The environmental and economic effects of European emissions trading

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Abstract

In this article, we analyse the effects of emissions trading in Europe, with special reference to Germany. We look at the value of the flexibility gained by trading compared to fixed quotas. The analysis is undertaken with a modified version of the GTAP-E model using the latest GTAP version 6 database. It is based on the national allocation plans (NAP) as submitted to and approved by the EU. We find that, in a regional emissions trading scheme, Germany, Great Britain and the 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 and 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, (negative) terms-of-trade effects can offset the (positive) allocative efficiency gains for the cases of the Netherlands and Italy, while all other regions end up with positive net welfare gains. All regions, however, experienced increases in real GDP as a result of regional emissions trading.

Keywords: European emissions trading; Computational general equilibrium; Economic assessment

1. 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 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%, the EU has committed to an 8% reduction.

Compliance with this target, however, is not easy for the EU. Figure 1 depicts the development of the emissions of CO_2 and of all greenhouse gases (GHGs). It shows that although emissions in

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the EU were reduced quite effectively in the first half of the 1990s, this was due to a large extent to the massive breakdown of the economy and the modernization of industries in the former East Germany. Since then, emissions have been fluctuating and, since the end of the 1990s, they have actually been increasing (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 programme was the establishment of a European CO_2 emissions trading scheme (EU ETS) (Babiker et al., 2001, 2002). 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 emissions by creating rights to emissions and to make these rights – which are called allowances – tradable. The scarcity of emission allowances gives them a market value and those emitters whose avoidance costs are lower than the market value of allowances will reduce their emissions and buy fewer certificates or sell excess emissions rights, and vice versa for other emitters.

There is a fundamental difference between the EU ETS and the emissions trading scheme as envisaged under the Kyoto Protocol. In the latter case, emissions trading is to occur between the Parties to the protocol at the level of the States. Under the EU ETS, however, trading is to occur between individual emitters, which comprise 11,428 installations in 25 Member States. There have been other studies which look at the effects of emissions trading in Europe. Böhringer et al. (2004), for example, used a set of 'reduced form' equations which represent marginal abatement costs derived from a general equilibrium model to conduct simulation experiments to analyse the efficiency and equity aspects of different allocation rules for the EU ETS (European Commission, 2001, 2004). In these studies, the approach adopted is often 'partial equilibrium' in nature, which implies that important market interactions (including terms-of-trade effects) are not taken into account.

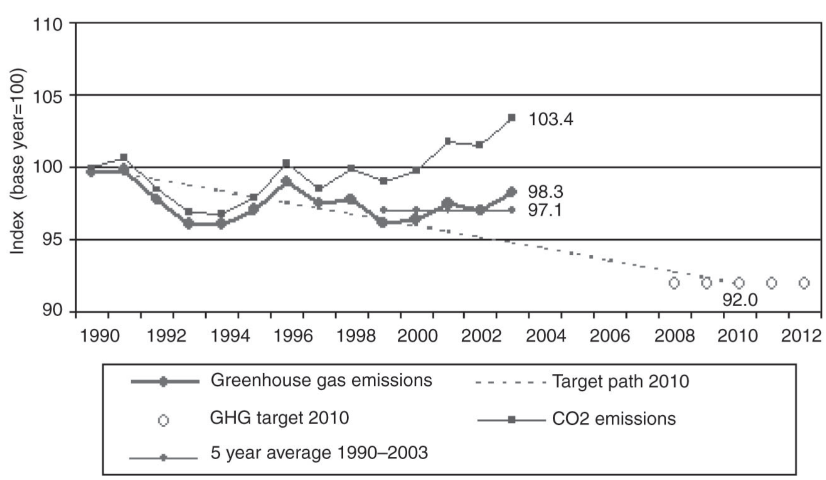

Figure 1. Total EU greenhouse gas emissions in relation to the Kyoto target.
Source: EEA (2005).

