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THE ENVIRONMENTAL AND ECONOMIC EFFECTS OF EUROPEAN EMISSIONS TRADING

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Abstract

In 2005, the EU introduced an emissions trading system in order to pursue its Kyoto obligations. This instrument gives emitters the flexibility to undertake reduction measures in the most cost-efficient way and mobilizes market forces for the protection of the earth's climate. In this paper, we analyse the effects of emissions trading in Europe, with some special reference to the case of Germany. We look at the value of the flexibility gained by trading compared to fixed quotas. The analysis will be undertaken with a modified version of the GTAP-E model using the latest GTAP version 6 data base. It is based on the national allocation plans as submitted to and approved by the EU. We find that, if the NAP is combined with a regional emissions trading scheme, then Germany, Great Britain, and Czech Republic are the main sellers of emissions permits, while Belgium, Denmark, Finland, and Sweden are the main buyers. The welfare gains from regional emissions trading – for the trading sectors only - are largest for Belgium, Denmark, and Great Britain; smaller for Finland, Sweden, and smallest for Germany and other regions. When we take into account the economy-wide and terms of trade effects of emissions trading, however, the (negative) terms of trade effects can offset the (positive) allocative efficiency gains for the cases of the Netherland and Italy, while all other regions ended up with positive net welfare gains. All regions, however, experienced positive increases in real GDP as a result of regional emissions trading.

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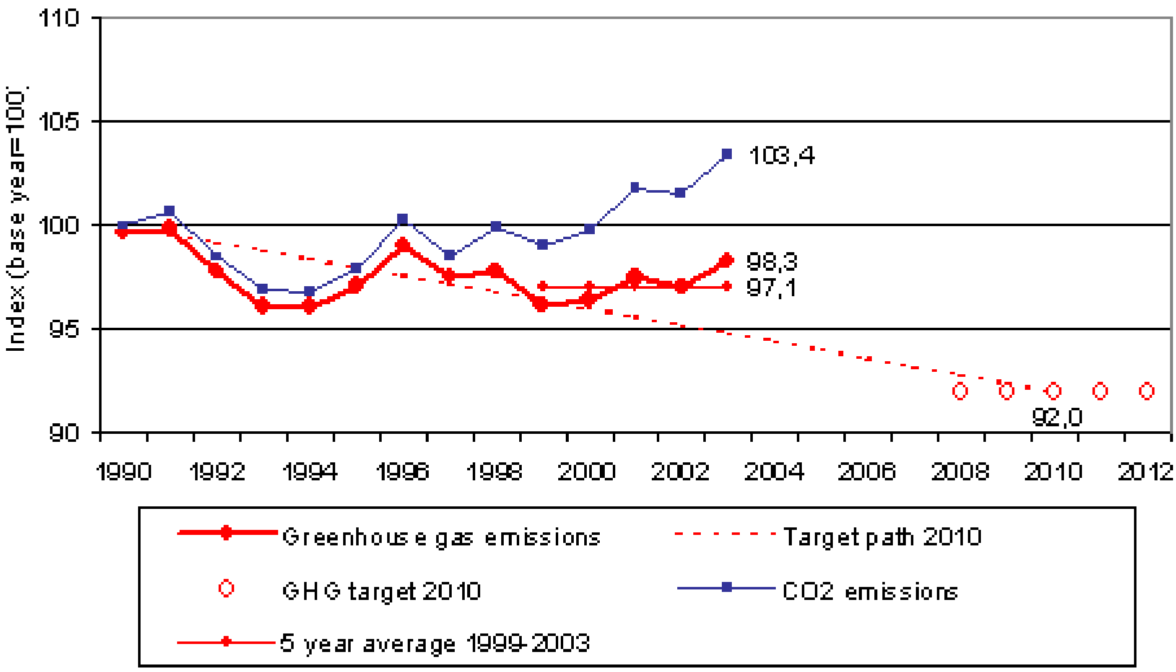
Introduction

The European Union considers climate change as "one of the greatest environmental, social and economic threats facing the planet." It therefore took a leading role in the negotiations for international action against climate change, in particular for the Kyoto Protocol. In order to set an example, it accepted relatively ambitious targets. Whereas all Annex B countries were to reduce the emissions of greenhouse gases by about 5 percent, the EU has committed to an 8 percent reduction.

Compliance with this target, however, does not come easily for the EU. Figure 1 depicts the development of the emissions of CO_2 and of all greenhouse gases (GHGs). It shows that the emissions in the EU were reduced quite effectively in the first half of the 90s. This was to a large extent due to the massive breakdown and modernisation of the industry in the former East Germany. Emissions have been fluctuating since then and increasing since the end of the 1990s (EEA 2005).

Figure 1: Total EU greenhouse gas emissions in relation to the Kyoto target



Source: EEA 2005

Therefore, in 2000 the EU Commission launched the European Climate Change Programme (ECCP), a continuous multi-stakeholder consultative process which serves to identify cost-effective ways for the EU to meet its Kyoto commitments, to set priorities for action and to implement concrete measures.[1] One of the main elements of this program was the establishment of a European CO_2 emissions trading scheme. The EU considers this as "a cornerstone in the fight against climate change" which will help its Member States to achieve compliance with their commitments under the Kyoto Protocol and the EU burden sharing at lower costs. The basic idea of emissions trading is to limit the amount of some kind of emission by creating rights to emit a certain amount of a gas and to make these rights – which are called allowances – tradable. The scarcity of emission allowances gives them a market value and thus a positive price which increases the costs for emitters. This creates an incentive to reduce emissions in an efficient way. Those emitters whose avoidance costs are lower than the market price of allowances will reduce their emissions and buy less certificates or sell excess emissions rights and vice versa.

