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

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1. Abstract

While it is often assumed in the economic literature that the Kyoto Protocol will be implemented through a cost-efficient comprehensive emissions trading system, 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. In this paper we assess the welfare effects associated with implementing the EU emissions trading Directive – or a similar scheme for other regions. We also assess how differentiation of commitments affects the sectors that do or do not have a permit obligation. We find that sectoral differentiation comes at a relatively high welfare cost – in all our scenarios more than doubling the cost - and with only limited benefits to the sectors that are granted concessions.

2. Introduction

2.1 Efficient implementation of environmental agreements

The industrialized countries that are parties to the Kyoto Protocol have committed themselves to reduce their annual emissions of six greenhouse gases by around 5% by the first commitment period (2008-2012) as compared to their emissions in 1990. These reductions should be achieved primarily through domestic action. The protocol also establishes three so-called flexibility mechanisms, through which Parties to the protocol may acquire permits, and use them to comply with their commitments. The use of these mechanisms should be “supplemental to domestic action”. The three mechanisms are emissions trading, Joint Implementation, and the Clean Development Mechanism.

Standard economic theory predicts that, in the absence of any pre-existing distortions, a policy that yields equal marginal abatement costs across sources will achieve emission reductions at least cost. In much of the economic literature concerning the implementation of the Kyoto Protocol it is assumed that governments will adopt such a theoretically ideal means of reducing their emissions. With the options available under the Kyoto Protocol, this means that the required emission reductions will be achieved through a comprehensive emissions trading system (or alternatively an emission tax, which theoretically speaking has the same effect).

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, concessions have be granted to particular sectors. The emerging evidence of how governments are planning to implement the Kyoto Protocol suggests that what is true in general, will also be true in this case; governments will not choose a fully comprehensive trading system. For example, both the EU and Norway are planning for a combination of emissions trading for certain industries, and other measures, such as technical standards or voluntary agreements for other industries. These new measures might come in addition to existing to existing climate mitigation measures – such as the Norwegian CO_2 tax – or replace them[1].

2.2 The literature on differentiated commitments

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. Fear of these effects, leads to the granting of concessions. The authors study the economic effects of these 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). They find that granting these concessions 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 exempted sectors, 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. 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).

They 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 (such that other sectors having to reduce more), to 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

[1] From an efficiency point of view you should not have to taxes designed to achieve the same target – i.e. reducing greenhouse gas emissions. However, concern with tax revenue might mean that such overlapping measures will exist.

in excess of 1% to the entire economy, and that the tax-cum-subsidy policy is Pareto superior to making the exemption.

Boemare and Quirion (2002) review ten emissions trading systems that are implemented or being planned. While they also look at issues such as permits allocation, temporal flexibility and monitoring, they investigate the issue that this paper is mainly concerned with – sectoral coverage. They note that standard theory suggests that, provided administrative and monitoring costs are not disproportionately large, as many emitters (sectors) as possible should be included. This is both because a large number of participants are required to benefit from significant differences in abatement cost between emitters, and to lower the risk of market power in the permit market. However, they find that in most cases regulators have chosen not to include as many emitters as possible (at least not initially). One possibility is to have a phase-in system where more emitters or sectors are brought into the system over time – in order to alleviate the problems associated with implementing a large system. The authors suggest that while, among other sources, process emissions from the chemical industry are not included in the EU emissions trading (EU-ET) Directive, these emissions (as well as other gases than CO_2) are likely to be phased in over time. They argue that a more comprehensive (and upstream) system was excluded for political reasons – because it would have looked too much like a tax.

2.3 Scope of this study

In this paper we will analyse the welfare cost of implementing a climate agreement with sectoral differentiation of commitments. Furthermore, we will explore the economic impact on those sectors that are granted concessions, and those that are not. One reason for why concessions are granted might be political concern with competitiveness and employment. Another might be that it does not pay off to include sectors with small emissions where it is very expensive to monitor and verify these emissions. We will not discuss the motivations further.

To do the analysis we will employ the DEEP model, which is a computable general equilibrium model developed at CICERO for the purpose of climate policy analysis. While the model does include taxes and tariffs, we will not analyse second-best effects as such (but they will enter into the results).