In this article we use a general equilibrium multi-sectoral and multi-regional trade model to analyse the effects of the EU ETS and, in particular, examine the cost reduction that may be obtained by the establishment of this trading scheme. Because of the nature of the general equilibrium modelling approach adopted, we can take account of the important interactions between changes in fuel prices, fuel and factor substitution, terms-of-trade effects, and therefore we can evaluate the efficiency and equity aspects of emissions trading in a more realistic fashion than by using partial equilibrium analysis. In fact one of the most important findings of our results is that terms-of-trade effects cannot be ignored, as they can sometimes mask the domestic efficiency aspects.

We conduct three simulation experiments to analyse the effects of the EU ETS. In all experiments, we maintain the same emissions reduction target but each experiment has a different set of rules regarding trading which account for different degrees of trading flexibility. In Experiment 1, fixed quotas are assumed, which do not permit any trading flexibility at all. In Experiment 2, emissions trading is allowed between the sectors within a national economy but not across the national borders. The results of this experiment are to be compared with those of Experiment 3, where emissions trading is allowed also across national borders of the EU Member States. The difference between the results of Experiments 2 and 3 will show the combined efficiency and terms-of-trade gains (or losses) from such emissions trading schemes. In both experiments, we have assumed that the emissions reduction targets have already been fixed at the national Member State level. This means there is to be no further 'optimal adjustment' of these national targets to achieve the same total level of emissions at the EU level.[2]

2. The European emissions trading scheme

The EU ETS started on 1 January 2005. The first trading period – which has been nicknamed the 'warming-up phase' or 'learning phase' – covers the years 2005–2007. The second phase corresponds to the Kyoto period 2008–2012.

The framework for EU ETS has been defined by a Directive in October 2003,[3] which outlines the basic features of the scheme, 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:[4]

– The European ETS is a cap-and-trade system; i.e. the absolute quantity of emission rights (rather than relative or specific emissions) is fixed at the beginning.
– Only one of the six greenhouse gases of the Kyoto Protocol (CO_2) is 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.
– The EU ETS is implemented as a *downstream* system; i.e. the users (rather than the producers and importers of fossil fuels) will be obliged to hold emission allowances.[5]

This has some fundamental consequences. All users of fossil fuels which are covered by the ETS have to be monitored and can participate actively in the trading system. In order to limit the administrative costs of the ETS, the system is 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 subjected 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 and ceramic production)
– Pulp and paper.

The thresholds refer to the production capacity of the installation, e.g. in the case of combustion installations these are 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 which can only be avoided if the total quantities of allowances are set at a level which equalizes the marginal avoidance costs between the emissions trading sector and other emitters. This, however, is unlikely to be the case because the marginal avoidance costs of these emitters are not known.

– Allowances are issued by each Member State, but trading can take place between any EU participants.
– The so-called 'linking Directive' will allow participants in emissions trading to count credits from Clean Development Mechanism and Joint Implementation emission reduction projects around the world toward their obligations under the European Union's emissions trading scheme, even if the Kyoto 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 have made strong lobbying efforts to ensure that emissions trading will not impair their competitive position. This has 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 set down in a national allocation plan (NAP).

3. Quantitative impact assessment

3.1. Model, data, and description of experiments

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) (see Figure 2). The model uses version 6 of the GTAP database, which consists of 57 commodities/sectors and 87 regions including the 25 European Member states (Dimaranan and McDougall, 2006). The regional and sectoral aggregation used for this study is shown in Table 1. It includes most of the EU Member States except for those States with small allocations.[6]