Emissions trading has been introduced to international climate change policy through the Kyoto Protocol. However, there is a fundamental difference between the two approaches: The Kyoto Protocol permits trading between the Parties to the protocol on the level of states, the EU ETS comprises 11,428 installations and involves trade among individual emitters in 25 Member States.

In this paper we analyse the effects of the European Emissions Trading System (ETS), in particular the cost reduction that may be obtained by the flexibility of trading. This will be done by comparing three scenarios where the same reduction target is achieved with different degrees of flexibility. In the first case (Experiment 1), fixed quotas do not permit any flexibility at all. The second scenario (Experiment 2) allows trading between the sectors within the national economy. The third scenario (Experiment 3) represents the EU ETS where all participating European emitters can trade emission allowances among each other.

[1] Communication from the Commission to the Council and the European Parliament on EU policies and measures to reduce greenhouse gas emissions: Towards a European Climate Change Programme (ECCP), Com(2000)88 final.

European Emissions Trading

The ETS started on 1 January 2005. The first trading period – which has been nick-named "warm up phase" or "learning phase" – covers the years 2005 to 2007. The second phase corresponds to the Kyoto period 2008 to 2012.

The framework for European Emissions Trading has been defined by a Directive in October 2003[2] which lines out the basic features of the system, but leaves substantial scope for the Member States to decide on important aspects of the implementation. The most important features set by the EU are the following:[3]

- The European ETS will be a cap-and-trade system, i.e. the absolute quantity of emission rights (rather than relative or specific emissions) will be fixed at the beginning.
- Only one of the six greenhouse gases of the Kyoto Protocol will be subject to the ETS, at least during the first period from 2005 to 2007. The main reason for this is that CO_2 is the greenhouse gas which is easiest to monitor, since the emissions are directly related to the use of fossil fuels for which most countries have already established a monitoring system in order to levy energy taxes.
- In order to limit the administrative costs of the ETS, the system will be restricted to large installations. Therefore, only installations belonging to one of four broad sectors which are listed in the Directive and which exceed a sector-specific threshold are subject to emissions trading. The four sectors are
    - Energy activities (such as, electric power, direct emissions from oil refineries)
    - Production and processing of ferrous metals (iron and steel),
    - Mineral industry (such as cement, glass, or ceramic production),
    - pulp and paper.

  The thresholds refer to the production capacity of the installation, e.g. in the case of combustion installations with a rated thermal input exceeding 20 MW. The Emissions Trading Scheme will cover around 45 % of the EU's total CO_2 emissions or about 30 % of its overall greenhouse gas emissions. This partial coverage of the ETS is likely to produce inefficiencies. This can only be avoided if the total quantities of allowances are set at level which equalises the marginal avoidance costs between the emissions trading sector and other emitters.

[2] "Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC," Official Journal of the European Union, L 275/32, 25.10.2003.
[3] For a more detailed description and good discussions of the ETS see Kruger / Pizer (2004).

- At least 95% of the total quantity of allowances must be issued for free in the 2005/07 period, at least 90% in 2008/12.
- Allowances are issued by each Member State, but trading can take place between any EU participant.
- The so-called "linking Directive" will allow participants in emissions trading to count credits from emission reduction projects around the world towards their obligations under the European Union's emissions trading scheme. Thus the project-based mechanisms of the Kyoto protocol ("Clean Development Mechanism" and "Joint Implementation") will be available for European business, even if the protocol did not enter into force.

Within this framework, the Member States have three important tasks. First, they have to decide which quantity of emissions should be allocated to the installations participating in the ETS. This decision must take into consideration the burden sharing target of the country and must list the policies and measures which are to be applied in the sectors which are not part of the ETS. However, in almost all countries business representatives made strong lobbying efforts to make sure that emissions trading will not impair their competitive position. This led to very generous allocations in some cases. Second, they have to draw up a list of all installations which are subject to emissions trading. Third, they have to decide how to allocate the total quantity to individual installations. The Directive sets some general rules according to which the allocation has to be made, but there is substantial scope for national priorities.

These decisions have to be written down in a "National Allocation Plan" (NAP) which was supposed to be notified to the Commission by the end of March 2004, in the case of the new Member States by the end of June 2004 for review and approval. On 20 June 2005, the EU accepted the last NAP.

The National Allocation Plan (NAP) in Germany

Germany's National Allocation Plan consists of two elements: the so-called Macroplan which defines the national emissions budget and determines the total quantity of allowances to be allocated and a Microplan for the intended allocation of allowances to operators of individual installations (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2004) and Bundesregierung (2004)).[4]

The starting point of the **Macroplan** is Germany's commitment of the Kyoto protocol and the European burden sharing agreement to reduce its emissions of greenhouse gases by 21 % by 2008 to 2012 compared to 1990 levels. Up to now a 19 % reduction has been achieved already. Taking into account the projected development of non-CO_2 emissions, the German Government fixed the CO_2 target for the period 2005 to 2007 at 859 mill. tons – only 0,5 % less than 2000-2002 amounting to 863 mill. tons. Within these limits, the total quantity of allowances allocated to the trading sector are 499 mill. tons of CO_2, compared to 501 mill. tons in 2000-2002. This corresponds to a reduction of 0.4% and gives the trading sectors a comfortable position.

