A Unilateral versus a Multilateral Carbon Dioxide Tax

- *a numerical analysis with the European model GEM-E3*[1]

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Abstract

Simulation experiments are conducted, comparing the effects of a common reduction of CO_2 emissions within the European Union to a Swedish unilateral decision to reduce CO_2 emissions. A numerical general equilibrium model, GEM-E3, has been used as analytical tool. The model covers all European Union countries, with production disaggregated into 18 sectors. The 13 consumption goods included are classified into three consumption categories (durable, non-linked non-durable and linked durable goods) in order to improve the energy allocation description. In addition, industry exemption of CO_2 tax is studied.

The results indicate that if Sweden unilaterally decides to increase its carbon dioxide tax, the total European Union carbon dioxide emissions will increase, i.e. there will be a "carbon leakage" effect. Perhaps more surprisingly, a European Union multilateral implementation of a carbon dioxide tax rate will induce a lower welfare (excluding environmental benefits) in Sweden as compared to the situation where the same carbon dioxide tax was introduced unilaterally in Sweden.

Keywords: CO_2 taxation; Climate policy; Computable General Equilibrium; Unilateral actions; Multilateral actions.

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[1] This paper has been written as part of the project "Climate Technology Strategy within Competitive Energy Markets", which is a project within the JOULE programme, project number JOS3-CT95-0008, European Commission DG-XII / F1. Financial support from the European Union is gratefully acknowledged. I would like to thank project members and Lars Bergman, Anni Huhtala, Martin Hill, Göran Östblom, Pekka Sulamaa and Åsa Johannesson for helpful comments and suggestions.

1. Introduction

1.1 Background and purpose

During the last decades there has been a growing concern about the rise in concentration of greenhouse gases in the atmosphere. These gases cause what is commonly known as the "greenhouse effect" or "global warming" and is one of the main environmental threats of today. This is due to the fact that even small levels of global warming could disturb the adaptation of the ecosystem resulting in the expansion of deserts, a more humid climate which will increase the spread of diseases, effects on farmlands, especially in dry areas, etc.. Such changes would have a dramatic impact on economic life. Even though there is extensive uncertainty, not to say controversy, about the magnitude of the damage from global warming, many politicians and scientists argue that it is important to start reducing the emissions of greenhouse gases now, because of the inertia of the climate system and the long life cycle of the emission in the atmosphere[2].

Several international agreements have been signed aiming at reducing the emissions of greenhouse gases. The most recent international agreement was signed in Kyoto (Japan) in December 1997. The European Union (EU) was one of the signatories[3]. According to EU policy each member state has to achieve its EU agreed country specific goal, without resorting to a common EU policy. An alternative strategy would be to impose a common EU policy, e.g. an EU carbon dioxide tax, which would, in a more direct way, secure implementation.

If the common decision to reduce carbon dioxide emissions (one of the most important greenhouse gases) falls through, there might be some countries that would decide unilaterally to reduce their emissions. The arguments for such measures are that these countries hope to make at least some contribution, however small, in the right direction to reduce global CO_2 emissions, and that other countries may be persuaded to follow suit. In this paper, the costs and effects of a unilateral Swedish decision to reduce carbon dioxide emissions are analyzed. The results of a unilateral reduction are compared to the results of the implementation of a European Union multilateral agreement. The computable general equilibrium model, GEM-E3[4], is used as an analytic tool. In all scenarios, a carbon dioxide tax is used as the economic instrument to induce the reduction. In other words, the purpose of this paper is to compare the

[2] See Grennfelt (1986) for a discussion about the biological characteristics of carbon dioxide.
[3] For details about the Kyoto Protocol see "Kyoto Protocol to the United Nations Framework Convention on Climate Change"
[4] See European Commission (1995) for a background to the GEM-E3 project.

cost and effect of a Swedish unilateral and an EU multilateral decision to reduce CO_2 emissions.

1.2 Related literature

CGE models nowadays cover a large spectrum of environmental issues. These models mostly deal with man-made emissions of carbon dioxide, which arise, to a large extent, from the combustion of fossil fuel. A few of these models focus on Sweden and the Swedish CO_2 reduction policy. Most of the Swedish models are single country models, which is a serious limitation: feedback effects from other countries are not reflected, nor are imported effects of policies in other countries. This is an unrealistic feature for a small economy, especially if important trading partners are influenced by an economic shock.

The most recent study which covers the issue of climate control policies in Sweden was carried out by the Green Tax Commission appointed by the Swedish Government. In order to study the effects of an increased carbon dioxide tax in Sweden a single country CGE model was used (see Harrison and Kriström [1996]). Another Swedish single country CGE model has been developed by Bergman (1991), who has studied the overall effects of Swedish environmental policy. The present paper relates the problems studied in Harrison and Kriström (1996) and Bergman (1991) to a European perspective. Moreover, by using the GEM-E3, the difference between a unilateral and an internationally coordinated policy can be analyzed.

There are other multicountry models, which are used to study the problem of global warming and the reduction of greenhouse gases[5]. The OECD Secretariat has developed a large multicountry CGE model, GREEN (Van der Mensbrugghe [1994]), that can be used to quantify the economy-wide and global costs of policies to curb the emissions of carbon dioxide. The GREEN model is highly aggregated, both in sectors and in countries. For example, the European Union is one aggregated country (region) so that Sweden cannot be studied separately. In the GEM-E3 model all EU countries are represented separately and can therefore be analyzed in more detail. Another multicountry model is presented in Böhringer, Harrison and Rutherford (1997). This model is designed for calculating the cost sharing

[5] See OECD (1993) for a survey of global models.

schemes in connection with reduced CO_2 emissions. The model focuses on Europe, but it covers only six of the EU member states and Sweden is not one of them.

The purpose of the paper is to test the hypotheses derived analytically by Hoel [1991]. Hoel has used game theory to study the effects of unilateral actions to reduce CO_2 emissions. In his two country non-cooperative game, when one country unilaterally decreases its emission, the other country will increase its emission. In fact, the same type of behavior is observed in the simulation results in this paper. The use of the GEM-E3 model enables quantification of emission and other economic effects.

