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The cost of sectoral differentiation:
The case of the EU emissions trading scheme

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Sammendrag:
I den økonomiske faglitteraturen blir det ofte forutsatt at Kyotoprotokollen vil bli iverksatt gjennom et kostnadseffektivt og altomfattende system for kvotehandel. Erfaringene med gjennomføring av andre miljøtiltak viser imidlertid at myndighetene ofte velger en mer differensiert tilnærming. Planleggingen av gjennomføringen av Kyotoprotokollen bekrefter dette; utslippsforpliktelsene vil bli differensiert mellom sektorer. Denne artikkelen analysere velferdskostnadene knyttet til gjennomføringen av EUs kvotehandelsdirektiv – eller et tilsvarende differensiert kvotesystem for andre land. Artikkelen analysere også hvordan differensieringen av forpliktelsene påvirker de sektorene som har en kvoteforpliktelse sammenlignet med de som er fritatt. Resultatene indikerer at den sektorelle differensieringen kommer med en relativt høy pris – sammenlignet med et altomfattende system, blir kostnadene ved gjennomføring mer enn tredoblet i alle scenarier. Samtidig oppnår de sektorene som blir fritatt kun begrensede fordeler.

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Abstract:
It is often assumed in the economic literature that the Kyoto Protocol will be implemented through a cost-efficient, comprehensive emissions trading system. However, the general experience from implementation of environmental policies suggests that governments will adopt a more differentiated approach. Emerging evidence on how the Kyoto Protocol will be implemented confirms this: climate commitments will be differentiated between sectors. This paper assesses the welfare effects associated with implementing the EU emissions trading Directive – or a similar scheme for other regions. It also analyses how differentiation of commitments affects the sectors that have a permit obligation compared to those that are exempted from it. Findings indicate that sectoral differentiation comes at a relatively high welfare cost – in all scenarios more than tripling the cost of implementing climate policy, with only limited benefits to the sectors that are granted concessions

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1 Introduction

The industrialized countries that are parties to the Kyoto Protocol have committed to reducing their annual emissions of six greenhouse gases by around 5% by the first commitment period (2008-2012) as compared to their emissions in 1990. The Protocol also establishes three so-called flexibility mechanisms – emissions trading, Joint Implementation, and the Clean Development Mechanism – that allow Parties to acquire cheap emission permits from other states that can be used to comply with their commitments. The use of these mechanisms should, however, be “supplemental” to domestic action.

Standard economic theory predicts that, in the absence of any pre-existing distortions, a policy that equalizes marginal abatement costs across all sources will achieve emission reductions at least cost. In much of the economic literature, it is assumed that governments will adopt such a theoretically ideal means of achieving their Kyoto Protocol commitments. Given the options available, this means that the required emission reductions should be achieved through a comprehensive emissions trading system that includes as many sectors (and gases) as possible and puts no restrictions on emissions trading with other Annex B countries, or on the use of credits from project-based mechanisms. However, this is certain to be the most efficient implementation only if pre-existing distortions are removed at the same time.

There are, however, few examples of governments implementing the theoretically ideal environmental policy instruments. More generally, due to political concern about issues such as loss of competitiveness or work places, or high transaction costs, exemptions have been granted to particular sectors.

For example, the Norwegian CO2 tax, which was introduced in 1991 as the first in the world of its kind, includes numerous exceptions. The tax is levied on the use of mineral oil, petrol, coal and coke (Ministry of Finance 2002). Mineral oil for use in international flights, ships in foreign trade, fishing vessels operating in Norwegian waters and coal and coke as raw materials or reducing agents in industrial processes is fully exempted from this tax. Due to competitiveness concerns domestic flights and the paper and pulp industry pay the tax at a reduced rate.

The emerging evidence suggests that exceptions will be granted also when it comes to national implementation of the Kyoto Protocol; governments will not choose a fully comprehensive trading system, but rather one that is sectorally differentiated.

For example, both the EU and Norway are planning for a combination of emissions trading for some industries and other measures, such as taxes, technical standards or voluntary agreements for other industries. The paper will focus exclusively on the recently adopted EU Emissions Trading (EU-ET) Directive. It is a particularly relevant example both because the EU is likely to be the biggest regional emissions trading scheme[1], and because it is the scheme that has come the furthest towards implementation with most of the details known.

The purpose of this paper is to compare the welfare cost of implementing a climate agreement with sectoral differentiation of commitments to an agreement with theoretically ideal implementation, and also to assess the effects of exemption upon specific sectors. Unlike earlier work in this field, this paper will focus on a specific scheme that is about to be implemented – the EU-ET scheme. Section 3 begins by looking at what theory and previous experience has to say on the issue of efficient implementation of environmental policy. This is followed by a look at the details of the EU-ET Directive and some explanations for why the

[1] According to the UNFCCC national greenhouse gas inventory data for 1990, the EU-25 countries were responsible for 46% of total Annex B emissions (without the USA and Australia).