In the non-trading sectors, the CO_2 emissions have to be reduced from 362 mill. tons in 2000/2002 to 360 mill tons in 2005/2007. This also seems to be only a small reduction. But considering the fact, that the temperature adjusted emissions in 2000/2002 add up to approximately 373 mill. tons, the reduction rate (3,5 %) will be much higher than the rate for the trading sectors.[5]

The **Microplan** gives information on the intended allocation of allowances to operators of individual installations.[6] This allocation has been guided by the following basic principles:

- For existing installations (incumbents), the allowances allocated will be based on historical emissions in the reference period 2000-2002 (Grandfathering).
- New installations will be allocated free of charge if they do not receive such a transfer (New entrant rule). A reserve of 3 Mt CO_2 is set aside for this purpose.
- Allowances from installations which have been decommissioned can be transferred for four years to installations or extensions to installations commissioned from 1 January 2005 (Transfer rule).

Furthermore, several special rules relating to early action, process-related emissions as well as for combined heat and power generation and a hardship clause have been

[4] Federal Ministry for the Environment, Nature conservation and Nuclear Safety: National Allocation Plan for the Federal Republic of Germany 2005-2007. Berlin, 31 March 2004.
[5] In contrast to the obligations given by the EU directive, no clear information is given in the German NAP which policies and measures will be implemented to guarantee that these targets will be achieved.
[6] In total 1849 installations participate in the emissions trading system in Germany.

designed to take account of special circumstances which according to the EU Directive may justify a more generous treatment.

In order to reconcile the Macroplan with the Microplan, a so-called compliance factors need to be applied. Since the trading sectors are to reduce emissions by 0,4%, a factor of 0.996 is applied to all allocations based on historical emissions. Since special rules increase the allocation to some installation and a reserve for newcomers is to be set aside, the allocation to other installation must be reduced by an additional compliance factor. The effective reduction varies between 0 % and 7.5 %.

All in all the German NAP – as well as many of the NAP in other European countries – seems to be not very ambitious, especially concerning the allowances given to the trading sectors, and not very clear in respect of the non-trading sectors. Nevertheless, special rules for many installations lead to relatively large reductions for others and potentially large cost differences. This creates ample scope for efficiency gains through trading.

Quantitative Impact assessment

Model, Data, and Experiments Description

In this study we use a version of the GTAP-E model (Burniaux and Truong, 2002) which is based on the latest version 6.2 of the standard GTAP model (Hertel, 1997). The model uses version 6 of the GTAP data base which consists of 57 commodities/sectors and 87 regions including the 25 European Member states (Dimaranan and McDougall, forthcoming). For the purpose of this study, we use an aggregation which includes most of the EU member states[7] and all of the 'allocated' sectors (see Tables 1 and 2). The projected percentage changes in CO_2 emissions for the various sectors for the period 2005-07 to satisfy the NAP are as shown in Table 3.

First, we notice that if we adhere strictly to the NAP, then some shocks to the emissions would be positive (shaded areas). A positive emission shock would imply no abatement effort is involved, and furthermore, a *negative* abatement cost may result, which does not make sense in practice. Therefore, to avoid this situation, we have chosen to swap a positive emissions shock with a zero shock for the marginal abatement cost (i.e. zero carbon tax) and let the emissions levels be determined endogenously by the model. The

[7] Except for those states with small allocations which are then aggregated into a single "rest of European Union" (REU) region (see Table 1).

resulting emissions will then be positive but often would be less than the actual NAP allocations (see Table 4).

Next, for non-NAP sectors (i.e. sectors which are not part of the NAP), we assume that there will be no abatement cost (zero carbon tax) imposed on these sectors, hence, their emissions levels will be determined endogenously by the model, according to the production and relative price relationship between these sectors and other NAP sectors. In general, we will expect a positive increase in emissions rather than a reduction in emissions for these non-NAP sectors, which means a ‘leakage’ of emissions from NAP to non-NAP sectors.

We carry out three experiments. In Experiment 1 (“No Trading”), we shock the emissions of each designated sector of each region by the projected percentage changes to satisfy the NAP requirement, and let the model estimate the required carbon price (marginal abatement cost). In Experiment 2 (“Domestic Emissions Trading” only), we allow all designated sectors of each region with a NAP allocation to trade in emissions with each other. This will result in a uniform MAC across all trading sectors for each region but the MAC will be different for different regions. In Experiment 3 (“Regional Emissions Trading”), we allow not only domestic trading, but also trading between regions (EU member states). This will result in a uniform MAC across all NAP sectors and regions. The changes in MACs between the three experiments are used to measure the potential gains (reduction in MAC) that can result from either domestic trading, or from domestic plus regional trading. The results of the experiments are shown in Tables 4-14. All costs are reported in 1995US$.

