Opt-in of the agricultural sector to the European trading scheme for greenhouse gas emissions – a proposal and its possible effects

Teilnahme des Agrarsektors am europäischen Emissionshandelssystem für Treibhausgase – ein Vorschlag und mögliche Auswirkungen

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Abstract

In light of international discussions on a possible opt-in of the agricultural sector to the current European emission trading system for greenhouse gases, the objective of this article is to present a feasible implementation strategy for a market of emission permits in European agriculture and to simulate its economic effects within the regionalised agricultural sector model CAPRI. With this purpose, we compare the effects of a 15% reduction of greenhouse gas emissions from European agriculture with and without a trading scheme. Our findings suggest that if significant emission abatement is to be achieved in the agricultural sector, efficiency gains from expanding the current emission trading scheme to this sector can be appreciable. An additional finding of this paper is that under the current protective measures in the CAP and in the absence of a successful WTO reform round, emission reduction does not result in a net income loss for the agricultural sector due to the 'quota effect' caused by the isolation of European agricultural markets from world markets.

Key words

climate gas emissions; emission trading; abatement costs; agricultural policy; modelling

Zusammenfassung

Vor dem Hintergrund der für den europäischen Emissionshandel für Treibhausgase vorgesehenen Opt-in-Möglichkeit für andere Sektoren stellen wir in diesem Beitrag ein mögliches Emissionshandelssystem im Bereich der Landwirtschaft vor und simulieren die damit zusammenhängenden ökonomischen Effekte mit Hilfe des regionalisierten Agrarsektormodels CAPRI. Wir vergleichen die Effekte einer 15% Verringerung der Emissionen aus der Landwirtschaft mit und ohne ein Emissionshandelssystem. Unsere Ergebnisse weisen auf erhebliche Emissionsgewinne hin, die durch einen Emissionshandel realisiert werden können, wenn ein ehrgeiziges Emissionsvermeidungsziel verfolgt wird. Wir zeigen aber auch, dass unter der immer noch existierende Marktabschottung in der GAP Emissionsreduktionsmaßnahmen nicht zu einem Nettoeinkommensverlust im landwirtschaftlichen Sektor führen.

Schlüsselwörter

Treibhausgase; Emissionshandel; Vermeidungskosten; Agrarpolitik; Modellierung

1. Introduction

In December 2002, the Kyoto Protocol (KP) was formally approved by the European Union (COUNCIL OF THE EUROPEAN UNION, 2002). This decision was an important step towards taking action. Member states committed themselves to establishing a 'European emission bubble' (provided for in Article 4 of the KP) whereby the obligations contained in the KP for the EU were considered to be 'internal law' (Article 3). In order to deliver on this commitment, the European Union was allowed to formulate an internal 'burden-sharing agreement' (BSA) to enable member states to combine their efforts towards the achievement of an overall emission abatement objective.[1] This decision led to the signature in 2003 of the 'emission trading directive' (COUNCIL OF THE EUROPEAN UNION, 2003). This directive established a scheme for trading greenhouse gas (GHG) emission allowances within the EU in an effort to promote emission reductions in a cost-effective and economically efficient manner (Article 1). The following aspects can be briefly highlighted:

- It applies to a list of energy and industrial production activities and covers all GHGs included in Annex A to the KP. Nevertheless, according to the categories of polluting activities defined in Annex 1 to this directive, only CO_2 emissions are currently covered by the scheme.
- It defines a coordinated Emission Trading Scheme (ETS) across all member states.
- It provides for an implicit voluntary opt-in for other sectors through possible amendments (Article 30). Whereas trading is first applied only to industrial and energy-producing activities, other sectors might be included in the future *with a view to further improving the economic efficiency of the scheme.*

[1] The approval of the BSA by the member states reflects the 'principle of subsidiarity' in the Community, i.e. individual emission reduction objectives should be *achievable* for each country and avoid *unduly burdening* ongoing industrialisation efforts by member states. The Council agreed to the contributions of each member state to the overall 8% reduction commitment at its meeting of Environment Ministers on 15-16 June 1998 in Cardiff (COMMISSION OF THE EUROPEAN COMMUNITIES, 2001: 3). The Council Conclusions set out the commitment of each member state and assert that the terms of this agreement will be included in the Council Decision on the approval of the Protocol by the European Community.

