estimate of the total damage of both SO_2 and NO_X using the emission taxes is SEK 3 billion. In other words, this is the value of SO_2 and NO_X emissions reduction lost when CO_2 reduction is not carried out within Sweden. If this damage estimate (approximately SEK 3 billion) is added to the loss in GDP (SEK 3,9 billion), the total cost of fulfilling the Kyoto Protocol by engaging in international trade at a price of 50 dollars per ton CO_2 emission is SEK 6,9 billion. This indicates that the obvious gain from international trade has almost vanished if the secondary benefits are taken into account in the calculations.

The same calculations can be performed for the scenario where the emission price is US $ 100 per ton of CO_2. In this case, the SO_2 emissions must decrease by 2314tons and the NO_X emissions by 16147 tons in order to correspond to the case of emissions levels of no trading. This means an additional damage cost of SEK 0,7 billion. Adding this sum to the GDP loss, the total cost for Sweden of meeting the Kyoto target by allowing international trade at US $ 100 per ton of CO_2 is SEK 7,5 billion. In other words, taking into account the damage costs, estimated by the present tax rates for SO_2 and NO_X, the total economic costs of complying with the Kyoto Protocol, when emission permits cost US$ 100, are higher than if the emission were reduced just within the country.

The conclusion from our model calculations and estimates of the damages of SO_2 and NO_X emissions is that taking into account secondary benefits may affect the attractiveness of emissions trading when the effectiveness of environmental policy as whole is an issue. A word of caution is in order here because of the uncertainties regarding the development of abatement technology for SO_2 and NO_X emissions. Potential technological developments in abatement have not been included in our model for the very reason that it obviously is very difficult to forecast future technological development. Moreover, as a damage estimate for pollution we used constant, current environmental tax rates. This is a justified assumption if we believe that the tax rates are optimal as well as that firms are rational and they today clean emissions as long as abatement costs are lower than taxes. It is also a standard assumption that instead of being constant the marginal benefits of abatement tend to decrease with abatement. That is why our damage estimates would be rather conservative measures and give a relatively strong support to the importance of secondary benefits when emissions tend to increase. However, the marginal abatement costs may decrease over time due to technological development, which would affect optimal taxes.

6. Conclusions

International emissions trading is a textbook example on an efficient way to reduce global pollutants such as CO_2 emissions. However, some writers emphasize cases when CO_2 trading as such does not necessarily guarantee an efficient emission reduction. In this paper we have considered another critical argument, secondary benefits. If there are other important environmental goals than reducing CO_2 emissions only, which are related to energy use and combustion of fossil fuels, the reduction of carbon content in the atmosphere has positive by-effects that should be taken into account.

In a CGE-modeling framework, we have analyzed the Swedish environmental goals conforming to the Kyoto Protocol, when simultaneously meeting national goals to alleviate acidification and eutrofication effects by reducing SO_2 and NOx pollutants. We have found that when secondary benefits of measures aiming at reducing CO_2 are taken into account, it may still be in the government's interest to decrease CO_2 nationally, instead of engaging in seemingly low-cost trading.

One counter argument for our reasoning is also evident: since SO_2 and NO_X emissions do not obey national territorial borders (in the similar way as the CO_2 emissions do not), the emissions reductions elsewhere also benefit the country that buys CO_2 permits. However, this is not our point. Lack of data prevents us from studying, e.g., the effects of diminished benzene emissions (in addition to sulfur and nitrogen) due to decreased fuel consumption in national transports, which contribute clearly and, for the major part, *only* to local environmental benefits. Here, sulfur and nitrogen emissions have been used as an example of secondary benefits phenomenon, since there are relatively reliable data on these emissions. The point of the paper is that there may also be "selfish" reasons to engage in efforts to reduce carbon dioxide emissions domestically, when there is no cleaning technology available and tackling initially a very specific environmental problem leads to measures (such as energy saving) that affect also other emissions.

Seemingly irrational or inefficient environmental policy should not be condemned without a careful investigation on what the total benefits of the policy measures are. In reality, specific measures, focused on solving a certain environmental problem, often have economic and environmental “spillover” effects. We have emphasized here that the spillover effects can also be positive, and this should affect the net cost-efficiency considerations of environmental policy.