The rest of the paper is organized as follows. Section 2 gives a general description of the GEM-E3 model[6]. In Section 3 the underlying conditions of the simulations are discussed and Section 4 presents the scenarios and scenario results. Section 6 concludes.

2. The GEM-E3 model

The GEM-E3 model is an applied general equilibrium model that describes the economy, the energy system and the environment in each European Union member state[7], and on a European Union level. National economies are linked together by endogenous trade. Each country has the same model structure, but parameters and variables are country specific.

There are eighteen producing sectors: four sectors (sectors 2-5 in Table 1) for the supply and distribution of energy and the remaining sectors are broad aggregates of the rest of the economy[8]. The production in each sector is modeled as a nested constant elasticity of substitution (CES) production function (see Figure 1). This implies that the demand for inputs and primary factors in each sector follows a procedure involving several steps. At each step, inputs and primary factors are optimally combined according to a constant returns to scale CES production function and the producer behavior is modeled on the standard assumption about profit maximization in a perfectly competitive environment.

The two primary factors of production are capital and labor. The labor market is assumed to be perfectly competitive and total labor supply is determined by the utility maximization of

[6] For a detailed description and a complete list of all model equations see Nilsson (1998), which can be ordered from the author (charlotte.nilsson@konj.se).
[7] The model covers all European Union countries; Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the UK.
[8] See Table 1 for a complete list of the production sectors.

the households[9]. For each period, the model endogenously allocates the available labor force over sectors. Capital is a quasi-fixed variable, and is defined such that the firm can change next year's capital stock, by investing in the current year. It is further assumed that the stock of capital is immobile between sectors and countries.

Government production is modeled in the same manner as the other producing sectors in the economy. Thus, the use of inputs is determined through cost minimization and the remaining part of government will be treated as exogenous; i.e. expenditure, investment demand and tax levels are exogenous. Financing of government expenditures is provided by nine different sources of government revenues. These are: indirect taxes, environmental taxes, direct taxes, value-added taxes, product and export subsidies, social security contributions, import duties, foreign transfers and profits or losses from state-owned firms.

The households are modeled as one representative household, which can supply labor, save, invest and consume thirteen consumer goods. The model distinguishes between three consumption categories. These are: durable goods, linked non-durable goods and non-linked non-durable goods (see Table 2). The categories are introduced to improve the model's ability to replicate the relationship between the durable goods such as "Heating appliances" and "Transport equipment", and the energy (linked non-durable goods) that these durable goods require, i.e. to improve on the energy allocation description. It is particularly important to capture this relationship when modeling implications of a CO_2 tax, because consumption of durable goods is affected by energy price changes.

The representative household allocates its resources in an inter- and intratemporal environment. The household's consumption behavior, derived from the utility maximization, can be described in two steps (see Figure 2). First, the household allocates its resources between future and present consumption, given the wage rate, the interest rate and the long term social time preference. In the second step, the household takes total consumption in a period as given and makes an intratemporal decision about how to allocate total consumption between the different consumer goods in the economy[10].

[9] Unemployment is modeled as voluntary
[10] See Figure 2 the household consumption scheme.

The demand for products by the household, the producers and the public sector constitutes the total demand. This total demand is allocated between domestic products and imported products, following the Armington specification. In this specification, cost minimizing sectors and households use a composite commodity that combines domestically produced and imported goods, which are considered as imperfect substitutes. The GEM-E3 model also distinguishes between goods imported from EU countries and from those from the rest of the world. An index for optimal allocation of imported goods according to country of origin and price is calculated, and this index price is then used to allocate consumption between the imported and the domestically produced goods, as discussed above.

The rest of the world (non-EU countries) is largely treated as exogenous in the GEM-E3 model. The import demand for good *i* from the rest of the world depends on the ratio between the export price set by the exporting European country and the export price of the rest of the world. The export of good *i* from the rest of the world to the European Union is exogenous.

It is further assumed that countries apply a uniform rule for setting export prices, independently of the country of destination. The Armington assumption implies that the various countries within the European Union can supply exports at different prices. Finally, the total amount of exports is derived through the identity that the total volume of exports of good *i* from country *u* to country *v* should be equal to the total volume of imports of good *i* from country *u* to country *v*.

Emissions of several environmentally harmful gases are linked to the consumption of fossil fuels. The government has economic instruments at its disposal for controlling the consumption of the corresponding energy products. Here a carbon dioxide tax is the only economic instrument. This tax is uniform across sectors and energy products, but the actual amount paid by each sector differs according to energy product and sector, because of industry exemptions.

The absence of financial assets in the model implies that the absolute price level is exogenous. All prices are in relative terms and the exchange rate is the numeraire. The ratio between the current account and GDP is fixed for each European country.

3. Scenario conditions

The model is calibrated to fit benchmark data for 1985. The GEM-E3 project began in 1994 and at that time the only year for which Eurostat had a complete data set for the SAMs (Social Accounting Matrix), for all European countries, was 1985. Böhringer, Harrison and Rutherford (1997) had the same base year problem. In their simulations they use 1985 "as if" it were 1995. The Swedish production structure changed little between 1985 and 1995. The largest change is the expansion of the equipment goods industries (sectors 9-11). In 1985 these sectors constituted 13 percent of total production while in 1996 their share had grown to 17 percent. Here, too, simulations use 1985 "as if" it were 1996.

The Swedish carbon dioxide tax structure from 1996 is the starting point of the simulations in this study. The manufacturing industry pays only 25 percent of the carbon dioxide tax rate, emission from purely industrial processes and electricity production are completely exempted. In scenarios where a carbon dioxide tax is implemented in all European countries the Swedish structure is imposed on all countries. No consideration is given to the phaseout of nuclear plants in Sweden or any other European country. All countries have a fixed current account, and changes in CO_2 tax revenue is assumed to be redistributed to the household as a lump sum.