Figure 1 Standard GTAP-E Production Structure

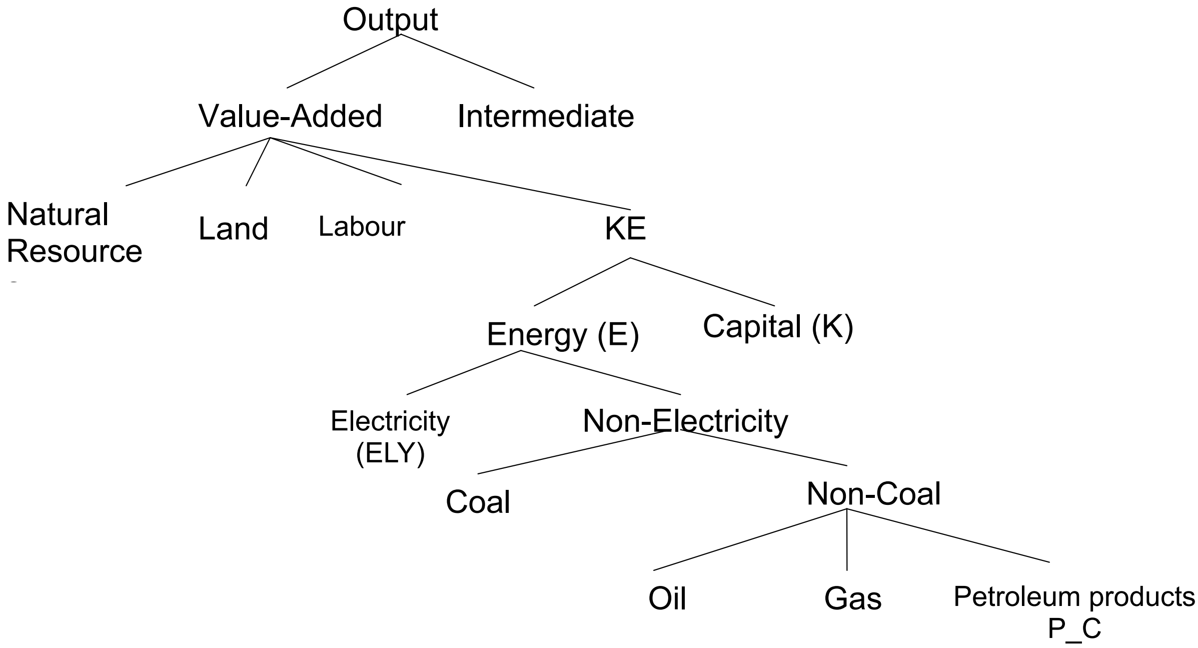


Table 1 Categorisation of Regions/Countries

	Description
aut	Austria
bel	Belgium
dnk	Denmark
fin	Finland
fra	France
deu	Germany
grc	Greece
gbr	United Kingdom
ita	Italy
nld	Netherlands
prt	Portugal
esp	Spain
swe	Sweden
cze	Czech Republic
hun	Hungary
pol	Poland
REU	Rest of European Union
CHIND	China and India
JPN	Japan
USA	United States
RoW	Rest of the World

Table 2 Categorisation of Sectors

	Description
Coal	Coal Mining
Oil	Crude Oil
Gas	Natural Gas Extraction
Electricity	Electricity
Oil_Pcts	Refined Oil Products
Metals	Metals products
Min_Prod	Mineral Products
Paper	Paper
Motor_Equip	Motor machine & equipment
Constr	Construction
Textile	Textile
Oth_Ind	Other Industries
ROE	Rest of the economy

Table 3 Percentage deviation of emissions from projected level for period 2005-2007 according to the NAP(*)

\Sector Region	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor_ Equip	Constr	Textile	Oth_ Ind	ROE
aut	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9		
bel	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	
dnk	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	
fin	-12.5									
fra	-0.4	-2.8	-10.3	-8.1						
deu	-3.1	-2.6	-0.5	-0.4	-1	-2.2	-2.2	-2.2	-2.2	
grc	-6.5	-16.8			-6.6					
gbr	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5		
ita	-5.5		-4.2	-1.7	-3.4					
nld	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	
prt	-6.2			-1.2						
esp	-6.5	-3.6	-2.9	-5.4	-4.5					
swe	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	
cze	-4.5	-4.3	-4.6	-4.5	-4.1					
hun	-3.1	-5.1	-5.1	-5.1	-5.1					
pol	-9.3	-3.8	-10.3	-2	-7.5					

(*) (Allocated emissions – Projected Emissions)/(Projected Emissions) * 100

Results

Table 4 shows the percentage change in emissions for all sectors and regions in Experiment 1. For the sectors subjected to the NAP, these are the same as in Table 3 (i.e. negative) except for those sectors with *positive* emissions changes according to the NAP constraints which have been replaced with a zero MAC constraint. For these sectors, as well as all other non-NAP sectors which are subject to a zero MAC constraint, the estimated changes in emissions can be positive, which implies a 'leakage' from NAP to non-NAP sectors. Table 5 shows the estimated MACs for the NAP sectors in the case of no emissions trading (Experiment 1). These estimated MACs can range from a very low figure of less than a dollar per ton of CO_2 (\$/tCO_2) for some sectors, to a high figure of 163 (\$/tCO_2) for the Oil Refining (Oil_Pcts) sector in Sweden (swe). The high figures of the MACs in the Oil Refining sector reflects the fact that there is limited capacity for fuel substitution or fuel efficiency improvement in this sector (as compared to other sectors such as electricity generation).

Table 6 and Table 7 show the percentage change in emissions relative to the baseline, and the MAC, for all sectors and regions in Experiment 2 where there is emissions trading between the sectors but no emissions trading between the regions. The MACs in this case are now uniform for a given region but varies across different regions. It can range from a low figure of less than 1\$/tCO_2 for Great Britain (gbr) to a high figure of 8.4 \$/tCO_2 for the case of Sweden (swe).