We will take the EU-ET directive as our example. It is a particularly relevant example both because the EU is likely to be the biggest regional emissions trading scheme[2], and because it is the one that has come the furthest towards implementation and where most details are known.

In the EU-ET Directive (European Parliament and Council 2003) emission reduction commitments are differentiated between sectors in the respect that only certain industries have a permit obligation (are required to reduce emissions), while other industries are exempted from this obligation. The sectors that have an obligation under this scheme are energy activities (power plants, mineral oil refiners and coke ovens), production and processing of ferrous metals, the mineral industry (a.o. cement and glass), and other activities (paper and pulp). The Directive is further differentiated in that only one of the six Kyoto Protocol gases are included – CO_2. According to Convery et al. (2003) this

[2] 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).

system will cover 46% of European Union CO_2 emissions, and 38% of total greenhouse gas emissions[3].

3. Model and scenarios

3.1 The DEEP model

The DEEP model is multi-sector, multi-region, multi-gas dynamic computable general equilibrium model. The production and the demand structure is based on the GTAP-EG model (Rutherford and Paltsev 2000), with some modifications in the demand structure for fossil fuels (oil is separated from other fossil fuels in the nesting structure). Production is modelled as a nested CES function, with bilateral trade (invoking the Armington assumption), and with taxes and tariffs. There is a representative agent that demands a consumption good that is produced through a nested CES function. The representative agent maximises his net present utility across all time periods of the model. Growth is determined through an exogenous growth rate for consumption.

In addition to CO_2, the DEEP model also includes methane and nitrous oxide emissions. The non-CO_2 emissions are modelled as direct inputs to the production function – based on the approach used in the EPPA model (Hyman et al. 2002).

The economic (individual country input-output and international trade) data is from the GTAP (v5) data base, while 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]. The model is fully described in Kallbekken (forthcoming).

3.2 Policy scenarios

We will consider two main policy scenarios. In the first scenario we look at the implementation of the EU-ET Directive in the time period before the first commitment period (2005-2008) [5]. We include the same sectors and gases (CO_2 only) as the Directive does. We call this scenario *early-diff* (because the EU is taking early action in preparation for the Kyoto Protocol and implementing a differentiated policy).

In the second scenario we extend the time horizon of the model to include the first commitment period of the Kyoto Protocol (2009-2012). In this scenario all Annex B regions[6] implement the Kyoto Protocol with the same type of differentiated commitments as the EU. We assume that this will be a competitive international market where there are no real barriers to trade across countries (in other words we assume "linking" between the different trading systems). We do, however, not include credits generated by CDM-projects. This scenario we call *KP-diff* (Kyoto Protocol with differentiated commitments).

[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.
[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.
[5] We run our model in four-year steps, and therefore we cannot match the duration of the EU early action or the first commitment period. The time periods should have been 2005-2007 and 2008-2012.
[6] Except the USA and Australia who have rejected the Protocol.

For these two scenarios we will make a very 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 our analysis and the comparisons we make. While the EU-ET scheme is the cornerstone of the Climate Change Program, the EU will also implement other mitigation measures. The following measures are underway for sectors and gases not covered by the EU-ET Directive; improving the energy performance of buildings, reduce the average CO_2 emissions of new cars, increase the share of bio-fuels in the road transport sector, reduce emissions of fluorinated gases, and reduce methane emissions from landfills (Delbeke 2003).

We develop two scenarios that parallel the two main scenarios for the purpose of making comparisons. These are idealized (i.e. fully comprehensive) emissions trading schemes that in principle would achieve the emission target at least cost[7]. By a comprehensive emissions trading scheme we means that all sectors and all Kyoto gases are included. The DEEP model includes CO_2, 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). We denote these two scenarios as *early-comp* and *KP-comp*.