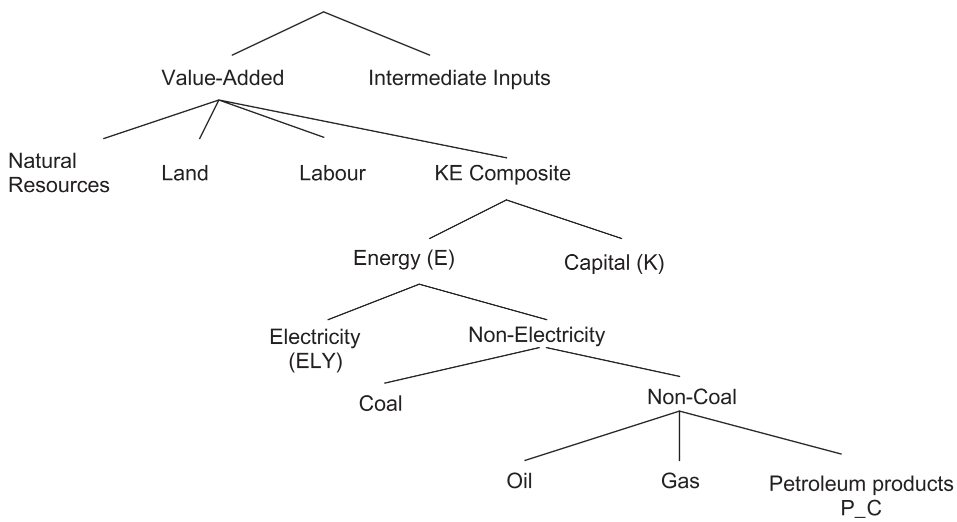

Figure 2. Standard GTAP-E production structure.

Table 1. Categorization of regions/countries and sectors

Regions/ Countries	Description	Sectors	Description
aut	Austria	Coal	Coal mining
bel	Belgium	Oil	Crude oil
dnk	Denmark	Gas	Natural gas extraction
fin	Finland	Electricity	Electricity
fra	France	Oil_Pcts	Refined oil products
deu	Germany	Metals	Metals products
grc	Greece	Min_Prod	Mineral products
gbr	Great Britain	Paper	Paper
ita	Italy	Motor_Equip	Motor machine & equipment
nld	Netherlands	Constr	Construction
prt	Portugal	Textile	Textile
esp	Spain	Oth_Ind	Other industries
swe	Sweden	ROE	Rest of the economy
cze	Czech Republic		
hun	Hungary		
pol	Poland		
REU	Rest of European Union		
CHIND	China and India		
JPN	Japan		
USA	United States of America		
RoW	Rest of the World		

The percentage differences between the CO_2 emissions in the reference case and the allocation of allowances in the respective NAPs for the various sectors in the period 2005–2007 are shown in Table 2.

These data have been derived from the information available in the NAPs.[7] Most countries made projections of emissions in a 'business-as-usual' (BAU) scenario. In these cases, percentage changes have been derived from the projected emissions and the allowances allocated to the sectors by the NAPs for this period.

For Germany, a different procedure was applied, as there are no data available either on historical or on projected emissions of the ET sector. Therefore, reference emissions were calculated from the quantity of allocated allowances, taking into account the allocation rules of the German NAP.[8] As a basic rule, the allocation to installations commissioned before 2003 is based on historical emissions in the base period (usually 2000–2002). The quantity of the allowances is determined by multiplying the historical emissions data by compliance factors which are necessary to balance the Macroplan with the Microplan. In some cases more generous rules could be applied, e.g. for 'early action',[9] CHP plants or process-related emissions.[10] Moreover, hardship provisions could be applied to compensate for economic burdens. As a consequence, a compliance factor between 0.926 and 1.00 was applied to base-period emissions. New entrants (including extensions of existing installations) obtain free allowances based on the production capacity and a product-specific benchmark.[11] For them, a compliance factor of 1.00 was applied. From the number of allowances allocated by the diverse rules, the reference emissions were calculated by applying the reverse compliance factors.

The Directive does not refer to economic sectors, but rather to activities. Only installations belonging to one of four broad activities and which exceed a sector-specific threshold are subject to emissions trading.

Table 2. Percentage deviation of emissions from projected level for period 2005–2007 according to the NAP(*)

Sector/ Region	Electricity	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	–1.0	–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

Three of the ‘activities’ (production and processing of ferrous metals, mineral industry, pulp and paper) correspond (more or less) to economic sectors. The fourth category, energy activities, however, may be undertaken by any sector. Due to the threshold of a rated thermal input exceeding 20 MW, installations of this type are concentrated in electricity generation and manufacturing. Some large installations (e.g. hospitals with CHP plants above 20 MW, which are subject to ET too) belong to other sectors. Often, NAPs do not contain sectoral information on projected and allocated emissions. If no information was available, we assumed uniform percentage shocks to all ET sectors.