Trade in emission allowances has already been implemented in Europe for other problems, partly within agriculture. Examples are fish catch quotas (Common Fisheries Policy) and milk production quotas (Common Agricultural Policy). In all these cases, a certain degree of transferability has been introduced (COMMISSION OF THE EUROPEAN COMMUNITIES, 1992). Including agriculture in an emission trading scheme is an option that is also discussed in Australia and Canada (AUSTRALIAN GOVERNMENT, 2007; CLIMATE CHANGE CENTRAL, 2002).

Against this background, the objective of this study is to design a feasible implementation strategy for a market of emission permits in European agriculture and to simulate its economic effects within the regionalised agricultural sector model CAPRI.[2] The proposed emission trading system (ETS) is intended to be in line with the current legislation, mainly the above-mentioned 2003/87/EC emission trading directive. Since a feasible system must build on information that is easy to obtain, regional inventories for GHG emissions from agricultural sources in the year 2001 have been calculated on the basis of IPCC emission factors and activity data from public European statistics.

For our calculations we assume a 15% reduction goal for agriculture in 2001 (see 'efficiency model' in the following sections) and compare two scenarios: (a) 15% emission reduction in each member state and (b) 15% emission reduction for European agriculture and a Europe-wide emission trading scheme.[3] This allows us to assess the marginal abatement cost for agriculture, taking explicit account of the Common Agricultural Policy (CAP) and price feedback from agricultural markets in the rest of the world. It also allows us to estimate possible gains from trade and identify the winners and losers of integrating agriculture into the European ETS. Since no official documents have been produced to date, including recommendations on specific emission reduction targets for agriculture, the rather ambitious goal of 15% is chosen in this modelling exercise. This should help to make the effect of emission trading clear and visible. Moreover, smaller reduction goals below 10% would show the same trend (static model) but to a much lesser extent (see PEREZ, 2003).

The article is structured as follows: In the following section 2 we explain the approach taken to estimate marginal abatement costs. Section 3 describes the assumptions concerning the trading scheme and section 4 presents efficiency results with prices kept constant. In section 5 prices are endogenous and income and welfare effects are deduced. A discussion of the results in section 6 completes the contribution.

2. Calculating abatement costs

GHG emission abatement costs are considered '*economic costs (in terms of income losses) faced by producers by complying with an emission abatement objective'*. We assume that emissions of agricultural producers can be calculated by coupling GHG emissions to all agricultural activities (using an accounting system where weights per activity are included through the IPCC emission factors). Thus, the only way of emission reduction open to producers is a change in the level or intensity of their different activities. This would firstly imply restructuring all production processes at farm level, meaning that activities with a lower contribution to farm income per emission unit (low revenue per tonne of CO_2^{eq}) would be more likely to be affected in terms of production reduction than 'emission-efficient' activities (high revenue per tonne of CO_2^{eq}). Secondly, variations in production intensity could also appear through increasing or decreasing yields. Abatement costs and the production and economic effects of emission abatement therefore depend on the exact definition of emission quantities per activity.

Existing modelling approaches

Several economic models have covered the analysis of GHG emissions in agriculture, e.g. the ASMGHG and AROPAj models (DE CARA and JAYET, 2001; SCHNEIDER, 2000). Both are based on *direct* modelling of carbon prices. In the optimisation problem, emissions are taxed at a price that is entered as an additional input cost in the objective function. By varying this carbon price iteratively a different abatement response is achieved at the optimum, thus generating a marginal abatement cost (MAC) curve as a succession of equilibrium points. Usually, polluters are assumed to face a uniform emission tax, meaning that the modelling response is different for each of them. Nevertheless, price differentiation between polluters would also be possible.