EU ended up with sectoral differentiation. Section 4 introduces the DEEP model that will be used to quantify the cost of sectoral differentiation by comparing a number of scenarios. Section 5 presents the model results, in terms of both welfare effects and the impact on the sectors that are granted concessions, and those that are not. Finally, section 6 concludes on the consequences of sectoral differentiation.

2 Ideal and real emissions trading systems

2.1 Theoretical requirements and previous experiences

Boemare and Quirion (2002) review ten emissions trading systems that are either implemented or being planned. On the issue of sectoral coverage the authors note that standard theory suggests that as many emitters as possible should be included. This is provided that the location of emissions does not matter and that administrative and monitoring costs are not disproportionately large. There are two main reasons to include as many emitters as possible. First, by including a large number of emitters you increase the scope for efficiency gains as there will be larger differences in abatement costs between firms. Second, it lowers the risk that any participant will be able to manipulate the market as a monopolistic seller or monopsonistic buyer. However, the authors find that in most cases regulators have chosen not to include as many emitters as possible, at least not initially. They argue that this might be to avoid facing too much opposition at one time, and to begin with the simplest system possible. As a means to reduce the problems associated with implementing a large system at once, they suggest that phasing in different industries over time can expand coverage and achieve the most comprehensible system possible.

Babiker et al. (2000) study the effects of differentiating climate policy by sector. They employ a CGE model to run a set of scenarios. They argue that while a policy that yields equal abatement costs across all sources would be ideal, actual policies rarely approach this ideal. One reason is that an across-the-board scheme may lead to shifts in international competitiveness among sectors and to variations in burden among sub-national regions. The authors argue that it is the fear of these effects that leads to the granting of concessions (differentiation). They then move on to study the economic effects of granting such concessions for a range of scenarios – where different sectors receive concessions (such as sectors heavily involved in international trade, energy intensive sectors and households and agriculture). Babiker and his colleagues find that granting these concessions would amount to an increase in the welfare loss in meeting the US Kyoto commitments by between 32% and 300%. Furthermore, they find that exemption from the scheme does not necessarily improve the competitiveness of all the sectors that are exempted, and that the value added decreases in all sectors that are not exempted. They conclude that sectorally differentiated policies can increase the cost of meeting a carbon emissions target.

Babiker et al. (2001) look at the welfare costs of hybrid carbon policies in the EU. While numerical studies find that equalizing marginal abatement costs across sectors greatly reduces the cost of achieving a given target, they show that in the presence of pre-existing tax distortions, other allocations may be preferable in some cases. The paper focuses on domestic carbon policies in EU countries, and without emissions trading among countries. They look at three different burden sharing systems: economy-wide trading; a scheme where each sector is assigned an equal share of overall reductions (without trading among sectors); and a scheme where each sector is assigned a target based on estimates of abatement costs (no trading among sectors). They find that equalizing marginal abatement costs across sectors can greatly reduce the cost of achieving the target in all EU countries. However, they also show that welfare costs can be reduced in some countries compared to the economy-wide trading scheme. A carbon tax interacts with other taxes and effectively increases existing fuel taxes. While the first-best solution is to remove the pre-existing distortions, they find that "over-allocating" permits to the heavily taxed sectors and not allowing trade can be an improvement over an economy-wide cap and trade system (if distortionary taxes are not removed).

Babiker and his colleagues then go on to consider strategies that might limit the impact of a carbon constraint on exports from energy intensive sectors. They compare exempting these sectors from the climate policy (requiring other sectors to reduce more) with a tax-cum-subsidy policy (where the energy intensive sector is subsidized at a level equal to the amount of carbon tax it pays). They find that exempting this sector causes a welfare loss in excess of 1% to the entire economy, and that the tax-cum-subsidy policy is Pareto superior to making the exemption.

2.2 The EU Emissions Trading Directive

The EU Emissions Trading (EU-ET) Directive was adopted on 13 October 2003 by the European Parliament and Council (European Parliament and Council 2003).[2] The Directive establishes a scheme for EU emissions trading in greenhouse gases for the purpose of achieving cost-effective emissions reductions. It will be implemented in two phases. The first phase is a preparatory phase during the three-year period 2005-2007, while the second phase coincides with the first commitment period of the Kyoto Protocol (2008-2012).

Under the Directive emission reduction commitments are differentiated between sectors. Certain industries have a permit obligation, while other industries are exempted from this obligation. The sectors included in the scheme are:

- energy activities (power plants, mineral oil refineries and coke ovens)
- production and processing of ferrous metals
- the mineral industry (including cement and glass)
- other activities (paper and pulp).

Within these sectors, participation is mandatory for installations above certain given capacity thresholds. The Directive does, however, allow installations to opt-out during the preparatory phase (Article 27). On the other hand, Member States are allowed to include installations below the capacity threshold from 2005, and can include more activities, installations and greenhouse gases from 2008 (Article 24).