5. Scenario results

5.1 A scenario description

The purpose of the simulations in this paper is to analyze the long-term effects of carbon dioxide reducing policies within the European Union. The focus is set on Sweden and the model is run through the year 2020, in steps of 5-years. A carbon dioxide tax is the policy instrument used to enforce the reduction. The scenarios analyze the effects of a Swedish unilateral tax and a common European Union tax. Some attention will also be paid to the question of industry exemptions.

The results of the scenarios are presented with the focus on Sweden. The CO_2 tax used in all scenarios is twice the rate of the 1996 Swedish CO_2 tax (0.74 SEK/kg CO_2 emission). Table 3 presents the scenarios.

5.2 A unilateral CO_2 tax in Sweden

Table 4 shows that introducing a unilateral CO_2 tax in Sweden has a very small effect (ceteris paribus) on the GDP of the aggregated European Union. Despite a more than fifteen percent change in Swedish carbon dioxide emissions, as compared to the reference scenario in 2020, the aggregated EU emissions *increase*. There are two important reasons for this. Firstly, the Swedish share of CO_2 emissions is very small, not even three percent of total European Union emissions in the base year. A fifteen percent decrease corresponds to only a half percent decrease of total EU emission, ceteris paribus. Secondly, Sweden reduces its production and exports due to the relative price changes. Other countries, among which some are EU members, take over the Swedish world market shares. When production moves, energy consumption and thereby emissions also move. This phenomenon is referred to as the "carbon leakage effect", i.e. production, and hence emissions, simply move to another country. The new producers consume more carbon intensive fuels or produce with a technology that demands more energy compared to the Swedish producers. Also GDP of the European Union as a whole decreases slightly. In the no exemption scenario these effects are intensified, but the total change of EU CO_2 emissions is negative due to the larger decrease in Swedish domestic demand, which outweighs the effect from the EU carbon leakage. However, total EU carbon dioxide emissions, excluding Swedish emissions increase in both scenarios

The time profile for changes in CO_2 emissions within the EU are illustrated in Figure 3. The emissions of carbon dioxide decrease by almost the entire Swedish reduction during the first simulation year. Then, especially during the period 1996-2000, firms adjust to the new opportunities and start producing more and emitting more. Shortly after the first five-year period the EU emissions are above the reference level and increase slowly during the remaining periods.

The effects on Sweden of the policy are shown in table 5. Both the capital stock and the labor supply decrease during the simulation period, causing a reduction in GDP of 1.9 percent as compared to the reference scenario in 2020, according to Scenario 1. Scenario 2 has similar trends in the macroeconomic variables, but the trends are more poignant. One exception is private consumption, which hardly changes between the two scenarios. The interest rate is higher in Scenario 2, implying a stronger negative effect on private consumption, but the effect is outweighed by the relative increase in real disposable income.

The final macroeconomic results are obtained through a number of general equilibrium effects. The direct effect is an increase of fossil fuel consumer prices, which is propagated through the cost functions and the input-output structure. The process of transmission generates substitution and income effects for both producers and households. The CES production function allows the producer some leeway to change the input structure, in case of a relative price change. Consequently, when prices of fossil fuels increase a direct effect is a substitution away from fossil fuels cf. Figure 1. Substitution between the different fuels also occurs since coal, oil and gas have different carbon intensities. However, a complete removal of fossil fuels is not possible due to the finite elasticities in the production process. Households are affected by the price change in much the same way. Consumption of fossil fuel, and thereby consumption of durable goods, decreases due to the substitution effect, cf. Figure 2.

The relative measure in SEK "Equivalent Variation per kilogram of carbon dioxide reduction" (EV/CO_2) is approximately equal in the two unilateral scenarios and indicate a welfare cost of 0.9 SEK per kilogram of carbon dioxide reduction (see Table 5). However, this indicator of welfare cost per unit of environmental benefit might not be optimal, since the increase in temperature is a global problem, and there is no environmental benefit as long as global emissions of carbon dioxide have not been reduced. A better measure would be "Equivalent variation per unit of global carbon dioxide reduction", but as a second best alternative the "Equivalent variation per unit of European Union emission reduction" could be used. Then, the welfare cost per environmental benefit is enormously high in the unilateral scenarios, since reduction of carbon dioxide is approximately zero within the European Union.

The microeconomic effects are even larger than the macroeconomic effects discussed above cf. Table 6. An economic structural change takes place. The manufacturing sectors have decreased more than the service sectors. Even when the manufacturing industries pay only 25 percent of the full rate, a noticeable change towards services is observed. Despite the inertia of the substitution mechanisms in the input structure, the service sectors manage to keep a modest decrease in production, as compared to the energy intensive industries (Sectors 6-8). High labor intensity and low fossil fuel dependency is the key to the service sectors' success. The energy intensive sectors, on the other hand, are strongly influenced by the CO_2 tax. Even though the energy intensive sectors are exempted in Scenario 1, the effects are large, as compared to the service sectors. The decrease in production is due to a relatively high proportion of fossil fuels in a rigid input structure. The characteristics of the energy intensive industries lead to a large decrease in demand for labor in these sectors, in both Scenario 1 and Scenario 2.

The increased price level of domestic production has a negative effect on exports and the export decline is unevenly distributed across the sectors of the economy, cf. Table 7. One important difference between the sectors is in how other countries react to price changes in Swedish exports. The model assumes that import demand from a specific country is more sensitive to price changes in the manufacturing sectors than in the other sectors of the economy. This will add to the negative effects on the energy intensive industries. Furthermore, these industries are a very export oriented group. They constitute more than 25 percent of total exports, but only 12 percent of total domestic production. Consequently the large drop in energy intensive exports will, account for much of the decrease in total aggregated export.