We will use an alternative approach, including emission restrictions directly in the optimisation problem. Outside agriculture this approach has been used by the models EPPA and RAINS for industry.[4] Marginal abatement costs are approximated by the shadow values of the emission abatement constraints. Normally, this emission restriction is considered to be equal across polluters and expressed as a percentage of emissions in a reference period. This option results in different MACs for polluters that face a similar abatement target. MAC curves can thus be constructed by changing the emission abatement levels iteratively and storing the shadow values.

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2 In this section farms, agricultural firms and regions might be used indistinctly in certain theoretical explanations. It is important to note that, in the model, Nuts 2 regions and not agricultural firms are the agents interacting in the market of emissions. However, each region is a consistent aggregation of individual farms so that the assumed behavioural response is the same. More details on the CAPRI models can be found in BRITZ, 2005.

3 The reader might pay attention to the fact that this emission reduction objective is set up for year 2001 and not for 1990 (baseline for the negotiations of the Kyoto protocol), so that emission reductions achieved until that year are not considered in the current analysis (e.g. de-industrialisation process in Eastern Germany).

4 The EPPA Model was developed within the Joint Programme on the Science and Policy of Global Change at the Massachusetts Institute of Technology (see PALTSEV et al., 2005). For a regional analysis in the EU a version called EPPA-EU is derived.
The Regional Air Pollution Information and Simulation model (RAINS) and its application to the estimation of GHG emissions (GAINS) is owned by the International Institute for Applied Systems Analysis (IIASA) and provides a consistent framework for the analysis of mitigation strategies for air pollutants (see WAGNER et al., 2006).

Table 1. Restrictions in the supply model

Restrictions	Crop activities	Animal Activities
Coverage of animal requirements (animal requirement minus delivery in feedingstuff) - fibre, dry matter - energy, crude protein		 < 0 = 0
Dry matter intake (corrected dry matter intake minus delivery of dry matter in feedingstuff) - maximum share - minimum share		 > 0 = 0
Minimum nutrient need covered by synthetic fertilizer (corrected nutrient need minus import of mineral fertilizer)	<,= 0	
Area for crop production	= total arable land	
Area for pastures and grazings	= total grassland	
Set Aside (obligatory, minimum and maximum)	=, > or <policy objective	
Quotas (milk and sugar)	<,= quota	
GHG emission abatement (methane and nitrous oxide)	<,= policy objective	<,= policy objective

This approach has the following advantages: (1) it allows direct modelling of emission standards at regional level, (2) it offers a more straightforward interpretation of results, since emission abatement is considered as a binding restriction and not as an input cost, and (3) it produces the necessary input data for further analysis on market-based abatement instruments with explicit consideration of transaction costs. The inclusion of emission constraints can, however, be more problematic from a technical perspective since it implies a more complicated algorithm than the direct modelling of carbon prices through the derivation of the Lagrange function.[5]

MACs are crucially influenced by production constraints built into the model. In the following table the different restrictions included in the supply module of CAPRI are listed. For each of them, a shadow value is generated in the optimisation process (zero if not binding).

These restrictions have to be fulfilled at every equilibrium point. As an example, the introduction of an emission abatement target in a region where the constraint on 'minimum nutrient need covered by synthetic fertiliser' is binding might lead to a depreciation of manure and indirectly to a drop in animal production, since (1) manure is only applied to ensure that the minimum application rate for mineral fertiliser is fulfilled and (2) crop activities making use of this minimum fertiliser amount have to remain in the regional production programme.[6] In general, at the market clearing equilibrium point regional MACs will be higher if restrictions are binding compared to a counterfactual situation of no binding constraints.

3. Modelling marginal abatement cost curves and emission trading in CAPRI

When constructing abatement cost curves we consider all greenhouse gases according to their global warming weights, i.e. carbon dioxide equivalents, as measurement units. By doing this, a uniform abatement policy can be modelled, all gases and sources being affected at the same time. MAC curves are constructed so that each point of the curve represents the implementation of a single regional emission standard in the base year situation (2001 emissions). Economically optimal adjustment in the regional models to the singular emission targets is achieved through production substitution and shifts in yields. Since the model is calibrated to an observed regional production mix in the base year, the optimum can only be reached through expansion or contraction of these endogenous production activities if the emission abatement goal and the rest of the restrictions in the model are to be met.