During the first phase the Directive covers only CO_2 emissions. According to Convery et al. (2003), the sectors included are responsible for 46% of European Union CO_2 emissions and 38% of total greenhouse gas emissions.[3] What exact proportion it makes up will depend on how many allowances are issued. This issue is left for each Member State to decide. The Member States are, however, restricted by the Directive in that the total quantity of permits allocated must be "consistent with the Members State's obligation to limit its emissions" (Annex 3, Directive). During the preparatory phase at least 95% of the allowances must be allocated free of charge, while during the second phase at least 90% must be allocated free of charge.

A final issue of cost-efficiency is the degree to which installations or Member States are allowed to buy cheap allowances or credits from other countries. Article 25 of the Directive

[2] The EU Emissions Trading Directive will hereafter be referred to as the Directive. All mention of Articles refers to the Articles of the Directive.

[3] The EU-ET scheme covers 36% of total emissions in our model - which includes methane and nitrous oxide emissions in addition to CO_2, but does not exclude installations below the capacity thresholds.

states that “agreements should be concluded with third countries listed in Annex B to the Kyoto Protocol […] to provide for the mutual recognition of allowances…” The Directive does not state exactly how this “linking” will take place, only that the Commission *shall* draw up any necessary provisions. Furthermore, the Directive states that emission credits from the project mechanisms (i.e. CDM and JI) will be recognised under the scheme. The details are left up to further provisions – which have now taken the shape of a proposed “linking” directive. The text of this directive was adopted by the European Parliament on 20 April 2004. The “linking” directive states that “the use of [credits from CDM and JI projects] from 2008 is allowed up to a percentage of the allocation to each installation, to be specified by each Member State in its National Allocation Plan” (European Parliament 2004).

2.3 Why the EU chose sectoral differentiation

In many regards the EU-ET Directive is theoretically efficient. It includes many installations, it does not put any restrictions on trading with other Annex B countries, and it does allow the use of credits (but leaves it up to each Member State to set a ceiling on the use of credits). What is of interest in this paper, however, are the exemptions that were granted to certain sectors, and what this means for the overall efficiency of the scheme.

The Commission explains its reasons for choosing a system of limited coverage in an explanatory memorandum (Commission of the European Communities, 2001). The Commission puts emphasis on trying to keep the Directive as simple as possible, and to minimise distortions in the market. The concern for the competitiveness of EU industries is clearly revealed in statements such as “emissions trading is, first, an instrument for environmental protection, and, second, one of the policy instruments that will impair competitiveness the least” (Commission, 2001, p.2).

According to the memorandum, the sectoral coverage of the Directive “builds upon the framework of regulation arising from the IPPC Directive.” The Commission explains why certain sectors were not included: “The decision not to include the chemical sector initially is taken for two reasons: first, the chemical sector’s direct emissions of carbon dioxide are not so significant […]. Second, the number of chemical installations in the Community is high, in the order of 34 000 plants, and their inclusion would substantially increase the administrative complexity of the scheme” (Commission, 2001, p. 10).

The memorandum is very clear on why only CO_2 emissions were included in the Directive: “Inclusion of the other greenhouse gases listed in the Kyoto Protocol is desirable but would be dependent on resolving monitoring, reporting and verification issues […]. In particular, emissions trading presupposes a sufficiently accurate monitoring of emissions, but the monitoring uncertainties are still too great for greenhouse gases other than carbon dioxide. For these reasons, emissions of greenhouse gases other than carbon dioxide are not included in the first phase of the scheme” (Commission, 2001, p. 9).

The EU’s stated motivations for choosing this specific emissions trading scheme should of course not be taken just at face value. While the Directive is very recent, there are already some papers that critically discuss the motivations behind the choices made by the EU.

Christiansen and Wettestad (2003) discuss how the EU changed its position on emissions trading from sceptic to frontrunner. They also look at the then proposed EU-ET scheme. They argue that it was necessary to start with only a few sectors and CO_2 only to “reduce complexity and ensure expediency in the policymaking process” (Christiansen and Wettestad, 2003, p.16). They therefore seem to accept the arguments of the Commission for choosing a limited system, but they argue that the limitations on gas and sectoral coverage “could impair the effectiveness of the system in several ways. First, it could reduce cost-effectiveness. Second, it will not provide indications of abatement costs for sectors outside the system, which may prevent early action for outsiders” (Christiansen and Wettestad, 2003, p.14). One way of interpreting this is that the Commission anticipated lobbyist opposition, and rather than pick this fight, offered to grant concessions up-front.

Markussen and Svendsen (2005) analyse how industry lobbying has shaped the EU-ET Directive by looking at changes between the initial Green Paper proposal (before lobbying) and the final directive (after lobbying). On the issue of coverage, they find that the chemistry and aluminium sector managed to avoid getting a permit obligation. The authors argue that the reason for granting this concession was "administrative and concerns about their international competitiveness" (Markussen and Svendsen, p.9) The chemistry sector itself argued that a permit obligation would "constrain their competitiveness and ability to grow" (Markussen and Svendsen, p.8), while for the case of the aluminium sector the official reason was that the sector mainly emits other greenhouse gases than CO_2.