For all four scenarios we assume that no “hot air” will be sold during the first commitment period. This is a reasonable assumption for the *early* scenarios - given that the EU insists on real emission reductions taking place, and is planning to limit the extent to which member states can meet their obligations by purchasing cheap permits from outside the union. The assumption is more controversial when it comes to the first commitment period where all Annex B countries are involved:

Russia has not yet ratified the Kyoto Protocol, and because the Protocol will not enter into force without Russian ratification, some observers believe that Russia will try to bargain for deals with other Annex B parties to agree to purchase some of its “hot air”. However, it is also not unlikely that the countries with large endowments of “hot air”, primarily Russia and Ukraine, to a large extent will choose to go for Joint Implementation projects and investments in their energy infrastructure in the first commitment period, and bank “hot air” permits for use in future commitment periods. It is generally held that Russia and Ukraine will have market power in the permit market, and by banking permits they can both increase the permit price and have permits available to meet stricter emission reduction requirements in future commitment periods. A large proportion of the “hot air” might therefore not be available on the market during the first commitment period.

If we had chosen to include “hot air” sales, it would have had the effect of reducing the permit price – and thus also the cost of implementing the Kyoto Protocol. This would have had a direct impact on the welfare cost, but not on the general conclusions regarding the welfare effects. Furthermore, it would not have significantly changed the outcome of the comparisons we make between the sectors that are exempted and those that are not – generally it would only have had a scale effect.

Because the two pairs of scenarios have different time horizons, the results reported will always refer to the period 2005-2008 for the *early* scenarios, and the period 2009-

[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 our model.

2012 for the Kyoto Protocol scenarios. Prices are always given as net present value of the consumer prices (i.e. including all taxes and tariffs).

In addition to these four scenarios we will run a reference case with business-as-usual (BAU) emissions, i.e. where no emission constraints are imposed. This case we will refer to as *BAU*.

4. Results

4.1 Welfare effects

The major results of the scenarios are presented in tables 1 and 2. As one might expect, the permit prices are significantly higher in the scenarios with differentiated commitments that the comprehensive emissions trading scenarios. For the *early* scenario the permit price is USD 26.7 with a differentiated scheme, while it is only USD7.5 with a comprehensive scheme. The *KP* scenarios give similar results; a permit price of USD 23.2 with a sectorally differentiated scheme, and USD 5.0 with a comprehensive scheme.

Compared with 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 *early* comprehensive scheme in the EU is found to be 0.21%[8]. Implementing a similar scheme in all Annex B countries in the Kyoto Protocol period, results in welfare losses of 0.32% for the EU, 0.27% for the EFTA^{-}[9] region, and 0.23% for the “Rest of Annex B” region.

Implementing the sectorally differentiated scheme will increase the welfare loss to the EU to 0.55%. In other words the cost of achieving the same amount of emissions reductions are more than twice as high with this scheme. Achieving the targets for the first commitment period by implementing a differentiated scheme, will result in welfare losses of 0.82% for the EU, 1.11% for the EFTA^{-} region, and 0.59% for the Rest of Annex B region. For each region – choosing to meet their Kyoto commitments in this way, instead of choosing the comprehensive system, significantly increases their welfare losses. In the case of the EFTA^{-}region the losses increase fourfold.

There are some relatively obvious reasons why the different regions display this relatively large variation in the welfare effects; the Rest of Annex B region includes countries that hold excess permits (mainly Russia), and while we assume that they will not sell these excess permits, they have to undertake only limited abatement. The EFTA^{-} region on the other hand, emits only a small share of its total greenhouse gases from the sectors that are included in the differentiated scheme, and under that scenario they therefore have to undertake large emission reductions in these sectors – or purchase a correspondingly large amount of permits on the international market. Consequently the region experiences a relatively large welfare loss.

The reason why the differentiated schemes 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

[8] 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 that have no real economic value.
[9] The EFTA^{-} region consist of Norway, Iceland and Liechtenstein and was chosen because of a parallel project where we look at the impact of the EU-ET on the Norwegian gas sector.

no longer available, making it more costly to meet this target. This inefficiency has quite strong implications in terms of shifting activity between sectors – which is the issue we will turn to next.

Table 1 Permit prices (USD1997 per ton CO_2e)*

	EU	Annex B
Differentiated	26.7	23.2
Comprehensive	7.5	5.0

* Note that prices for the EU and Annex B scenarios do not relate to the same time period.