Although the Kyoto Protocol prescribes emission reductions with respect to 1990 values, this base year is not chosen in the current approach for two reasons: (1) no information gain is achieved for the calculation of MAC curves or technical comparison between abatement instruments and (2) for the agricultural sector less reliable information would be obtainable since the complete Economic Accounts of Agriculture from EUROSTAT (economic information for agricultural activities) are only available from 1994 onwards. Instead, emission abatement is calculated in comparison to a situation (three-year average around 2001) where the Agenda 2000 policy reform was fully implemented.

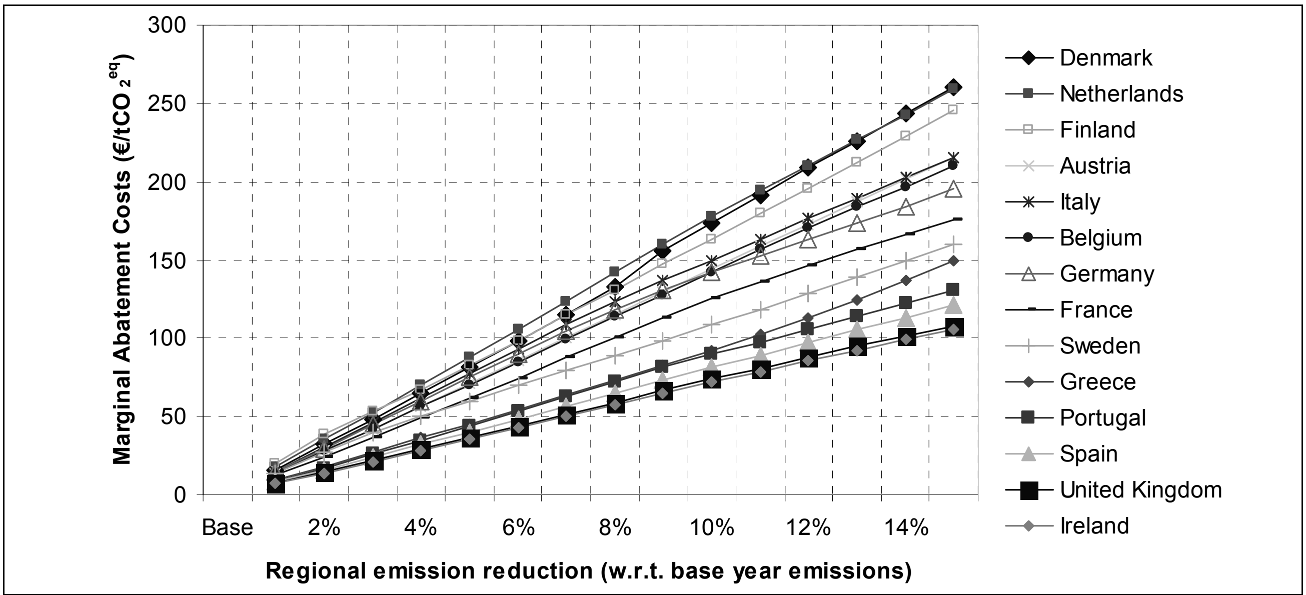
Figure 1 presents MAC (marginal abatement cost) curves for EU-15 member states. To calculate it, the model was iteratively solved for single Nuts 2[7] regions (15 iterations)

5 In the current modelling approach several systematic infeasibilities due to the violation of neighbour restrictions were observed for high emission abatement targets. Nevertheless, this problem does not affect the current application since it remains within feasible bounds.

6 A minimum share of mineral fertiliser out of total fertiliser need is introduced in order to calibrate the model to the fertiliser consumption statistics published by FAOSTAT.