From Table 2, we can see 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 that 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 within the model. The resulting emissions will then be positive but often less than the actual NAP allocations (see results in Table 3).

Table 3. Percentage change in emissions for period 2005–2007 in various experiments

Sector/ Region	Coal	Oil	Gas	Elec- tricity	Oil_ Pcts	Met- als	Min_ Prod	Pap- er	Motor Equip	Con- str	Tex- tile	Oth_ Ind	ROE	To- tal
Experiment 1 (No emissions trade)														
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	
Experiment 2 (Domestic emissions trade)														
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

Table 3. Percentage change in emissions for period 2005–2007 in various experiments *(Cont'd)*

Sector/ Region	Coal	Oil	Gas	Electricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE	Total
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
Experiment 3 (Regional emissions trade)														
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

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. This means that their emissions levels will be determined endogenously within the model, according to the production and relative price relationships between these sectors and the NAP sectors. In general, we may expect a positive increase in emissions from these non-NAP sectors, which represents a 'leakage' of emissions from NAP to non-NAP sectors.[12]

We carried out three experiments. In Experiment 1 ('No trading'), we shock the emissions of each designated trading sector of each region by the projected percentage change 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 Table 4. All costs are reported in 1995US$.

Table 4. Marginal abatement cost (tCO_2$) in various experiments

Sector/ Region	Coal	Oil	Gas	Electri- city	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE
Experiment 1 (No emissions trade)													
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
Experiment 2 (Domestic emissions trade)													
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

Table 4. Marginal abatement cost (tCO_2$) in various experiments *(Cont'd)*

Sector/ Region	Coal	Oil	Gas	Elec-tricity	Oil_ Pcts	Metals	Min_ Prod	Paper	Motor Equip	Constr	Textile	Oth_ Ind	ROE
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
Experiment 3 (Regional emissions trade)													
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

4. Results

Table 3 shows the percentage changes in emissions for all sectors and regions in Experiment 1 (No emissions trading). For the sectors subjected to the NAP, these are the same as in Table 2 (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 these sectors. Table 4 shows the estimated MACs for the NAP sectors in this case of no emissions trading (Expt 1). These estimated MACs can range from a very low figure of less than a dollar per tonne 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, mostly in the oil refining sector, reflect 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).

Tables 3 and 4 also show the results for Experiment 2. In this experiment, emissions trading is allowed but only between the sectors, and no trading occurs between the regions. The MACs in this case are now uniform for a given region but vary across different regions. They 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 Sweden (swe).

From Table 3, we can observe that some sectors will show positive changes in emissions levels when moving from Experiment 1 to Experiment 2. This indicates a 'buying sector'; i.e. one which buys the permits for the extra emissions from those sectors with negative changes in emissions. The 'buying sectors' are those with high MACs, which will acquire more permits to increase their emissions rather than incurring a higher MAC to reduce their emissions. The reverse is true for the sectors with low MACs. Both, however, will gain from emissions trading. These gains are measured (approximately) by the 'efficiency triangle' bordered by the changes in emissions quantities and prices, i.e. by 0.5 × (Change in emissions) × (Change in MAC). The change in emissions and change in MAC are normally opposite in direction except for those cases where the output effect may dominate the price or substitution effect. When we estimate the efficiency gains for regions when moving from the 'No trading' to the 'Domestic sectoral trading' experiments, we find that regions that gain the most from domestic emissions trading are those which have large variations in MACs across the trading sectors (and also large target reductions in emissions). Those regions are: Greece (grc) followed by the Netherlands (nld), Sweden (swe), France (frc) and Great Britain (gbr). Germany (deu) and Spain (esp) only gain moderately from domestic emissions trading.[13]