Table 8 shows that imports decline, despite the fact that the terms of trade improve, because the import price decreases relative to the export price. The dominant effect on import demand is a decrease in total Swedish domestic demand. Moreover, the assumption that Swedes treat imports and domestically produced goods as imperfect substitutes is a crucial assumption for this result. The Armington elasticities prevent consumers from consuming only imported goods. As in the case of input goods in production, this will cause an income effect, i.e. Swedes have less money for which to buy imported goods.

The link between durable goods and linked non-durable goods in the household sector is obvious when looking at the consumption result in Table 10 (cf. Figure 2). All household goods increase slightly, except for durable goods (heating appliances and transport equipment), linked non-durable goods (energy goods) and “Purchased transports”. The price of “Purchased transports” and fossil fuels increase more compared to other goods, which causes a substitution effect away from these goods. The durable goods “Heating appliances” and “Transport equipment” decrease due to the link with energy products (linked non-durable goods). At first households react to the price changes by adjusting the stock of durable goods to fit the new market conditions. This is done by a substantial decrease in the consumption of new “Transport equipment” and “Heating appliances” cf. Figure 4. Once these adjustment have been made the consumption paths are smooth, with only small changes. Energy consumption (linked non-durable goods), on the other hand, have no sudden movements and have downward sloping reduction curves during the entire simulation period.

5.3 A common European Union CO_2 tax

The implementation of a common European Union CO_2 tax produces rather different economic reactions among the member states shown in Table 11.

In Belgium, GDP, labor supply and the carbon dioxide emissions have decreased more than in any other country. In contrast to the macroeconomic variables, the Belgian households have managed to achieve only an *average* EU decrease in welfare. Belgium has the highest fossil fuel use per GDP among the member states. The manufacturing industries account for 45 percent of the total Belgian production. Despite the exemptions of the manufacturing industries, the decrease in domestic production of manufactured goods is relatively large. Considering the significance of the manufacturing industries, it is not surprising that the whole Belgian economy is affected rather hard, as a result of the higher price level. The increase in fossil fuel prices is transmitted through the input-output system and results in a higher price level overall. Domestic demand decreases because of the income effect. Export, labor supply and real wages decrease. The pressure on the current account results in an increase in the interest rate, which will influence consumer behavior.

Greece, contrary to what may be expected, has the lowest carbon dioxide reduction and one of the lowest GDP and labor supply reductions. The result would be quite different if the fossil fuel input in the electricity production were taxed. The power plants in Greece are highly fossil fuel dependent and are in these scenarios subsidized through the total exemption of carbon dioxide tax in this sector.

The Swedish effects, in comparison with the other European Union counties, are about average, but the equivalent variation expressed as a percentage of GDP is the lowest in EU. This is because of the high electricity dependency of the Swedish households. Since electricity is not taxed in these simulations, this will be a comparative advantage for the Swedish households.

5.4 A Swedish unilateral tax versus a common EU tax

The carbon dioxide tax in Sweden is the same in the multilateral as in the unilateral scenario. Thus, the direct effects (increased fossil fuel prices) on Swedish sectors and households are the same in both scenarios. Despite this, the effects on the economy are higher in the multilateral than in the unilateral case. The reason is the differences in terms of trade. In the multilateral scenarios, all European countries suffer from the direct effect of higher fossil fuel prices, and the price levels in all countries rise, due to the tax. The rise in price level consequently increases the export prices for each European member state. Therefore, due to the trade specifications, the import prices in Sweden will rise, as compared to the unilateral scenarios. The Swedish import prices are determined according to the Armington assumption, which assumes that imports are imperfect substitutes for domestic production, and in this model they also differ according to the country of origin. Thus the import prices are not world prices, but a mixture of prices from the Swedish trading partners. If the relative import prices change then the mixture changes, but since the elasticities are finite, there will not be a complete switch to the cheapest trading partner. In other words, when the price level in the European countries increases, the import prices in Sweden become higher, as compared to the case where only Sweden introduces a CO_2 tax.

The improvements in terms of trade have several positive effects on the Swedish economy. First, since the relative export prices have not decreased as much as in the unilateral case, the negative effect on exports is weakened. This has a positive impact on the domestic demand. Second, the terms of trade improvement, compared to the unilateral case, makes imports less advantageous. On the other hand, the decrease in EU demand decreases the demand for Swedish exports. Finally, the change in terms of trade also increases the pressure on the current account and thereby increases the interest rate as compared to the unilateral case.

The energy goods lose market shares on the world market. The export products “Electrical goods”, “Transport equipment” and “Other equipment goods” also decrease. The decrease in demand for these goods can, at least partly, be explained by the connection between consumer durable goods and linked non-durable goods. The increased price on fossil fuels in EU reduces the demand for cars, since the price of petrol rises substantially. Another important factor that influences “Other equipment goods” negatively is the general decrease in investments throughout EU. In the non-exemption multilateral scenario exports of energy intensive goods increase as compared to the unilateral case, i.e. Swedish production of these goods is relatively inexpensive.

A higher interest rate affects private consumption negatively, because it is preferable to save and to invest in the future if the interest rate is high. Since utility depends on consumption and the value of voluntary leisure, the welfare indicator, Equivalent Variation, has decreased more in the multilateral cases than in the unilateral cases. This is mainly due to the higher wage and interest rate, and the fall in disposable income.

In contrast to the variables mentioned above, the reduction of Swedish CO_2 emissions is the same in Scenarios 2 and 4. This is due to the fact that the structural change in the economy is not as prominent in the multilateral case. However, Equivalent Variation per kilogram of Swedish CO_2 reduction is higher in the multilateral case than in the unilateral case, i.e. the welfare cost is higher per kilogram of Swedish carbon dioxide reduction. As discussed previously, it is not obvious that the Equivalent Variation per kilogram of Swedish CO_2 reduction is a good relative welfare measure. Perhaps a better measure would be the Equivalent Variation per kilogram of global CO_2 emissions or the Equivalent Variation per kilogram of EU CO_2 emissions. If the latter measure were used, the welfare cost per benefit in the unilateral scenarios is much higher than in the multilateral scenarios. This is because when a common tax is introduced, all countries try to reduce their emissions and the carbon leakage effect, at least within the Union, ceases to exist.