7 In the CAPRI model, Nuts 2 regions are the lowest disaggregated level, meaning that a region stands for an "average regional farmer".

Figure 1. Marginal abatement cost curves for EU-15 member states



Source: own calculations; modification of PEREZ, 2003; year 2001; Luxembourg is modelled together with Belgium

and regional results were aggregated.[8] In the last step, a 15% reduction is achieved.[9]

For a 15% emission reduction, MACs vary between €105 for Ireland and €259 for the Netherlands, at an average of €171.3. Member states such as Denmark and the Netherlands have noticeably higher estimated MACs than the rest. This is due to their specialisation in intensive crop production, with high mineral fertiliser application per hectare together with high yield cattle production processes. The United Kingdom, Ireland, Spain and Portugal are able to contribute to the uniform emission standard at rather low costs. Crop production in UK and Ireland falls less sharply than in other countries as lower fertiliser application rates and higher income per emission unit are observed. The differences found in the course of MAC curves for Nuts 2 regions in Europe underline the fact that a 'non-uniform' emission abatement strategy might be profitable in agriculture. This could be achieved by the introduction of market-based abatement instruments that can differentiate between abatement possibilities in each region.

The information on MACs is applied to the explicit modelling of tradable emission permits within the CAPRI model. For this purpose, an emission trading module with the following characteristics is introduced: (1) cap and trade system, (2) 'grandfathering' of permits, (3) unrestricted trade between Nuts 2 regions and (4) direct modelling of transaction costs. This 'emission-capping' approach allows direct comparison with the results obtained above from the application of uniform emission standards.

In a grandfathering scheme, agricultural producers would obtain, based on historical records, the 'right' to release a certain amount of GHG emissions.[10] The number of permits needed in the reference period would depend on various factors: the production mix, the technology chosen (e.g. production intensity), and specific emission factors depending on the geographical situation (climate region) and type of management system selected. To calculate the total number of credits, activity levels (defined by production mix and technology) are multiplied by their corresponding regional specific emission factors according to IPCC international standards (IPCC, 1997). The accounting process mimics the calculation of national GHG inventories and is therefore consistent with the KP reporting obligations. The additional administrative burden for agricultural firms would be relatively low, as these data are already needed when asking for direct income support or calculating nutrient balances at farm level. In the initial situation, an 'accounting card' would provide the regulatory institution with the necessary information to allocate emission credits to agricultural producers (*issuing of permits*). In our case, the share of historical emissions is set at 85% of 2001 emissions.

The *Green Paper on emission trading* contemplated the possibility of implementing a market of permits at member state level (decentralised approach) or at EU level, member states trading with each other (COMMISSION OF THE EUROPEAN COMMUNITIES, 2000). For the European agricultural sector, a further disaggregation level is proposed in this study and producers are chosen as agents in the market of permits. This approach would be readily applicable to the European agricultural sector since similar EU-wide policy schemes have been largely implemented within the current Common Agricultural Policy and information at farm and

8 For the aggregation of shadow values or, in general, prices at an upper regional level, GHG emissions are used as weights: sum of all shadow values of the sub-regional models in a region multiplied by its CO_2^{eq} emissions divided by total CO_2^{eq} emissions in this region. As already mentioned, the minimum regional unit used in the model is the EUROSTAT Nuts 2 definition.

9 Note that a 15% abatement target is equivalent to an 85% emission standard. These two concepts are used indistinctly in this and the following chapters.

10 As already mentioned in the Green Paper (COMMISSION OF THE EUROPEAN COMMUNITIES, 1992: 9), emissions are linked to sources and are also reported by countries to the UNFCCC. Agricultural firms have several emission sources and thus a market of emissions could also be extended to them (usually only a certain number of activities are covered by a source).

regional level systematically collected (e.g. nitrate directive or milk quotas). Therefore, we model a system of inter-regional trade that already assumes that emission reduction within regions is undertaken cost-efficiently.