To return to Boemare and Quirion (2002), they suggest that while process emissions from the chemical industry are not included in the EU-ET Directive, these emissions are likely to be phased in over time. The same is true for other non-CO_2 gases. They argue that a more comprehensive (and upstream) system was excluded for political reasons – because it would have looked too much like a tax.

The remaining chapters of this paper analyse the welfare cost of the EU-ET scheme compared to a fully comprehensive scheme (i.e. theoretically most efficient). Because concern for competitiveness figures high on the list of motivations that can explain the exemptions granted under the EU-ET scheme, the effects of being included in or exempted from the scheme will also be assessed. In other words, the question is "what is the welfare cost to society of choosing a scheme of limited coverage, compared to a fully comprehensive scheme", and furthermore "what are the gains to the sectors that are exempted?"

3 Model and scenarios

3.1 The DEEP model

The DEEP model is a multi-sector, multi-region, multi-gas dynamic CGE model programmed in MPSGE. The structure of supply and demand has been adopted from the GTAP-EG model by Rutherford and Paltsev (2000), with some modifications. The model is utility maximising with a growth benchmark. A full description of the model is provided in Kallbekken (2004).

The economic data used in the DEEP model is the GTAP (v5) data base – which provides input-output data for each region, bilateral trade data, and information on taxes and tariffs. The interaction of emissions trading with pre-existing taxes, which was the main focus of Babiker et al. (2001), is therefore included in the model.

The DEEP model includes emissions of CO_2, CH_4 and N_2O. The emissions data is from the GTAP/EPA project "Towards an Integrated Data Base for Assessing the Potential for Greenhouse Gas Mitigation". The growth and technological change parameters in the model are based on the IPCC SRES A1B scenario (Nakicenovic and Swart, 2000).[4]

3.2 Policy scenarios

Much is yet to be decided before the Kyoto Protocol can be implemented. While the EU already has adopted it's emissions trading Directive, it still has the option of including more sectors, and gases, by 2008. All the other Annex B countries also have to decide on the design

[4] The SRES A1B scenario assumes "rapid and successful economic development", where the global economy grows at an average annual rate of 3%, and where technological progress is rapid.

of their emissions trading systems. The Norwegian government announced in March 2004 that it would propose a system based on the EU-ET scheme (Ministry of the Environment 2004).[5] Because these differentiated schemes make interesting case studies, Norway is included as a separate region in the model – alongside the EU, the Former Soviet Union (FSU) countries, and all other Annex B countries (grouped into one region).[6]

While it would have been interesting to include the early phase of the EU-ET scheme, this is not done for two major reasons. The first reason is that the National Allocation Plans have proved to give rather generous emission allowances, with the result that the early phase will not yield substantial emission reductions. The second reason is that, as a policy issue, it is of greater interest to analyse schemes yet to be finalized, than those finalised but not yet implemented. All policy cases are therefore concerned with the implementation of the first commitment period of the Kyoto Protocol (2008-2012).

The purpose of this paper is to compare the cost of a differentiated emissions trading scheme, taking the EU-ET scheme as an example, to a fully comprehensive scheme. It is also of interest to assess alternative differentiated schemes. The model will therefore be run with three different policy cases:

The first policy case is a differentiated scheme identical to the EU-ET scheme (which is also the short name for this scenario). This is, however, the EU-ET scheme as it stands today; with no new gases or sectors added. This policy case makes the strong assumption that all the required emission reductions will be achieved through the emissions trading scheme, i.e. that no emission reduction measures are implemented in any other sectors. This is done in order for the effects of other measures not to cloud the analysis and the comparisons made.

The second policy case is an alternative differentiated scheme that is an extended version of the EU-ET scheme: The scheme is extended to cover the aluminium (non-ferrous metal) and chemical sectors. This scenario makes it possible to assess the effects of exemption for two sectors that were granted exemptions due to competitiveness concerns (see above discussion). This scenario is called *extended*.

The third policy case is an idealized, fully comprehensive emissions trading scheme that in principle should achieve the emission targets at least cost (named *comprehensive*).[7] Here, "comprehensive emissions trading scheme" means that all sectors and all Kyoto gases are included. The DEEP model includes carbon dioxide, methane and nitrous oxide emissions – which accounted for 98.6% of EU emissions in 2001 (European Environment Agency 2003), but not the three other Kyoto gases (HFC, PFC and SF_6).

All policy cases assume that no hot air from former Soviet Union countries will be sold during the first commitment period. Also, they assume that there will be no banking of permits. These are simplifying assumptions; because very little is known about a possible second commitment period, this paper does not to make any explicit assumptions about a second period. The effect of excluding hot air sales is to increase the permit price, and the

[5] The reason the government gave for scrapping a more ambitious scheme and instead copying the EU-ET scheme was concern for avoiding negative effects on the competitiveness of Norwegian industries. The process industry, which was supposed to take part in emissions trading in the original Norwegian proposal, instead entered into a voluntary agreement with the government.

[6] The GTAP region "Rest of EFTA" consists of Iceland and Liechtenstein as well as Norway. However, Norway accounts for 94% of both GDP and CO_2 emissions in this region..