6. Discussion and conclusions

The question of how a country is affected by a unilateral versus a multilateral agreement is not new, but despite the importance of the global carbon dioxide issue there has until now been no tool which could be used to numerically estimate the effects on Sweden in a multicountry environment. The GEM-E3 model makes an analysis possible and the results are very different from those of Harrison and Kriström (1996). This is of course not only due to the multicountry aspect of the GEM-E3 model, but also to the differences in production structure, dynamics, and base year, just to mention a few differences.

Using the quasi-dynamic multicountry model, GEM-E3, the following two main results are obtained. Firstly, the unilateral increase in the carbon dioxide tax rate induces a carbon leakage effect. Despite a more than 15 percent decrease in Swedish carbon dioxide emissions, as compared to the reference scenario for year 2020, the aggregate EU emissions increase slightly. Secondly, the environmental benefits are obviously higher in the multilateral case, but the Swedish welfare effects (not including environment), GDP and other macroeconomic variables decrease compared to the unilateral scenario.

The carbon leakage effects indicate that it is not wise to pursue commitments to decrease carbon dioxide emissions if the international agreement breaks down. However, the result does not take into consideration that a continued effort to decrease carbon dioxide emissions might convince other counties to follow suit. Another issue that has not been discussed here is the fact that a decrease of carbon dioxide emissions also decreases other emissions that cause local environmental damages, like sulphur dioxide and nitrogen oxides. These local environmental improvements might outweigh the global environmental drawback caused by the carbon leakage.

When a multilateral action (scenario 3 and 4) to reduce carbon dioxide emission is implemented the negative effects on the Swedish economy are larger both in welfare and in GDP terms as compared to the unilateral case. This may seem counter intuitive for a small country like Sweden, but the imposed carbon dioxide tax increases the price level in all European countries and decreases the demand for goods in EU. The change in terms of trade puts pressure on the current account and since we have imposed a restriction on this variable the interest rate must increase to secure the balance in the current account. The income effect that EU has to pay when implementing a common carbon dioxide tax is caused by the relative price change, as compared to the rest of the world. In all simulations the rest of the world produces goods at the same price as in the reference case. This implies that EU loose shares on the world export markets due to the increased export prices. If the rest of the world were also implementing a carbon dioxide tax a different result maybe is expected.

The indicator “Equivalent variation per kilo of CO_2 reduction” is approximately equal in the two unilateral scenarios (exemption and non-exemption), but in the multilateral scenarios this indicator is slightly lower in the non-exemption scenario. It is difficult to draw a precise conclusion from this, since the emission reductions are not equal in all scenarios. However, since it’s more expensive to reduce emissions the larger the reduction and the non-exemptions scenarios (scenario 2 and 4) have higher absolute reduction as compared to respective exemption scenarios (scenario 1 and 3), the results obtained from the indicator is strengthen by this argument. Consequently, the scenarios indicate that industry exemptions do not lead to lower welfare costs per kilo of carbon dioxide reduction (environmental benefit) in the multilateral scenarios.

The linkage between durable goods and linked non-durable goods results in a change in consumption that can not directly be connected to the price changes in the economy. Households consume less ”Heating appliances” and “Transport equipment” due to the increase in fossil fuel prices.

The model used in this study obviously lacks some important effects from tax reforms. One such important effect is the substitution into alternative energy sources, which could not be analyzed here since the GEM-E3 model doesn’t allow for it. Preliminary results of a single country CGE-model (EMEC[11]) show that an increase of the carbon dioxide tax in Sweden substantially increases the use of biofuels and thereby decreases the effects on the economy. Since the use of biofuels is a topical issue in the whole EU this is an interesting area for more detailed further research.

[11] Environmental Medium term EConomic model (EMEC) is developed at the National Institute of Economic Research in Sweden.

Table 1. Production sectors

1. Agriculture, fishery and forestry
2. Coal
3. Crude oil and oil products
4. Natural gas and other gas products
5. Electricity
6. Ferrous and non-ferrous ore and metal
7. Chemical products
8. Other energy intensive industries
9. Electrical goods
10. Transport equipment
11. Other equipment goods industries
12. Consumer goods industries
13. Building and construction
14. Telecommunication services
15. Transports
16. Services of credit and insurance institutions
17. Other market services
18. Non-market services

Table 2. Consumer goods and their characteristics

Consumer goods:	**Characteristics:**
1. Food, beverages and tobacco	Non-durable good
2. Clothing and footwear	Non-durable good
3. Housing and water	Non-durable good
4. Fuels and power	Linked non-durable good
5. Housing furniture	Non-durable good
6. Heating and cooking appliances	Durable good
7. Medical care and health expenses	Non-durable good
8. Transport equipment	Durable good
9. Operation of transport	Linked non-durable good
10. Purchased transport	Non-durable good
11. Telecommunication	Non-durable good
12. Recreation, entertainment and culture	Non-durable good
13. Other services	Non-durable good

Table 3. A description of the scenarios

Reference Scenario	A business as usual case where no change is made in the economic structure as compared to the initial year.
Scenario 1	A Swedish unilateral carbon dioxide tax is introduced. For the remaining European countries there are no changes compared to the reference scenario. The Swedish manufacturing industries pay a reduced rate of only 25% of the carbon dioxide tax rate.
Scenario 2	Same as scenario 1, but no exemptions for the Swedish manufacturing industries.
Scenario 3	A common European Union carbon dioxide tax rate is introduced. The same tax level and same assumption regarding the manufacturing industries as in scenario 1, but applying to all EU manufacturing industries.
Scenario 4	Same as scenario 3, but no reduction for the manufacturing industries

Table 4. EU results, percentage change from reference scenario in the year 2020.