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

	early-comp	*early-diff*	*KP-comp*	*KP-diff*
EU	-0.21	-0.55	-0.32	-0.82
EFTA⁻			-0.27	-1.11
Rest of Annex B			-0.23	-0.59

4.2 Economic effects by sectors

The inclusion of some, and exemption of other sectors from the permit obligation, has significant economic consequences. The economic implications are shown in table 3 for the *early* scenarios, and in table 4 for the *KP* scenarios. The two pairs of scenarios are compared to the *BAU* case.

Independent of which scenario you look at, you will find that prices increase by the most in emission-intensive sectors, such as coal, oil, gas and electricity. The impact on other sectors is smaller (and even zero), but there is still a small price increase, resulting in part from more expensive energy-intensive inputs. As the prices increase, the demand for these goods decreases.

If we compare the differentiated and the comprehensive schemes, we find that the sectors that are included in the differentiated scheme experience a significantly higher price increase, and associated decrease in demand, than those who are exempted[10]. 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 emissions in the differentiated scheme. This has a big impact on prices, which increase by 18.6% more with the differentiated scheme than with the comprehensive one. Output is 10.6% lower.

If we look at a relatively emission intensive industry that is excluded under the EU-ET scheme, gas production and distribution, we find that this sector gains a great deal from this exemption; prices are 2.4% lower and output 12.0% higher than in the comprehensive case (where this sector has an obligation, and has to pay for permits). Gas output is, however, still lower in the differentiated case than it would be with business-as-usual. One might have expected the opposite - that with gas being the least carbon-

[10] One exception to the general picture, is the coal sector – where both output and the prices decreases. The cost of coal extraction does not change much. But the demand for coal decreases significantly as it becomes more expensive to use coal – as the power sector is required to hold permits when it burns coal. This shifts the demand curve down, decreasing both the price and output at the new market equilibrium.

intensive fuel there would be fuel-switching resulting in an increased demand for gas[11]. A likely explanation is that most of the gas that is produced is used for electricity generation, and the electricity sector is subject to such strict constraints in the differentiated case that the demand even for the "most preferred" fuel decreases.

Exempted sectors do not always gain from their exemption – at least not when other sectors are exempted at the same time. This seems to be the case for the crude oil sector – where output drops by 5.0% and the price by 0.2% in the differentiated case (where crude oil is exempted), as opposed to the comprehensive case. The reason for this 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 (7.4%) when it is subjected to relatively stringent emission constraints in the differentiated case. As demand for refined oil decreases (because of the increased price), so does the demand for the major input to this sector – crude oil.

If we look at the price and output changes in the EU under the *KP* scenarios, these are almost identical to those reported above for the *early* scenarios; while the EU's own emission restrictions become much stricter during the first commitment period of the Kyoto Protocol, they can also purchase cheaper credits from the other Annex B countries, with the overall result that there are almost no differences from the changes under the *early* scenario. All the general observations made for the *early* scenarios, also hold true for the *KP* scenarios.

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

	Sector	Change in output		Change in price	
		Early-comp	*early-diff*	*early-comp*	*early-diff*
Participating sectors	Coal	-20,9	-34,5	+1,7	-0,4
	Oil	-4,1	-11,5	+1,1	+4,0
	Electricity	-7,1	-17,7	+8,4	+27,0
	Minerals	-0,9	-2,5	+0,3	+1,5
	Ferrous metals	-2,5	-7,6	+1,3	+4,5
	Paper and pulp	-0,4	-1,2	+0,1	+0,9
Exempted sectors	Agriculture	-1,1	-0,3	+0,6	0,0
	Gas	-19,4	-7,4	+2,0	-0,4
	Crude oil	-2,4	-7,4	-0,1	-0,3
	Capital Goods	-1,6	-2,0	0,0	0,0
	Other man. and services	-0,3	-0,3	0,0	0,0

Table 4 Percentage change in price and output compared to *BAU* (*KP* scenarios)

	Sector	Change in output		Change in price	
		KP-comp.	*KP-diff.*	*KP-comp*	*KP-diff.*
Participating sectors	Coal	-16,5	-33,6	+1,6	-0,2
	Oil	-2,8	-10,2	+0,8	+3,9
	Electricity	-4,4	-13,9	+6,6	+27,6
	Minerals	-0,5	-1,5	+0,3	+1,6
	Ferrous metals	-1,1	-4,2	+1,2	+5,1

[11] Which would not necessarily translate into an increased output of gas from the EU, as the increased demand could be met through exports – but that is not the case. Both production and demand decreases.