[7] Such a scheme would achieve the target at least cost in the absence of pre-existing distortions, but not necessarily when they are present – which they are in this model.

effect of excluding banking is to decrease the permit price.[8] These two assumptions therefore offset each other to some extent.[9]

In addition to these three policy cases, a reference case will be run with business-as-usual (BAU) emissions, i.e. where no emission constraints are imposed. This case is referred to as *BAU*.

4 Results

4.1 Welfare effects

The major results of the scenarios are presented in Tables 1 and 2. Prices are always given as net present value (USD 1997). All relevant taxes and tariffs are included in the prices.

As one might expect, the permit prices are significantly higher in the scenarios with differentiated commitments than in the comprehensive emissions trading scenarios. With a differentiated scheme the permit price is USD 21.8 (per ton CO2-equivalent). Extending the scheme to include the aluminium and chemical sector, reduces the permit price to USD 18.7 With a fully comprehensive scheme the permit price is as low as USD 4.8.

Table 1 Permit prices (USD1997 per ton CO2e)

EU-ET	21.8
Extended	18.7
Comprehensive	4.8

Table 2 Welfare effect of emissions trading system (percent change real income, compared to BAU)

	EU-ET	**Extended**	**Comprehensive**
EU	-0.87	-0.83	-0.04
Norway	-1.30	-1.27	-0.41
RAB	-0.64	-0.61	-0.16
FSU	+0.85	-0.09	-1.02

Compared to the BAU case, introducing a policy that imposes emission constraints in a model where climate damages are not included will result in a welfare loss. The welfare cost of implementing the EU-ET scheme is found to be a 0.87% reduction in real income

[8] Banking can only increase the price in the first period, not decrease it. Whether or not this will happen depends on future permit prices (which are not modelled in this paper).

[9] The total number of permits available is 2.64 Mt CO_2-equivalent. This compares to a figure of 2.74 Mt for the model used in the paper by Kallbekken and Westskog (2003 – unpublished data), where both hot air sales and banking was included.

compared to the situation with no climate policy (BAU).10 Implementing the extended scheme would marginally reduce the welfare loss to the EU - to 0.83%. This can be compared to a welfare loss of 0.04% if a fully comprehensive emissions trading scheme was implemented.

Similar figures are found for Norway. The welfare cost of implementing the EU-ET scheme is 1.30%. This compares to a welfare loss of 1.27% with the extended scheme, and a still significant 0.41% with the comprehensive scheme.

For the "Rest of Annex B" (RAB) region, where Japan and Canada are the dominating economies, the differences between the different policy scenarios are less dramatic: The welfare loss of implementing the EU-ET scheme would be 0.64%, or 0.61% with the extended scheme, as compared to a loss of 0.16% with a comprehensive scheme.

Most studies find that Russia gains from implementation of the Kyoto Protocol (as compared to the business as usual scenario). This is due to hot air sales. However, because this study assumes no hot air sales, this gain does not materialise. Only in the EU -ET scenario, where Russia's business-as-usual emission constraint means that Russia can dominate the international supply of permits, does Russia gain from implementation.

The reason why the differentiated schemes, in general, have a higher welfare cost than the comprehensive schemes is that they introduce (new) inefficiencies in the economy. While the same emission target is to be achieved, some of the (cheaper) abatement options are no longer available, making it more costly to meet this target. This inefficiency has strong implications in terms of shifting activity between sectors – an issue that will be addressed in the following section.

These results show that, assuming that transaction costs are not prohibitive, there should be considerable scope for welfare improvement by extending the current EU-ET scheme, or any similar schemes, before implementation in the first commitment period of the Kyoto Protocol.

4.2 Economic effects by sectors

The previous section has showed that exempting sectors from the permit obligation causes a welfare loss. One important rationale for doing this was to protect the competitiveness of the exempted sectors. This section examines whether exemption produces this intended result, and also what the consequences are for sectors that are given a permit obligation. Table 3 shows changes in output and (market) prices for some of the most important sectors. The results for the three policy scenarios are in each case compared to the *BAU* scenario.

The results are not very surprising if we look at the emission-intensive sectors in the EU-ET scenario; market prices increase and demand decreases (with a matching reduction in output). The decreasing demand is both a result of the increased price, and for the fossil fuels also a result of the increased cost of using them in sectors covered by the scheme (notably the electricity sector). While the absolute size of the output reduction is massive (32.9% for coal and 13.5% for electricity), this is also not very surprising in light of the very restrictive emissions reduction assumptions (all reductions take place inside the scheme). What is more interesting is that output of coal is reduced by a factor of three more than output of refined oil. This is not reflected in the changes in market prices for these goods (the changes are minor compared to the shifts in output). The explanation is that a large share of the coal is used in the electricity sector – which now has to pay for its CO_2 emissions. Refined oil is used to a much lesser extent in electricity generation, and it is also a less carbon intensive fuel.

[10] Welfare is measured as change in real income across all time periods of the model – with a correction for the endowment effect of allocating permits; which have money-value but no real economic value.