Results for Experiment 3 are also shown in Tables 3–4. In Experiment 3, emissions trading is allowed to take place not only between the sectors but also between regions. The MAC in this case (\$2/tCO_2) is uniform not only across NAP sectors but also across trading regions. The small figure of MAC reflects the non-ambitious nature of the NAPs in the existing EU ETS.[14] From Table 3, it can be seen that the regions with positive changes in emissions levels between Experiment 2 and Experiment 3 are: Austria, Belgium, Denmark, Finland, Greece, Italy, The Netherlands, Spain, Sweden and Poland. These represent '(permit) buying regions', while regions with negative changes (Germany, Great Britain, the Czech Republic, Hungary) are 'selling regions'. The buying regions are those with relatively high MACs. All regions will gain in efficiency from emissions trading, however. The gains are generally smaller when we move from Experiment 2 to Experiment 3, as compared to the gains when we move from Experiment 1 to Experiment 2. This implies that the differences in MACs across different EU ETS regions are generally smaller than the differences in MACs across the trading sectors within these regions. The gains are also seen to be larger for Belgium, Denmark, Great Britain, Finland and Sweden, which reflects the fact that variations in MACs between these regions are greater when compared to other regions.

Finally, Table 5 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 5). The effects of emissions trading will bring about some positive trade balance for some regions (Great Britain, Germany and the Czech Republic – see second column of Table 5), and a negative trade balance for others (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 5) 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 5). This implies that even though the combined welfare effects of emissions trading for all NAP regions as a whole is positive, the distribution of these welfare gains across the regions may result in some regions having a net welfare loss (the Netherlands and Italy) rather than a welfare gain from emissions trading.

Table 5. Macroeconomic effects of domestic and regional emissions trading(*)

Region	Real GDP change (%)	Trade balance due to emissions trading ($millions)	Welfare decomposition: equivalent variation (ev) due to various components ($millions)			
			Allocative effects due to CO_2 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 emissions trading).
(**) Including a small effect due to changes in the price of capital goods.

5. Conclusions

Our study has shown that emissions trading is an important policy instrument to achieve a particular climate policy objective such as the fulfilment of the Kyoto obligations by the EU at minimum costs. The use of this ‘flexible’ policy instrument is seen to result in significant efficiency gains, measured either in terms of the reduction in marginal abatement costs or in terms of the efficiency gains for both (permit) buying and selling sectors. For buying sectors (those with high MACs without trading), the efficiency gains represent reductions in overall compliance costs. For selling sectors (those with low MACs without trading), increases in income from emission trading overcompensate additional abatement costs. As a result, real GDP is seen to increase for all regions. However, the efficiency gains in some cases may not be sufficient to offset the losses in revenue due to emissions trading (emissions permit purchasing); hence some regions may still experience a net welfare loss. For these regions, a net welfare loss implies a negative change in net national income even if there is a positive change in gross domestic product. This uneven distribution of the total welfare gains (income from emissions trading) across regions may warrant some attention being given to the initial distribution of the burden of emissions reductions across regions.

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Notes

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.
2 In terms of the Böhringer et al. (2004) experiments, we do not consider the scenario of 'NAP_Opt', where national allocation plans (NAPs) are coordinated between EU Member States to exploit the full potential of efficiency gains from 'where-flexibility'. This is because we want to focus attention on the existing nature of the NAPs rather than on the issue of optimal allocation between Member States, which is beyond the scope of this article and can be left for a future study.
3 Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 (EC, 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.
4 For a more detailed description and good discussions of the ETS see Kruger and Pizer (2004).
5 This means that the oil refining (Oil_Pcts) sector has to hold allowances, but only for their own emissions and not the emissions which are 'incorporated' in their product.
6 These are aggregated into a single 'Rest of European Union' (REU) region (see Table 1).
7 For an overview of the NAPs, see DEHSt (2005b).
8 Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2004): National Allocation Plan for the Federal Republic of Germany 2005–2007. Berlin, 31 March 2004. For an overview of the German allocation see DEHSt (2005a).
9 This rule applies to installations which have been modernized or newly built between 1994 and 2002 and which demonstrated a predefined reduction in emissions.
10 Process-related emissions are defined as the atmospheric release of CO_2 resulting from a chemical reaction other than combustion.
11 Operators of an existing installation can opt to be allocated allowances on the basis of their production capacity and the benchmark for new installations as well (option rule).
12 The alternative is to impose some emission restrictions on these non-NAP sectors, but this will require some price mechanisms (such as carbon tax). Given that most NAPs are unclear with respect to these mechanisms for the non-trading sectors, it was decided that for the purpose of our illustrative experiments, the non-trading sectors are subjected to no restrictions. This will allow a main focus on the trading sectors.
13 The results on efficiency gains are not shown in the article, but are available from Tables A and B, accessible via the Internet.
14 However, in Germany we currently observe much higher prices which do not seem to reflect market prices. An oligopolistic market situation, high fuel prices and market uncertainties seem to drive the prices above the competitive market price.