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Figure 1 The input-activity specification in *EMEC*

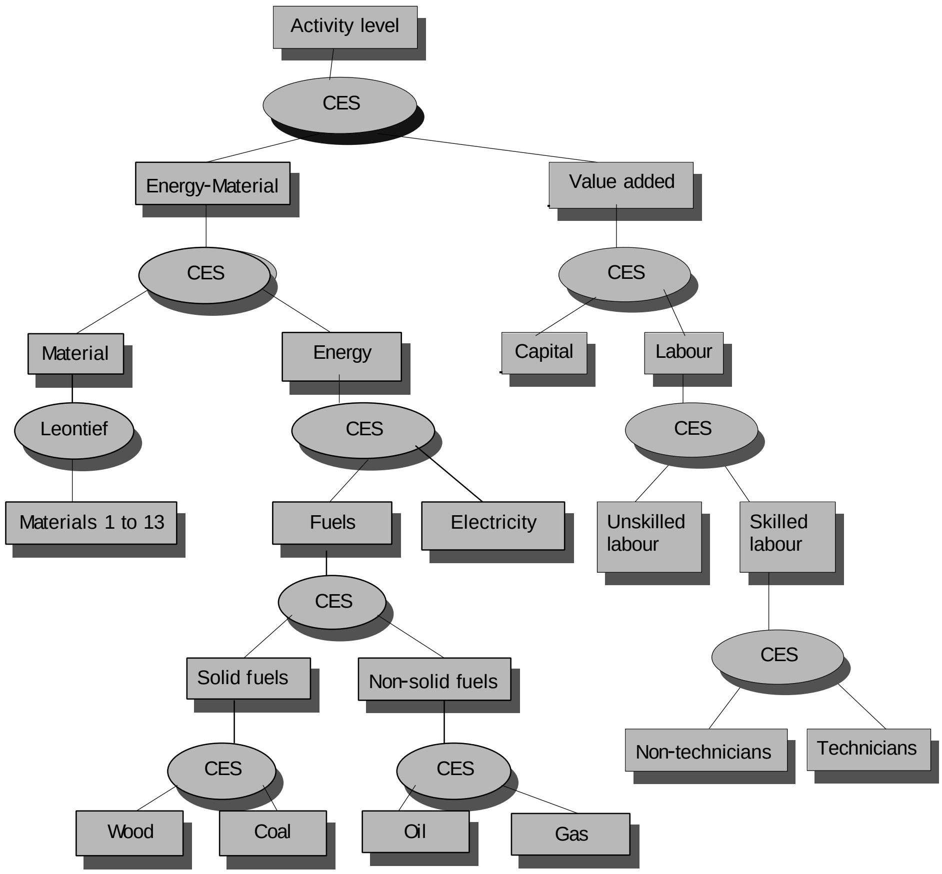


Figure 2 Value added. Percentage change compared to the reference scenario in 2015

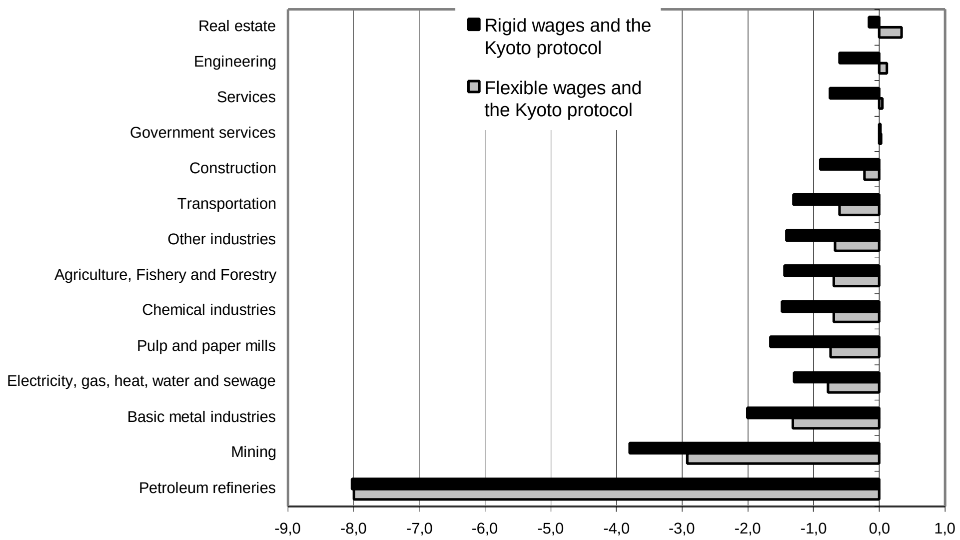


Figure 3 Employment. Percentage change compared to the reference scenario in 2015.