Comparing the EU-ET scheme and the comprehensive schemes shows that the sectors that are included in the EU-ET scheme experience a significantly higher price increase, and associated decrease in demand, than those who are exempted.[11] Take the example of the electricity sector (power plants): While it is responsible for only 1.2% of total output in the EU, it is responsible for 73% of the emissions covered by the EU-ET scheme. This has a big impact on prices, which increase by 25.8% in the EU-ET scheme. Output is reduced by 13.5%.

Changes in market prices do not say much about the effect on competitiveness. However, as the model employs a zero profit condition (as is common in the CGE literature), changes in profit levels can unfortunately not be observed. It is still possible to get some indication of what happens to competitiveness though by looking at the changes in output together with changes in the unit cost (less the cost of emission permits). Table 4 shows changes in unit cost for some sectors under the different scenarios. We observe that once again coal seems to be the big loser; The adjusted price is down 19.1%. For refined oil and electricity the adjusted price is down by only ~1%. For the other sectors that are included in the scheme (ferrous metals, minerals and paper and pulp) we observe a price increase also in the adjusted price. This is due to the increased price of inputs.

Table 3 Percentage change in price and output in EU (compared to *BAU)*

<table>
<tr><td colspan="3"></td><td>Sector</td><td colspan="3">Change in output (%)</td><td colspan="3">Change in price (%)</td></tr>
<tr><td rowspan="7">EU-ET</td><td rowspan="9">Extended</td><td rowspan="12">Comprehensive</td><td></td><td>EU-ET</td><td>Extended</td><td>compr.</td><td>EU-ET</td><td>Extended</td><td>compr.</td></tr>
<tr><td>Coal</td><td>-32.9</td><td>-31.5</td><td>-16.3</td><td>-0.4</td><td>-0.4</td><td>+1.4</td></tr>
<tr><td>Refined oil</td><td>-10.3</td><td>-8.8</td><td>-2.9</td><td>+3.7</td><td>+3.0</td><td>+0.7</td></tr>
<tr><td>Electricity</td><td>-13.5</td><td>-12.2</td><td>-4.2</td><td>+25.8</td><td>+22.3</td><td>+6.3</td></tr>
<tr><td>Minerals</td><td>-1.2</td><td>-1.1</td><td>-0.4</td><td>+1.4</td><td>+1.2</td><td>+0.3</td></tr>
<tr><td>Ferrous metals</td><td>-2.7</td><td>-2.4</td><td>-0.7</td><td>+4.7</td><td>+4.0</td><td>+1.0</td></tr>
<tr><td>Paper and pulp</td><td>-1.1</td><td>-1.1</td><td>-0.4</td><td>+0.9</td><td>+0.7</td><td>0.0</td></tr>
<tr><td rowspan="5"></td><td>Aluminium</td><td>+0.1</td><td>-0.6</td><td>+0.1</td><td>+2.1</td><td>+2.4</td><td>+0.7</td></tr>
<tr><td>Chemical</td><td>-1.2</td><td>-1.7</td><td>-0.4</td><td>+0.7</td><td>+1.2</td><td>+0.2</td></tr>
<tr><td rowspan="3"></td><td>Other man. & servs.</td><td>-0.3</td><td>-0.2</td><td>-0.2</td><td>+0.0</td><td>0.0</td><td>+0.0</td></tr>
<tr><td>Crude oil</td><td>-7.4</td><td>-6.3</td><td>-2.5</td><td>-0.4</td><td>-0.4</td><td>-0.2</td></tr>
<tr><td>Agriculture</td><td>-0.3</td><td>-0.2</td><td>-0.6</td><td>0.0</td><td>0.0</td><td>+0.3</td></tr>
</table>

[11] One exception to the general picture is the coal sector – where both output and prices decrease. The cost of coal extraction does not change much. But the demand for coal decreases significantly. This is because while it does not become more expensive to buy coal, it does become much more expensive to use it (particularly for the electricity sector which is the dominant coal user) due to the requirement of holding permits. This shifts the demand curve down, decreasing both the price and output at the new market equilibrium. Note that the producer price of coal (table 4) decreases, as you would expect when demand decreases.

Table 4 Percentage change in unit cost (adjusted for cost of permits and compared to BAU)

	Sector	Change in price (%)		
		EU-ET	Extended	compr.
EU-ET / Extended / Comprehensive	Coal	-19.1 %	-16.4 %	-2.7 %
EU-ET / Extended / Comprehensive	Refined oil	-1.2 %	-1.2 %	-0.4 %
EU-ET / Extended / Comprehensive	Electricity	-0.7 %	-0.4 %	+0.4 %
EU-ET / Extended / Comprehensive	Minerals	+0.6 %	+0.6 %	+0.2 %
EU-ET / Extended / Comprehensive	Ferrous metals	+2.0 %	+1.7 %	+0.4 %
EU-ET / Extended / Comprehensive	Paper and pulp	+0.9 %	+0.7 %	0.0 %
Extended / Comprehensive	Aluminium	-	0.0 %	0.0 %
Extended / Comprehensive	Chemical	-	-0.4 %	-1.3 %
Comprehensive	Other man. & servs.	-	-	-0.2 %
Comprehensive	Crude oil	-	-	0.0 %
Comprehensive	Agriculture	-	-	0.0 %

The impact on the exempted sectors under the EU-ET scenario is minimal, with the exception of the aluminium and chemical sectors. Prices in the chemical sector go up by 0.7% and output is down 1.2%. Prices in the aluminium sector are also up, by 2.1%, but in this case output also increases. This happens because the price of aluminium substitutes, such as ferrous metals, increases even more (4.7% in this case).