Table 8 shows the changes in emissions levels from Experiment 1 to Experiment 2. Sectors with positive increases in emissions from Experiment 1 to Experiment 2 represent 'buying sectors', which buy the 'permit' for the extra emissions from those sectors with negative changes in emissions. The 'buying sectors' are those with high MACs, who will rather buy more permits to increase their emissions rathe rathan incur high MAC to reduce their emissions (as required under the NAP). The reverse is true for the sectors with low MACs. Both, however, will end up with positive efficiency gains. These efficiency gains are calculated as (approximately) 0.5 x (Change in emissions) x (Change in MAC), where the changes in emissions and in MAC will often be opposite in directions as explained above (except for the cases where the output effect may dominate the price or substitution effect). The efficiency gains when moving from 'No Trading' to 'Domestic Sectoral Trading' are given in Table 9. From Table 9, it is seen that the regions that gain the most from domestic emissions trading are Greece (grc) followed by the

Netherland (nld), Sweden (swe), then France (frc) and Great Britain (gbr). Germany (deu) and Spain (esp) only gain moderately.

Tables 10 and 11 show the percentage changes in emissions relative to the baseline, and the MAC, for all sectors and regions in Experiment 3 where there are emissions trading not only between the sectors but also between regions. The MAC in this case (2 $/tC) is now uniform not only for all NAP sectors but also for all trading regions. Table 12 shows the changes in emissions levels from Experiment 2 to Experiment 3. Regions with positive increases in emissions from Experiment 2 to Experiment 3 (Austria, Belgium, Denmark, Finland, Greece, Italy, The Netherland, Spain, Sweden, Poland) represent regions which buy emission permits from those regions with negative changes in emissions (Germany, Great Britain, Czech Republic, Hungary). The 'buying regions' are those regions with higher MACs as compared to the 'selling regions'. All regions, however, will gain in efficiency when trading in emissions. Table 13 shows these gains. The gains are generally smaller than the those from sectoral trading alone (Table 9), which implies that the differences in MACs *between* the sectors within a region are generally greater than the differences in MACs *across* different regions. The gains are also largest for Belgium, Denmark, Great Britain, Finland, and Sweden, which reflect the greater variations in MACs between these regions.

Finally, Table 14 shows the overall macroecoomic effects of emissions trading. Firstly, compared to the case of no trading, emissions trading (across sectors as well as across regions) will bring about an improvement in GDP level for all EU regions (first column of Table 14). The trade effects of emissions trading however, are not uniformly distributed across EU regions, as expected. Some regions will gain in income from emissions trading (Great Britain, Germany, and Czech Republic), while others will lose (Belgium, Denmark, the Netherlands, Sweden). This means that even though emissions trading will bring about substantial efficiency gains for most regions (columns 3 and 4 of Table 14) the combined trade and efficiency effects can be negative for some regions, such as Italy (ita) and the Netherlands (nld) (see the last column in Table 14). This implies that even though the overall welfare effects of emissions trading is postive for all NAP regions as a whole, the *distribution* of these welfare gains may not be uniform across regions, with some regions (such as Germany (deu) and France (fra) gaining more from emissions trade, while others (the Netherlands (nld) and Italy (ita)) may lose due to adverse terms of trade effects.

Conclusion

Our study has shown that emissions trading is an important policy instrument to use in trying to achieve a particular climate policy objective such as in the fulfilment of the Kyoto obligations by the EU in their National Allocation Plans (NAPs). The use of this 'flexible' policy instrument is seen to result in significant efficiency gains, measured in either terms of the reduction in marginal abatement cost for a particular sector within a given region, or in terms of the 'welfare triangles' which measure the reductions in total compliance costs (for those sectors with high MACs), or the gains in revenue from emission trading (for those sectors with low MACs). The efficiency gains result in positive increases in real GDP growth for all regions. However, the adverse terms of trade effects (which depend to a large extent on the initial distribution of the total 'burden' of emission reductions across different sectors and different regions) may result in a net welfare loss for some regions. This implies net changes in national income maybe negative for some region even though changes in real GDP maybe positive. This unveven distribution of the total net benefit of emissions trading may call for some attention to be paid to the initial distribution of the burden of emissions reductions across regions.

Table 4 Percentage change in emissions for period 2005-2007 in Experiment 1 (No Emissions Trade)

\Sector Region	Coal	Oil	Gas	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE
aut	-5.3	-0.7	-0.4	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9	0.7	-1.5
bel	-1.8	-0.8	-1.6	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-0.9
dnk	-2.1	-0.2	-6.9	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-0.2
fin	-7.6	-0.2	-1.2	-12.5	4.1	3.3	1.0	2.1	2.9	0.9	1.7	1.8	0.8
fra	-3.0	-0.3	-0.2	-0.4	-2.8	-10.3	-8.1	0.3	0.2	-1.0	-0.2	0.2	-0.9
deu	-3.2	-0.5	-1.0	-3.1	-2.6	-0.5	-0.4	-1.0	-2.2	-2.2	-2.2	-2.2	-1.3
grc	-5.8	-2.5	-16.1	-6.5	-16.8	-4.9	-2.9	-6.6	-4.5	-4.8	-6.6	-7.0	-5.9
gbr	-3.6	-0.3	-1.5	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5	0.0	0.1
ita	-2.4	-0.2	-0.3	-5.5	0.4	-4.2	-1.7	-3.4	1.0	0.9	1.0	1.1	0.5
nld	-2.0	-0.3	-0.2	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	0.0
prt	-2.3	-0.5	-1.7	-6.2	0.8	0.6	-1.2	0.2	0.4	0.1	0.1	0.3	0.1
esp	-3.6	-0.4	-0.4	-6.5	-3.6	-2.9	-5.4	-4.5	-0.4	-1.4	0.2	-1.7	-1.1
swe	-5.6	-1.0	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-2.4
cze	-3.0	-0.5	0.2	-4.5	-4.3	-4.6	-4.5	-4.1	1.2	-0.8	2.3	1.8	-0.8
hun	-3.0	-0.4	-0.3	-3.1	-5.1	-5.1	-5.1	-5.1	0.2	-0.4	0.7	0.6	-0.7
pol	-5.1	-0.1	-0.1	-9.3	-3.8	-10.3	-2.0	-7.5	6.4	2.1	7.0	3.9	1.1