EU average	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GDP	-0.08	-0.09	-2.0	-2.6
CO_2 emission	0.03	-0.14	-15.4	-20.4

Table 5. Macro results for Sweden. Percentage changes from reference scenario in the year 2020.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
GDP	-1.9	-2.5	-2.1	-2.5
Labor supply	-1.8	-2.2	-1.9	-2.0
Investment	-2.2	-2.9	-2.8	-3.3
Private consumption	-1.0	-1.1	-1.8	-1.9
Exports by volume	-5.5	-7.8	-6.5	-8.1
Imports by volume	-3.3	-4.4	-4.8	-6.0
Consumer price index	8.2	9.2	9.2	9.0
GDP deflator	2.8	3.0	2.7	2.2
Real wage rate	-3.8	-4.6	-4.8	-5.2
Real interest rate	1.3	1.5	1.6	1.8
CO_2 emissions	-15.7	-20.6	17.0	20.6
EV in millions of SEK	-11985.9	-16123.4	-16484.1	-18954.4
EV/CO_2 reduction*	-0.9	-0.9	-1.2	-1.1

*SEK per kilo emission

Table 6. Swedish results. Percentage changes from reference scenario in the year 2020.

	Scenario 1 Domestic Production	Scenario 2 Domestic Production	Scenario 3 Domestic Production	Scenario 4 Domestic Production
Agriculture, forestry and fishing	-2.9	-3.6	-3.3	-3.7
Coal	-	-	-	-
Crude oil and oil products	-10.9	-13.6	-14.9	-17.5
Gas	-6.5	-15.1	-7.4	-15.1
Electricity	-6.6	-7.6	-7.3	-7.7
Ferrous and non-ferrous ore metals	-5.2	-10.4	-5.3	-8.5
Chemical products	-3.9	-7.7	-4.4	-7.5
Other energy intensive industry	-3.9	-6.3	-4.0	-5.8
Electrical goods	-3.6	-4.9	-4.2	-5.3
Transport equipment	-3.7	-4.9	-4.3	-5.1
Other equip. goods industry	-3.7	-5.2	-4.4	-5.7
Consumer goods industry	-2.4	-3.3	-2.8	-3.5
Building and construction	-2.2	-2.9	-2.8	-3.2
Telecommunication services	-1.5	-1.9	-2.1	-2.4
Transport	-6.5	-7.4	-6.9	-7.1
Credit and insurance	-1.7	-2.2	-2.0	-2.4
Other market services	-1.5	-1.8	-2.0	-2.2
Non-market services	0.0	-0.1	-0.1	-0.1

Table 7. Swedish exports. Percentage changes from reference scenario in the year 2020.

Sectors	Scenario1 Exports	Scenario2 Exports	Scenario3 Exports	Scenario4 Exports
Agriculture	-5.3	-5.5	-5.6	-5.8
Coal	-0.3	-0.1	-12.8	-18.9
Crude oil and oil products	-0.3	-0.1	-11.1	-12.8
Electricity	1.9	2.3	-0.1	-0.2
Ferrous and non-ferrous ore	-6.1	-12.7	-6.2	-10.2
Chemical products	-5.2	-10.6	-5.9	-10.8
Other energy intensive	-6.0	-10.3	-5.8	-8.5
Electrical goods	-4.1	-5.7	-5.2	-6.5
Transport equipment	-4.3	-5.8	-5.2	-6.2
Other equip. Goods ind.	-4.1	-5.7	-5.3	-6.8
Consumer goods industry	-6.1	-7.9	-6.8	-7.9
Telecommunication serv.	-5.3	-6.1	-5.8	-6.3
Transport	-15.5	-17.1	-15.9	-15.8
Other market services	-4.9	-5.3	-4.6	-4.99
Non market services	-3.4	-4.3	-3.3	-3.58

Table 8. Swedish imports. Percentage changes from reference scenario in the year 2020.

Sectors	Scenario1 Imports	Scenario2 Imports	Scenario3 Imports	Scenario4 Imports
Agriculture	-0.6	-1.2	-1.4	-1.9
Coal	-24.4	-37.6	-26.6	-38.1
Crude oil and oil products	-12.5	-16.1	-15.5	-18.3
Electricity	-6.8	-7.8	-7.5	-7.9
Ferrous and non-ferrous ore	-2.9	-4.9	-5.0	-8.3
Chemical products	-1.9	-3.2	-2.9	-4.7
Other energy intensive	-1.1	-1.8	-2.3	-3.5
Electrical goods	-2.1	-2.8	-3.0	-3.8
Transport equipment	-1.8	-2.4	-3.0	-3.7
Other equip. Goods ind.	-2.2	-3.1	-3.4	-4.3
Consumer goods industry	0.2	0.1	-0.9	-1.3
Telecommunication serv.	-0.4	-0.6	-1.1	-1.3
Transport	-0.4	-0.6	-4.2	-4.3
Other market services	-0.3	-0.5	-1.3	-1.4

Table 9. Terms of Trade[1] for Sweden. Percentage changes from reference scenario in the year 2020.

Sectors	Scenario 1 Terms of Trade	Scenario 2 Terms of Trade	Scenario 3 Terms of Trade	Scenario 4 Terms of Trade
Agriculture, forestry and fishing	3.7	3.9	3.0	2.9
Coal	-	-	-	-
Crude oil and oil products	-0.6	-0.8	-0.6	-0.7
Gas	0.3	-0.5	-0.9	-1.9
Electricity	-3.1	-3.8	-3.8	-4.0
Ferrous and non-ferrous ore metals	2.7	6.2	-0.1	-1.7
Chemical products	2.3	5.1	1.4	2.5
Other energy intensive industry	2.9	5.1	1.5	2.1
Electrical goods	1.8	2.7	1.4	1.8
Transport equipment	2.0	2.7	0.9	0.9
Other equip. goods industry	1.9	2.7	1.0	1.3
Consumer goods industry	2.5	3.3	1.6	1.9
Building and construction	4.6	5.3	5.1	5.1
Telecommunication services	3.5	4.3	3.0	3.5
Transport	7.9	8.9	1.8	2.2
Credit and insurance	2.7	2.6	2.4	1.7
Other market services	3.5	4.0	1.8	2.5
Non-market services	5.0	5.4	5.2	4.8

1) Terms of trade is here defined as the ratio between the export price and the import price.