For the extended policy scenario the results are much the same for the sectors already discussed. The price increases and output reductions are, however, somewhat smaller due to the lower permit price. What is interesting about this scenario is the effect on the aluminium and the chemical sector of being included. Do the sectors gain when they are granted exception from the emissions trading scheme?

The results show that prices in the chemical sector increase by 0.5 percentage points, and the resulting shift in demand results in a decreased output of 0.7 percentage points (as compared to the EU-ET scenario). It turns out that prices in the aluminium sector increase by a mere 0.3 percentage point compared to the EU-ET scenario, and output decreases by 0.7 percentage points. While the initial reaction might be that aluminium would seem to be price sensitive, it is important to keep in mind that at the same time as the price increases slightly in the aluminium sector, prices go down in the sectors that were included under the EU-ET scenario, and demand for these goods increases in response.

Both sectors seem to fare better under the EU-ET scenario, as output is higher for both sectors, and the unit cost is also higher for the aluminium sector, in this scenario.. However, revenue is only 0.53% higher in the EU-ET scenario, and the two sectors make up only 3.3% of the total value of output in the EU. The small gain obtained by exempting these two sectors (without being able to say exactly what happens to profits), should be compared to a loss of 0.04% of total real income if the EU-ET scheme is chosen over the extended scheme.

While the aluminium and chemical sectors do seem to gain somewhat if they are exempted, this is not true for all other sectors. If we look at the crude oil sector, which is exempted under the EU-ET scheme, we see that the price is down 0.4%, and output is down by 7.4%. The reason why both price and output decreases at the same time, is that most of the crude oil is used as an input in the refined oil sector – which is not exempted, and where output decreases quite significantly (10.3%). As demand for refined oil decreases (because of the increased price), so does the demand for crude oil – as a major input to the refined oil sector.

4.3 Sensitivity analysis

Sensitivity analyses were carried out for some of the key parameters and policy assumptions in the model. Because the main focus of this paper is to compare the welfare effects of implementing a differentiated scheme (EU-ET) to a comprehensive emissions trading scheme, all results will refer directly to this comparison. This is also done because changing for example the growth rates will have a great effect on welfare, and using absolute numbers would therefore cloud the analysis.

The sensitivity analysis was carried out on two key parameters and one policy assumption. The first key parameter is the annual growth parameter. The growth rates in the original model are based on the SRES A1B scenario, and in the sensitivity analysis the annual, regional growth rates (benchmark) were increased and decreased by 1%. These two analyses are called *high-growth* and *low-growth*.

The second key parameter was the elasticities of substitution between coal and liquid fuels, and between refined oil and gas. These elasticities are 0.5 and 2, respectively, in the original model. The elasticities were increase to 0.8 and 3 for the *elastic* analysis, and were decreased to 0.2 and 1 for the *inelastic* analysis.

Finally, the assumption that no hot air will be sold was relaxed, and the former Soviet Union countries were allowed to sell all their hot air. This analysis is called *hot air*.

Table 5 shows these welfare losses for each of the five sensitivity analyses and also with the original assumptions. The table shows that the results are robust; for the permit buying regions, the EU-ET scheme invariably creates a larger welfare loss than a comprehensive scheme. Norway is always the region that loses the most by choosing the differentiated scheme over the comprehensive. The reason for this is that in Norway only a very small share of emissions are covered by the differentiated scheme.

Table 5 Sensitivity analysis of welfare losses (EU-ET compared to comprehensive scheme)

(% change)	Original	High-growth	Low-growth	Elastic	Inelastic	Hot air
EU	-0.83	-1.02	-0.41	-0.59	-0.72	-0.44
Norway	-0.89	-1.37	-0.59	-0.79	-1.02	-0.84
RAB	-0.48	-0.79	-0.28	-0.43	-0.54	-0.31
FSU	+1.87	+3.90	+0.51	+1.62	+2.19	+1.16

The former Soviet Union countries are always better off if all regions choose the differentiated scheme. This is because, even with the assumption of no hot air sales, the region remains a permit seller and is better off the more restrictive the emission constraints in other regions.

As you might expect, the welfare losses are larger when the economic growth is higher. The reason being that with more rapid economic growth the emission targets become more stringent, and therefore more costly to achieve. The opposite is true when economic growth is less rapid.