Table 5 Marginal Abatement Cost (\$/t CO_2) in Experiment 1 (No Emissions Trade)

\Sector Region	Coal	Oil	Gas	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE
aut	0.0	0.0	0.0	3.8	42.2	1.6	3.0	1.0	2.0	3.2	2.0	0.0	0.0
bel	0.0	0.0	0.0	11.5	32.3	1.6	4.4	3.2	5.7	6.4	3.5	7.7	0.0
dnk	0.0	0.0	0.0	7.5	50.5	0.2	1.1	0.1	0.0	9.4	0.0	0.1	0.0
fin	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fra	0.0	0.0	0.0	0.5	17.3	4.1	11.6	0.0	0.0	0.0	0.0	0.0	0.0
deu	0.0	0.0	0.0	1.6	22.5	0.7	0.5	0.7	1.5	2.4	1.4	1.8	0.0
grc	0.0	0.0	0.0	2.8	137.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
gbr	0.0	0.0	0.0	2.2	13.3	0.4	0.3	0.0	0.0	0.2	0.0	0.0	0.0
ita	0.0	0.0	0.0	2.8	0.0	2.1	2.6	1.7	0.0	0.0	0.0	0.0	0.0
nld	0.0	0.0	0.0	3.8	30.7	1.8	8.7	1.1	0.2	0.0	0.4	13.9	0.0
prt	0.0	0.0	0.0	2.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0
esp	0.0	0.0	0.0	2.3	19.2	1.3	6.8	3.4	0.0	0.0	0.0	0.0	0.0
swe	0.0	0.0	0.0	5.1	163.1	10.7	16.2	15.0	13.4	26.9	18.7	8.8	0.0
cze	0.0	0.0	0.0	1.1	53.8	1.3	2.5	1.4	0.0	0.0	0.0	0.0	0.0
hun	0.0	0.0	0.0	1.0	28.6	1.9	3.9	1.9	0.0	0.0	0.0	0.0	0.0
pol	0.0	0.0	0.0	2.3	45.8	2.9	1.3	2.6	0.0	0.0	0.0	0.0	0.0

Table 6 Percentage change in emissions for period 2005-2007 in Experiment 2 (Domestic Emissions Trade)

\Sector Region	Coal	Oil	Gas	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE	Total
aut	-5.3	-0.7	-0.4	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9	0.7	-1.5	-4.3
bel	-1.8	-0.8	-1.6	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-0.9	-8.5
dnk	-2.1	-0.2	-6.9	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-0.2	-15.1
fin	-7.6	-0.2	-1.2	-12.5	4.1	3.3	1.0	2.1	2.9	0.9	1.7	1.8	0.8	-6.2
fra	-3.0	-0.3	-0.2	-0.4	-2.8	-10.3	-8.1	0.3	0.2	-1.0	-0.2	0.2	-0.9	-1.5
deu	-3.2	-0.5	-1.0	-3.1	-2.6	-0.5	-0.4	-1.0	-2.2	-2.2	-2.2	-2.2	-1.3	-1.8
grc	-5.8	-2.5	-16.1	-6.5	-16.8	-4.9	-2.9	-6.6	-4.5	-4.8	-6.6	-7.0	-5.9	-3.4
gbr	-3.6	-0.3	-1.5	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5	0.0	0.1	-5.0
ita	-2.4	-0.2	-0.3	-5.5	0.4	-4.2	-1.7	-3.4	1.0	0.9	1.0	1.1	0.5	-2.5
nld	-2.0	-0.3	-0.2	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	0.0	-3.7
prt	-2.3	-0.5	-1.7	-6.2	0.8	0.6	-1.2	0.2	0.4	0.1	0.1	0.3	0.1	-2.5
esp	-3.6	-0.4	-0.4	-6.5	-3.6	-2.9	-5.4	-4.5	-0.4	-1.4	0.2	-1.7	-1.1	-3.2
swe	-5.6	-1.0	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-2.4	-6.3
cze	-3.0	-0.5	0.2	-4.5	-4.3	-4.6	-4.5	-4.1	1.2	-0.8	2.3	1.8	-0.8	-3.5
hun	-3.0	-0.4	-0.3	-3.1	-5.1	-5.1	-5.1	-5.1	0.2	-0.4	0.7	0.6	-0.7	-2.4
pol	-5.1	-0.1	-0.1	-9.3	-3.8	-10.3	-2.0	-7.5	6.4	2.1	7.0	3.9	1.1	-6.4

Table 7 Marginal Abatement Cost (\$/t CO_2) in Experiment 2 (Domestic Emissions Trade)