References

Babiker, M., Viguier, L., Reilly, J., Ellerman, D., Criqui, P., 2001. The Welfare Costs of Hybrid Carbon Policies in the European Union. MIT Report 74.

Babiker, M., Reilly J., Viguier L., 2002. Is International Emissions Trading Always Beneficial? MIT Report 93.

Böhringer, C., Hoffmann, T., Lange, A., Löschel, A., Moslener, U., 2004. Assessing Emission Allocation in Europe: An Interactive Simulation Approach. Discussion Paper No. 04-40.

Burniaux, J.M., Truong, P.T., 2002. GTAP-E: An Energy-Environmental Version of the GTAP Model. GTAP Technical Paper No. 16 (revised), January.

DEHSt [German Emissions Trading Authority], 2005a. Emissions Trading in Germany: Allocation of Allowances for the first Commitment Period 2005–2007. 2nd edition: 28.02.2005 [available at http://www.dehst.de/cln_007/nn_76354/SharedDocs/Downloads/EN/e__Zuteilung/Allocation__of__Allowances,templateId=raw,property=publicationFile.pdf/Allocation_of_Allowances].

DEHSt [German Emissions Trading Authority], 2005b. Implementation of Emissions Trading in the EU: National Allocation Plans of all EU States, in cooperation with the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe and the Öko-Institut, Berlin [available at http://www.dehst.de/cln_007/nn_593634/SharedDocs/Downloads/EN/ETS/EU__NAP__Vergleich,templateId=raw,property=publicationFile.pdf/EU_NAP_Vergleich].

Dimaranan, B.V., McDougall, R.A. (Eds), 2006. Global Trade, Assistance, and Production: The GTAP 6 Database. Center for Global Trade Analysis, Purdue University [available at https://www.gtap.agecon.purdue.edu/databases/v6/v6_doco.asp].

EC [European Commission], 2001. Proposal for a Directive of the European Parliament and the Council establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, COM (2001) 581 final. Commission of the European Communities, Brussels.

EC [European Commission], 2003. 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.

EC [European Commission], 2004. Emissions trading: National allocation plans. Final national allocation plans and available drafts of national allocation plans. [Available at http://europa.eu.int/comm/environment/climat/emission_plans.htm].

EEA [European Environment Agency], 2005. Annual European Community greenhouse gas inventory 1990–2003 and inventory report 2005. Revised final version, 27.05.2005 [available at http://reports.eea.eu.int/technical_report_2005_4/en].

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2004. National Allocation Plan for the Federal Republic of Germany 2005–2007. Berlin, 31.03.2004, Translation: 07.05.2004 [available at http://www.bmu.de/files/pdfs/allgemein/application/pdf/nap_kabi_en.pdf].

Hertel, T.W. (Ed.), 1997. Global Trade Analysis: Modeling and Applications. Cambridge, Cambridge University Press.

Kruger, J., Pizer, W.A., 2004. The EU emissions trading directive: opportunities and potential pitfalls. Resources for the Future. Discussion Paper 04–24.

Table A. Efficiency gains ($ millions) when moving from 'No trade'(Experiment 1) to 'Domestic emissions trade' (Experiment 2) (*)

Sector/ Region	Electricity	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 × (Change in emissions) × (Change in MAC), where the changes will be opposite in directions (except where the output effect dominates the substitution effect).

Table B. Efficiency gains ($ millions) when moving from 'Domestic emissions trade' (Experiment 2) to 'Regional emissions trade' (Experiment 3) (*)

Sector/ Region	Electricity	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 × (Change in emissions) × (Change in MAC), where the changes will be opposite in directions (except where the output effect dominates the substitution effect).