Table 10. Household consumption in Sweden. Percentage changes from reference scenario in the year 2020.

	Scenario1 Household consumption	Scenario2 Household consumption	Scenario3 Household consumption	Scenario4 Household consumption
Food, beverages and tobacco	0.4	0.4	-0.3	-0.6
Clothing and footwear	0.1	0.2	-0.3	-0.4
Housing and Water	0.2	0.3	-0.6	-0.7
Fuels and power	-12.5	-13.5	-13.8	-13.9
Housing furniture	0.1	0.1	-0.2	-0.3
Heating and cooking appliances	-5.3	-5.8	-6.4	-6.6
Medical care and health expenses	0.0	0.0	-0.5	-0.7
Transport equipment	-1.0	-1.2	-1.6	-1.8
Operation of transport (petrol)	-3.5	-3.9	-4.1	-4.1
Purchased transport	-1.0	-1.1	-2.2	-2.3
Telecommunication	0.0	0.1	-0.7	-0.8
Recreation, entertainment and culture	0.2	0.3	-0.7	-0.9
Other services	0.0	0.2	-0.9	-1.1

Table 11. Aggregated results, Scenario 3 percentage changes from reference scenario in the year 2020.

	GDP	Labor supply	CO_2 reduction	Equivalent variation as percentage of GDP[1]
Austria	-2.3	-1.6	-17.1	-0.7
Belgium	-3.1	-2.6	-22.3	-0.8
Germany	-2.2	-1.9	-14.0	-0.5
Denmark	-2.2	-1.7	-13.8	-0.3
Finland	-1.4	-1.0	-16.4	-0.5
France	-2.1	-1.7	-16.1	-0.4
Greece	-1.4	-1.6	-12.0	-1.7
Ireland	-2.7	-2.1	-20.1	-1.1
Italy	-1.6	-1.3	-15.1	-0.6
Netherlands	-1.6	-1.0	-13.2	-0.4
Portugal	-1.7	-1.0	-16.4	-0.7
Spain	-2.0	-1.7	-14.7	-0.7
Sweden	-2.1	-1.9	-17.0	-0.2
UK	-2.1	-1.0	-15.5	-0.9
EU average	-2.0	-1.5	-15.4	-0.6