\Sector Region	Coal	Oil	Gas	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE
aut	0.0	0.0	0.0	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	0.0	0.0
bel	0.0	0.0	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	0.0
dnk	0.0	0.0	0.0	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	0.0
fin	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fra	0.0	0.0	0.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
deu	0.0	0.0	0.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.0
grc	0.0	0.0	0.0	3.5	3.5	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0
gbr	0.0	0.0	0.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.0	0.0
ita	0.0	0.0	0.0	2.6	0.0	2.6	2.6	2.6	0.0	0.0	0.0	0.0	0.0
nld	0.0	0.0	0.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	0.0
prt	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
esp	0.0	0.0	0.0	2.8	2.8	2.8	2.8	2.8	0.0	0.0	0.0	0.0	0.0
swe	0.0	0.0	0.0	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	0.0
cze	0.0	0.0	0.0	1.2	1.2	1.2	1.2	1.2	0.0	0.0	0.0	0.0	0.0
hun	0.0	0.0	0.0	1.3	1.3	1.3	1.3	1.3	0.0	0.0	0.0	0.0	0.0
pol	0.0	0.0	0.0	2.2	2.2	2.2	2.2	2.2	0.0	0.0	0.0	0.0	0.0

Table 8 Change in emissions (Million tons of CO_2) when moving from "No Trade" (Experiment 1) to "Domestic Emissions Trade" (Experiment 2)

\Sector Region	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind
aut	0.02	0.16	-0.18	0.08	-0.06	0.00	0.00	0.00	0.00
bel	1.85	0.18	-1.71	-0.25	-0.04	-0.01	-0.01	-0.02	0.00
dnk	1.48	0.07	-0.18	-0.34	-0.17	-0.21	0.02	-0.07	-0.60
fin	0.00	-0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
fra	-2.76	0.41	0.95	1.39	0.01	0.01	0.02	0.01	0.03
deu	0.56	0.54	-0.67	-0.52	-0.10	0.06	0.04	0.01	0.08
grc	-0.46	0.44	0.11	0.32	0.02	0.01	0.02	0.03	0.10
gbr	11.68	0.18	-1.42	-2.44	-2.80	-3.76	-0.16	-1.29	0.04
ita	0.42	-0.13	-0.21	-0.08	-0.12	0.00	0.00	0.00	0.00
nld	0.23	0.92	-0.51	0.57	-0.15	-0.75	-0.17	-0.16	0.03
prt	0.03	-0.03	0.00	-0.03	0.00	0.00	0.00	0.00	0.00
esp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
swe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
cze	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
hun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 9 Efficiency gains ($ millions) when moving from "No Trade"(Experiment 1) to "Domestic Emissions Trade" (Experiment 2) (*)

\Sector Region	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	Total
aut	0.0	3.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0	3.7
bel	3.3	2.2	5.4	0.4	0.1	0.0	0.0	0.0	0.0	11.5
dnk	1.1	1.6	0.5	0.8	0.5	0.6	0.0	0.2	1.8	7.5
fin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fra	2.2	3.1	1.0	6.6	0.0	0.0	0.0	0.0	0.0	12.9
deu	0.0	5.7	0.3	0.3	0.0	0.0	0.0	0.0	0.0	6.3
grc	0.2	29.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.8
gbr	8.2	1.2	0.3	0.6	1.0	1.4	0.0	0.5	0.0	13.1
ita	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.2
nld	0.0	12.4	0.5	1.5	0.2	1.3	0.3	0.3	0.1	16.5
prt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
esp	0.2	3.1	0.2	1.5	0.0	0.0	0.0	0.0	0.0	5.0
swe	1.2	13.3	0.2	0.6	0.5	0.1	0.5	0.1	0.0	16.4
cze	0.0	0.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.0
hun	0.0	1.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.2
pol	0.0	1.8	0.2	0.2	0.0	0.0	0.0	0.0	0.0	2.2

(*) Efficiency gain is calculated as -0.5 x (Change in emissions) x (Change in MAC), where the changes will be opposite in directions(except where output effect dominates substitution effect).

Table 10 Percentage change in emissions for period 2005-2007 in Experiment 3 (Regional Emissions Trade)

\Sector Region	Coal	Oil	Gas	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE	Total
aut	-3.9	-0.1	-0.3	-4.0	-0.6	-3.9	-1.7	-5.0	-3.2	-1.9	-3.7	0.8	0.3	-2.0
bel	-2.1	0.0	-1.1	-5.9	-0.3	-6.6	-2.1	-3.5	-1.8	-1.7	-3.3	-1.3	0.1	-2.4
dnk	-1.9	0.0	-3.1	-7.0	-0.3	-41.9	-10.0	-74.6	-53.4	-1.4	-72.5	-65.4	0.6	-6.2
fin	-2.9	0.0	-0.5	-2.8	0.2	1.8	0.6	1.0	0.8	0.3	0.7	0.6	0.2	-1.2
fra	-2.2	0.0	-0.2	-7.0	-0.5	-4.9	-1.4	0.5	0.4	0.0	0.2	0.6	0.0	-1.6
deu	-4.4	0.0	-0.7	-4.4	-0.3	-3.9	-2.5	-3.3	-2.0	-1.3	-2.5	-0.9	0.1	-2.7
grc	-4.4	-0.2	-0.9	-4.4	-0.4	1.3	1.3	-0.9	1.3	0.0	0.4	0.3	0.1	-1.9
gbr	-3.7	0.0	-1.4	-8.2	-0.2	-36.9	-30.4	-73.6	-70.8	-10.6	-72.9	0.5	0.5	-8.7
ita	-2.2	0.0	-0.2	-4.0	-0.3	-4.2	-1.5	-4.6	0.7	0.6	0.7	0.8	0.3	-1.9
nld	-1.7	0.0	-0.2	-4.2	-0.5	-9.2	-1.6	-14.9	-53.9	-30.9	-34.1	-1.1	0.2	-2.2
prt	-2.3	0.0	-1.7	-6.3	-0.3	0.6	-1.9	0.2	0.4	0.1	0.1	0.4	0.1	-2.6
esp	-3.2	0.0	-0.2	-5.7	-0.5	-4.2	-1.4	-2.4	0.3	0.3	0.4	0.1	0.0	-2.4
swe	-2.6	-0.1	-3.9	-5.4	-0.2	-2.1	-1.4	-1.5	-1.9	-1.0	-1.4	-2.4	0.1	-1.6
cze	-4.0	0.1	0.4	-10.6	-0.3	-7.4	-2.7	-4.9	3.0	0.6	3.7	2.4	1.0	-7.4
hun	-4.0	0.0	-0.4	-6.6	-1.0	-5.2	-2.4	-4.9	1.3	0.8	1.3	0.5	0.6	-3.9
pol	-4.3	0.2	-0.1	-8.7	-0.1	-6.6	-4.0	-5.1	5.8	2.5	6.2	3.8	2.0	-6.0