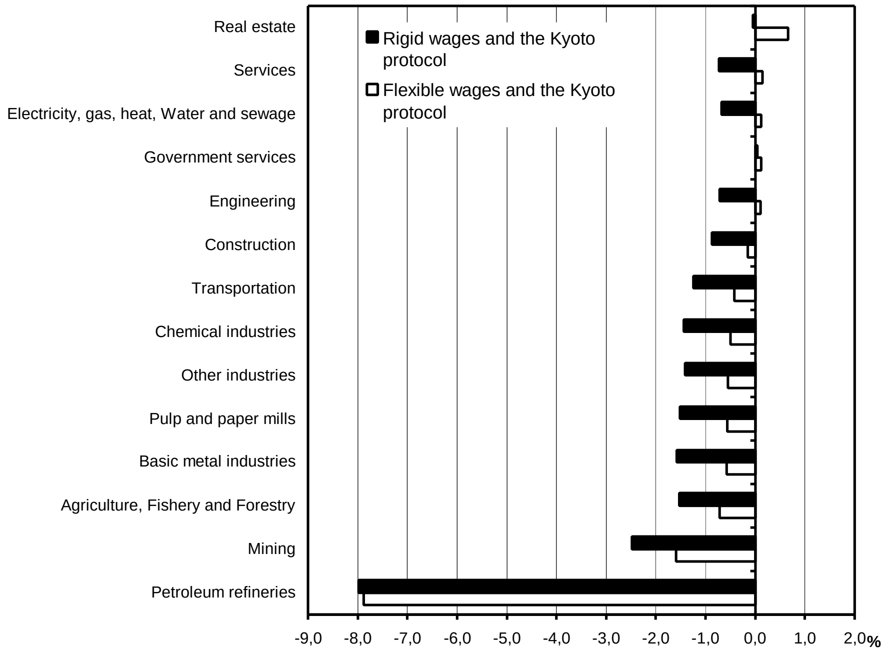
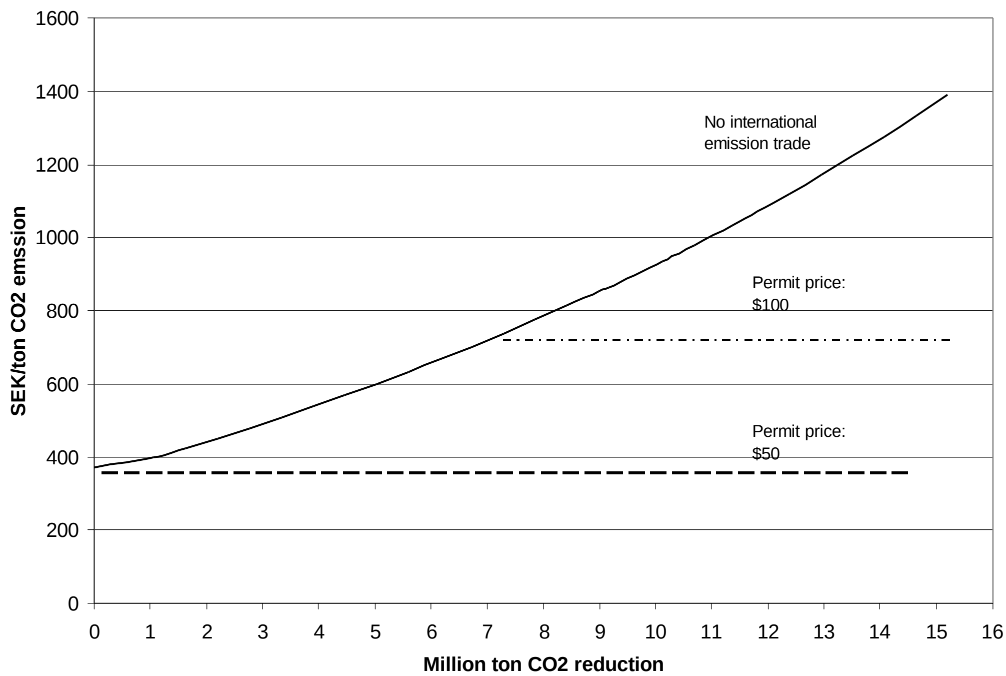


Figure 4 Marginal cost curves for Sweden [1) 2)]



1) The Swedish CO_2 tax was SEK 370 per ton in 1998.

2) When emissions trading is allowed, internationally determined permit prices represent Backstop technology costs for Sweden (dashed lines).