1) (Final year EV / final year GDP -1)*100

Figure 1. The Nested Production Function

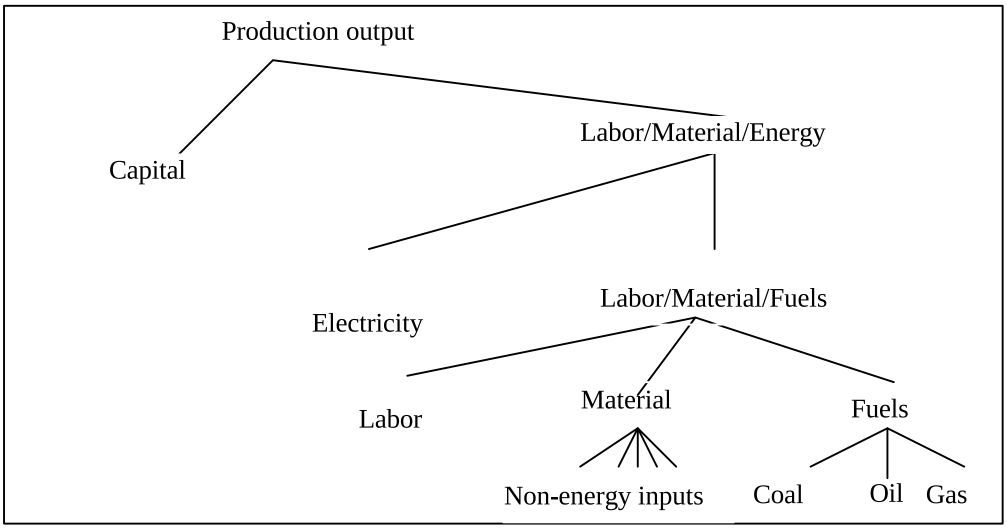


Figure 2. Household consumption scheme

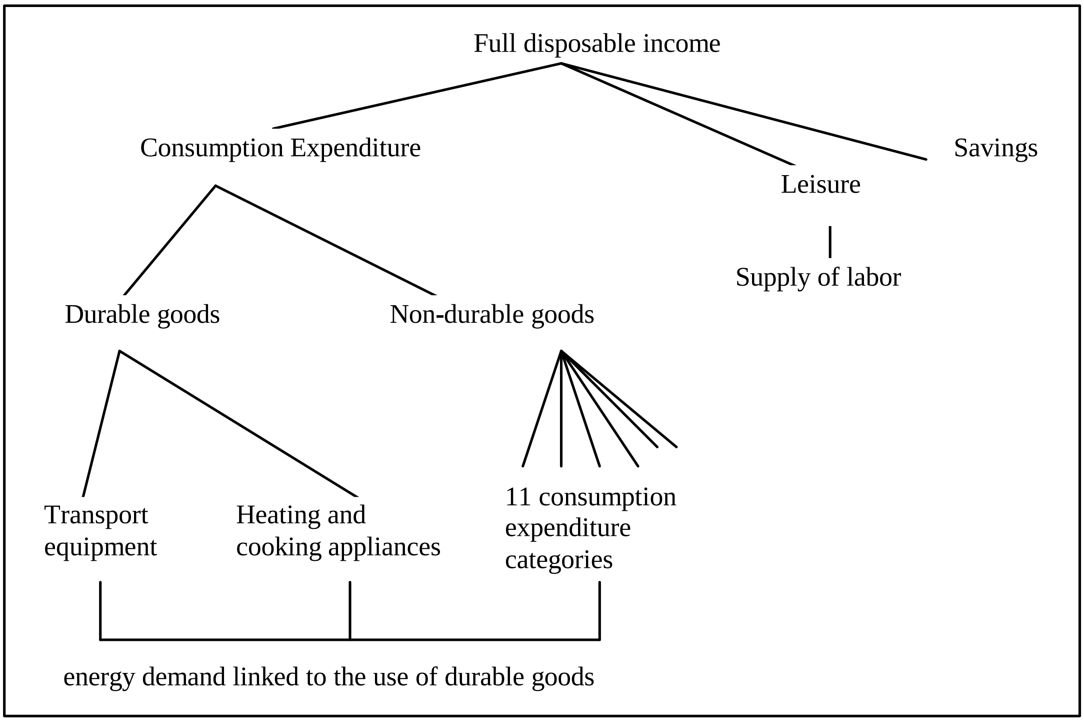


Figure 3. Percentage change of carbon dioxide in EU, as compared to the reference scenario.

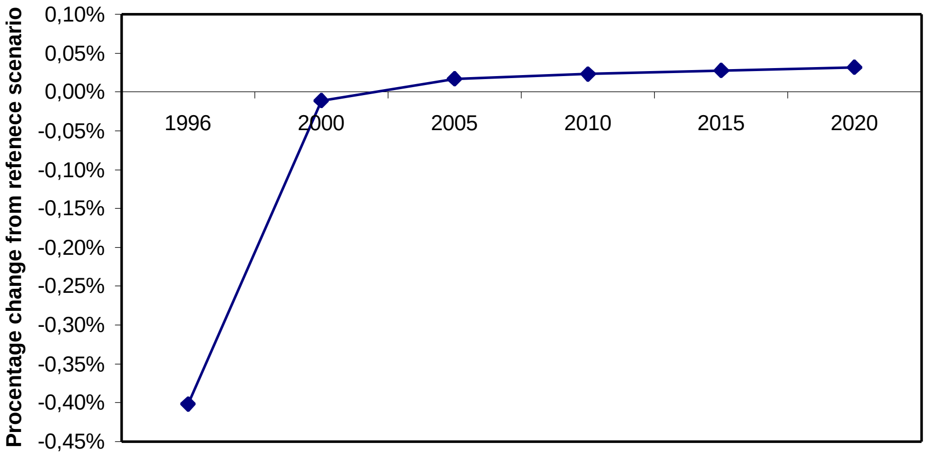
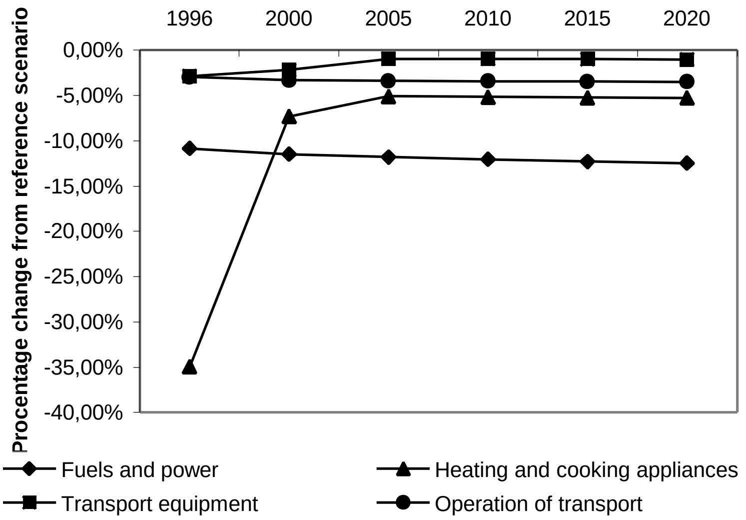


Figure 4. Household consumption of durable and linked non-durable goods; results from scenario 1.



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Sammanfattning

Detta Working Paper NO 66 är en simuleringsstudie med den Europeiska modellen GEM-E3. GEM-E3 är en kvasi-dynamisk allmän jämviktsmodell som inkluderar alla Europeiska Unionens medlemsländer. Syftet med simuleringsexperimenten som utförs i detta Working Paper är att analysera de långsiktiga effekterna av en koldioxidrestriktion inom den Europeiska Unionen. För att minska koldioxidutsläppen används en koldioxidskatt som ekonomiskt instrument och scenarierna analyserar effekterna på svensk ekonomi då Sverige ensidigt inför en höjning av koldioxidskatten och effekterna av en gemensam koldioxidskatt för hela Europeiska Unionen.

De två huvudresultaten från simuleringsexperimentet är för det första att ett unilateralt svenskt åtagande att minska koldioxidusläppen genom en fördubblad koldioxidskatt ger en läckageeffekt av koldioxidutsläpp. Detta innebär att trots en minskning av koldioxidutsläppen med 15 procent inom Sverige ökar utsläppen något i hela Europa. Detta är en effekt av att energiintensiv produktion flyttar till andra Europeiska länder med högre kolintensitet i sin produktion.

Det andra huvudresultatet är att när hela Europa inför samma koldioxidskatt blir den Europeiska koldioxidreduktionen hög i förhållande till det unilaterala fallet. Däremot kommer de svenska välfärdseffekterna (utan miljöfördelarna), BNP och andra makroekonomiska variabler att minska i förhållande till det unilaterala scenariot. Detta är en effekt av att efterfrågan på svenska varor i Europa minskar på grund av den generellt minskade efterfrågan inom unionen. Det är även så att Sveriges importvaror nu blir dyrare och därmed kommer de svenska konsumenterna att drabbas.

Slutligen poängteras att modellen saknar vissa viktiga samband som skulle kunna förbättra beskrivningen av en koldioxidskattereform. Till exempel finns inga alternativa energikällor representerade i modellen, så som biobränsle. Detta är något som Konjunkturinstitutet har implementerat i sin modell EMEC och har visat sig vara viktigt för den svenska el- och fjärrvärmeproduktionen vid en höjning av koldioxidskatten.