Exempted sectors	Paper and pulp	-5,3	-5,9	+0,2	+1,0
	Agriculture	-0,8	-0,4	+0,5	+0,2
	Gas	-11,7	-7,9	+1,8	-0,4
	Crude oil	-2,0	-7,7	0,0	-0,2
	Capital Goods	-0,3	-0,5	+0,2	+0,3
	Other man. and services	-0,2	-0,4	0,0	0,0

5. Discussion

5.1 The consequences of sectoral differentiation

By choosing a sectorally differentiated emissions trading system, instead of a comprehensive one, the EU significantly increases the cost of meeting its Kyoto commitments; costs are about 2.5 times higher both for early action and for implementation during the first commitment period (2008-2012). While we in this paper only estimate the costs of climate mitigation, and not the benefits, it should be noted that for the cases we compare, the absolute emission reductions are the same – and climate benefits should be roughly the same[12].

Large industries and installations with significant greenhouse gas emissions are exempt from the EU-ET system (notably process emissions in the chemical industry). Also, CO2 is the only greenhouse gas that is included. The results from the model show that there is considerable scope for efficiency gains through including more sectors and gases (in the *comprehensive* scenarios all sectors and CO_2, methane and nitrous oxide were included). It is also the intention that the coverage of the EU-ET scheme will 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. Our results therefore serve to illustrate the extreme case, where no further action is taken, and to show the economic consequences of this. Unless, and this is highly unlikely, the EU is able to carry out abatement in other sectors to the exact same marginal abatement cost, some of the inefficiencies that we have illustrated, will materialize. Furthermore, some of the positive impacts on sectors that are exempted, and the negative impacts on those that are not, will also remain.

If the EU trading system was to be adopted as an Annex B-wide system[13], the same types of effects would occur in the other countries as well. The relative impact would, however, be different. The EFTA^{-} region, for example, would find such a system very inefficient, as it is only a very small share of their emissions that take place within the sectors that are covered by the EU-ET – and these sectors would consequently have to undertake very significant abatement (or, as this would in most cases be cheaper, purchases significant amounts of permits from other countries). The other Annex B countries, as a group, would find this less costly in relative terms; a larger share of their emissions take place within the sectors that are included, and also their total emission

[12] Which gases are included differs, and the different greenhouse gases have very different physical properties; despite the terminology abating one ton CO_2-equivalent of methane is not exactly the same as abating one ton of CO_2.

[13] There are reasons why other regions could choose to adopt a similar system to the EU, one being that this would most likely enable trading with the EU system.

reduction commitment is less strict, due to larger (relatively speaking) emission allowances.

5.2 Limitations to this study

In the DEEP model the monitoring and verification costs involved in an emissions trading system are not included. When for example small installations are not required to monitor their emissions and hold permits, this is largely because the cost might be too high to make trading an efficient option. A fully comprehensive emissions trading system could therefore be less than ideal in terms of economic efficiency. Also, the emissions trading system will interact with pre-existing tax distortions in ways that decrease the welfare gain of choosing a comprehensive system. In the paper by Babiker et al. (2001) it was shown that it is possible to reduce the welfare cost of climate mitigation by “over allocating” permits to heavily taxed sectors *in a scheme without economy-wide emissions trading*. In the DEEP model emission permits can not be allocated directly to sectors, and it was therefore not possible to study whether any “over allocation” could have reduced the welfare cost.

By using the DEEP model in our analysis, some significant issues could not be analysed. What could be the major component of the cost of mitigation – foregone economic growth, is not included as (consumption) growth is determined exogenously. Also, the model assumes full employment of all factors of production. At the same time we know that unemployment is a primary concern when it comes to the issue of protecting the international competitiveness of sectors – and including unemployment could have changed some of our conclusions. For instance – the gain from exempting the chemical process industry might be larger then our model estimates if this sector is particularly likely to lay off workers if costs increase, and if laid-off workers are not mobile and do not have transferable skills.

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