One might also predict that higher elasticities would decrease the welfare loss (both in absolute numbers and compared to a comprehensive scheme). The reason being that choosing a less efficient scheme is less costly when abatement is cheaper (as a result of higher elasticities). The results confirm this intuition for the *elastic* analysis. For the inelastic analysis the opposite is true – except when it comes to the EU. The EU seems to experience a smaller welfare loss when elasticities are lower. However, results for single regions cannot always be expected to be in line with the general intuition, as trade allows benefits to be redistributed when the competitive situation changes.

Finally, with hot air sales the permit price is significantly lower – and in relative terms it is reduced by the greatest factor in the EU-ET scenario - and the welfare losses are consequently smaller.

Table 6 presents the permit prices for the sensitivity analyses. Again the results are what we would expect; there is a positive correlation between economic growth and permit prices, and there is a negative correlation between substitution elasticities and permit prices. Allowing hot air sales decreases the permit price to as little as USD 0.7 for the EU-ET scheme, and 11.1 for the comprehensive scheme. This is not very surprising, as the overall emission reduction target is significantly relaxed.

Table 6 Sensitivity analysis: permit prices (USD 1997 per ton CO_2e)

(USD)	Original	High-growth	Low-growth	Elastic	Inelastic	Hot air
Differentiated	21.8	31.1	14.3	19.9	23.9	11.1
Comprehensive	4.8	10.6	0.8	4.4	5.4	0.7

5 Discussion – the consequences of sectoral differentiation

That a policy that equalizes marginal abatement costs across all sources should achieve emission reductions at least cost is something of a truism in environmental economics. What this paper does is to highlight just how great the welfare loss can be if a differentiated emissions trading scheme is implemented instead of a more comprehensive scheme.

If the EU was to meet its Kyoto commitments by implementing the EU-ET Directive, as it stands today, this would cost around twenty times as much as implementing a fully comprehensive scheme. For Norway and the Rest of Annex B region the cost would by around 3-4 times greater if they were to implement the EU-ET scheme, or a similar differentiated scheme.[12] The absolute welfare losses are perhaps more informative to look at. These show that Norway would find such a system very inefficient, as it is only a very small share of the country's emissions that take place within the sectors that are covered by the scheme. The other Annex B countries, as a group, would find the EU scheme less costly; a larger share of their emissions take place within the sectors that are included. These results make it all the more surprising that Norway has already chosen to adopt an emissions trading scheme closely based on the EU-ET scheme.

The EU-ET scheme makes exemptions for large industries, notably the chemical and aluminium industries, and installations with significant greenhouse gas emissions. Also, CO_2 is the only greenhouse gas that is included in the EU-ET scheme. This paper shows that there is considerable scope for efficiency gains through including more sectors and gases.

[12] Norway will decide in autumn 2004 whether to adopt the EU scheme. This scheme would cover only 10% of Norway's greenhouse gas emissions. Norway will therefore keep its CO_2-tax, and the process industry has entered into a voluntary agreement with the government.

One main argument for making exemptions is that industries exposed to international competition might experience adverse effects on their competitiveness if they are covered by a scheme that their competitors are not. This paper shows that for the cases of the chemical and aluminium industries these exemptions are not necessarily very important; the major price changes occur when inputs into these industries become more expensive, and not when the sectors have a permit obligation themselves. Furthermore, exempting these sectors does not seem to be rational for society: The direct gain in revenue for the two sectors is only about half of the total welfare loss to society (and that does of course include the initial gain).

The main conclusions are robust. The sensitivity analysis shows that changing some of the key assumptions of the model does not affect the major conclusions. However, there are some qualifications to this result. First of all, it should be noted that the coverage of the EU-ET scheme is indeed intended to be extended over time (Delbeke 2003). The EU will, of course, also undertake mitigation measures in the sectors that are exempted from the emissions trading. However, unless the EU is able to carry out abatement in other sectors at the exact same marginal abatement cost, some of the inefficiencies illustrated in this paper will materialize.

The major weakness of this analysis is that the model does not include the monitoring and verification costs involved in an emissions trading system. Nor does the model include the structure of firms, i.e. it cannot distinguish between firms of different sizes. This is important, as the high cost of monitoring and verification was one of the EU's arguments for exempting *sectors* and non-CO_2 gases. This was also important in the decisions not to include small installations – where the monitoring and verification costs might be prohibitively high.

Without including these transaction costs this paper cannot provide a full assessment of whether or not differentiation is a sound policy. However, the paper does show that the welfare losses (transactions costs not included) vary dramatically between the differentiated EU-ET scheme and a fully comprehensive scheme. This shows that at least there is considerable scope for improving efficiency – provided that transaction costs are not very large. Including certain sectors, such as transportation, through an upstream emissions trading system, would most likely not entail very large transaction costs (as systems for monitoring and verification are already in place due to the imposition of petrol taxes), and would improve the efficiency of the scheme.

While this paper does not provide a full analysis of the issue, it does highlight some of the key economic impacts (both direction and magnitude) of implementing a differentiated emissions trading scheme. The large differences in welfare costs between a differentiated and a comprehensive scheme show that this is certainly a consideration that should enter into the policymaking process before measures for implementing the Kyoto Protocol are finalised.

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