Table 11 Marginal Abatement Cost (\$/t CO_2) in Experiment 3 (Regional Emissions Trade)

\Sector Region	Coal	Oil	Gas	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE
aut	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0
bel	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
dnk	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
fin	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
fra	0.0	0.0	0.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
deu	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
grc	0.0	0.0	0.0	2.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
gbr	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0
ita	0.0	0.0	0.0	2.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
nld	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
prt	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
esp	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
swe	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
cze	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
hun	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0
pol	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0

Table 12 Change in emissions (Million tons of CO_2) when moving from "Domestic Emissions Trade" (Experiment 2) to "Regional Emissions Trade" (Experiment 3)

\Sector Region	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind
aut	0.8	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0
bel	4.2	0.1	1.6	0.5	0.0	0.1	0.1	0.0	0.0
dnk	5.3	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.1
fin	2.8	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
fra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
deu	-4.9	0.0	-0.4	-0.3	-0.1	0.0	0.0	0.0	0.0
grc	1.2	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
gbr	-10.8	0.0	-1.6	-3.9	-0.3	-0.2	-0.1	-0.1	0.0
ita	1.6	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0
nld	2.0	0.1	0.4	0.2	0.1	0.2	0.0	0.1	0.0
prt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
esp	1.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
swe	1.6	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0
cze	-3.6	0.0	-0.5	-0.1	0.0	0.0	0.0	0.0	0.0
hun	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
pol	1.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Table 13 Efficiency gains ($ millions) when moving from "Domestic Emissions Trade" (Experiment 2) to "Regional Emissions Trade" (Experiment 3) (*)

\Sector Region	Elec tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	Total
aut	0.7	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.0
bel	12.6	0.2	4.7	1.6	0.1	0.2	0.2	0.1	0.1	19.8
dnk	10.7	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.2	11.7
fin	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4
fra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
deu	1.3	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.5
grc	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
gbr	6.9	0.0	1.0	2.5	0.2	0.2	0.1	0.1	0.0	10.9
ita	0.5	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6
nld	1.5	0.1	0.3	0.2	0.1	0.1	0.0	0.0	0.0	2.2
prt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
esp	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
swe	5.3	0.1	0.7	0.3	0.3	0.1	0.1	0.0	0.1	6.9
cze	1.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.8
hun	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
pol	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

(*)Efficiency gain is calculated as -0.5 x (Change in emissions) x (Change in MAC), where the changes will be opposite in directions(except where output effect dominates substitution effect).

Table 14 Macroeconomic effects of Domestic and Regional Emission Trading(*)

Region	Real GDP change (%)	Trade Balance due to Emission Trading ($Millions)	Welfare Decomposition: Equivalent Variation (EV) due to various components ($Millions)			
			Allocative effects due to CO2 Tax	Other Allocative effects	Terms of Trade effects	Total(**)
aut	0.10	-2.4	10.5	181.7	-20.4	171.9
bel	0.11	-13.4	43.2	209.5	-127.7	125.2
dnk	0.12	-11.7	33.8	163.8	-10.0	187.1
fin	0.04	-5.7	14.2	35.2	-7.7	37.9
fra	0.05	0.0	31.9	660.2	-85.3	606.0
deu	0.06	11.6	39.7	1155.7	118.0	1312.4
grc	0.33	-2.4	30.6	357.2	-99.5	286.1
gbr	0.02	34.6	-7.7	249.4	14.4	259.1
ita	0.00	-4.1	3.5	-40.8	-13.1	-49.8
nld	0.05	-5.9	21.8	183.5	-377.2	-171.8
prt	0.00	0.1	0.6	1.1	9.2	10.2
esp	0.06	-3.7	9.1	334.6	-68.7	275.9
swe	0.13	-4.4	28.3	264.0	-122.2	174.1
cze	0.05	8.5	-4.3	31.3	-6.9	19.4
hun	0.10	1.5	3.0	49.7	-5.6	47.0
pol	0.02	-2.7	6.9	30.3	11.9	50.1

(*) The values shown in this Table are *changes* from Experiment 1 (No Emissions Trading) to Experiment 3 (Regional Emission Trading).
(**) Including a small effect due to changes in the price of capital goods.

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