Emission restrictions would be technically incorporated as a quota system on all 'polluting' agricultural activities. Agricultural producers would therefore be allowed to trade allowances with each other in order to minimise their income losses.

Transaction costs are costs that arise from initiating and completing transactions, such as finding partners, holding negotiations, consulting with lawyers or other experts, monitoring agreements, etc. (COASE, 1937). These costs have to be acknowledged in an ETS since there is a continuous transfer of property rights in such a market. Table 2 lists the typical transaction cost components found in a KP emission trading mechanism:

Table 2. Definition of transaction cost components linked to the Kyoto Protocol emission trading scheme

a) Search costs	b) Costs incurred by investors and hosts as they seek out partners for mutually advantageous projects (e.g. market brokerage fees)
c) Negotiating costs	d) Includes costs incurred in the preparation of the market (e.g. legal and insurance fees charged for participation in the market)
e) Monitoring costs	f) Costs needed to ensure that participants are fulfilling their obligations (e.g. costs of annual verification)
g) Enforcement costs	h) Costs of administrative and legal measures incurred in the event of departure from the agreed transaction

Source: modification of ECKERMANN et al., 2003: 2, based on PRICE WATERHOUSE COOPERS, 2000

Emission trading also requires the formation of the *necessary institutions*. This is naturally linked to the presence of 'non-negligible' transaction costs, an important issue that has often not been taken into account in policy simulations and might have a significant effect on trading (KERR and MARE, 1995: 23; STAVINS, 1995: 144). The directive on emission trading does not include any reference to this issue.

A feasible solution for an emission trading market in agriculture could be based on a central database listing all permit holders in the scheme and their current permit endowment. An internet portal and a call centre would be required to manage permit transactions. We propose internalising the transaction costs arising from such a system. The proposed approach is based on stock market trading, *costs being paid 'per transaction' in additional to the permit price*. This issue is considered to be important in the current analysis for the sustainability of the scheme to be correctly evaluated.

Transaction costs can be derived from different estimates found in the literature for similar emission abatement projects.[11] Compared to a situation without transaction costs, purchase costs for permit buyers would rise and the trade volume decrease. Consequently, a uniform permit price equal to the average MAC across firms would not be achieved (ECKERMANN et al., 2003: 3). This issue is further analysed in the following section.

To summarise, the proposed ETS for European agriculture considers: (1) distribution among agricultural producers of permits free of charge and linked to historical emission records *(grandfathering),* (2) inter-regional emission trading at European level, (3) explicit transaction costs and (4) no enforcement penalties.

Modelling of tradable emission permits has been implemented in the CAPRI model in a separate module since a simultaneous solution for all Nuts 2 regions was technically not feasible. Nuts 2 regions are therefore allowed to trade emission permits which each other, facing different transaction costs depending on trade taking place between national agents (within a member state) or between agents across borders (within the EU-15).[12] Moreover, additional costs for setting up the necessary institutions (fixed transaction costs) are also included in the decision-making process.

Technically, a two-stage approach is adopted. Firstly, *a uniform emission standard is introduced in the regional supply models*, delivering a vector of binding emission targets and a vector of non-negative marginal abatement costs per region (as already explained in section 2). Secondly, *economically optimal distribution of permits is achieved* in a parallel permit trade module. To this end, three identities are used:

- 'Emission targets' are considered as 'permit allowances' (1 tonne of CO_2^{eq} = 1 permit), with no cost attached to their distribution ("grandfathering" assumed).
- 'Marginal abatement costs' equal 'permit prices' (MAC = PermitP).
- 'Permit demand functions' (i.e. from a technical perspective regional supply models acting as consumers of emission permits).[13]

In the permit trading module, regional supply and demand models are allowed to trade permit allowances between them so that the total number of permits on the market is kept constant and the *total rent from trading* is maximised. At the market clearing point transaction costs should account for the remaining differences in regional permit prices.[14] This is shown in figure 2 for two regions:

where:

$AllowP_r$: allowance of permits for region r (A or B) in the initial (i) or final (f) situation

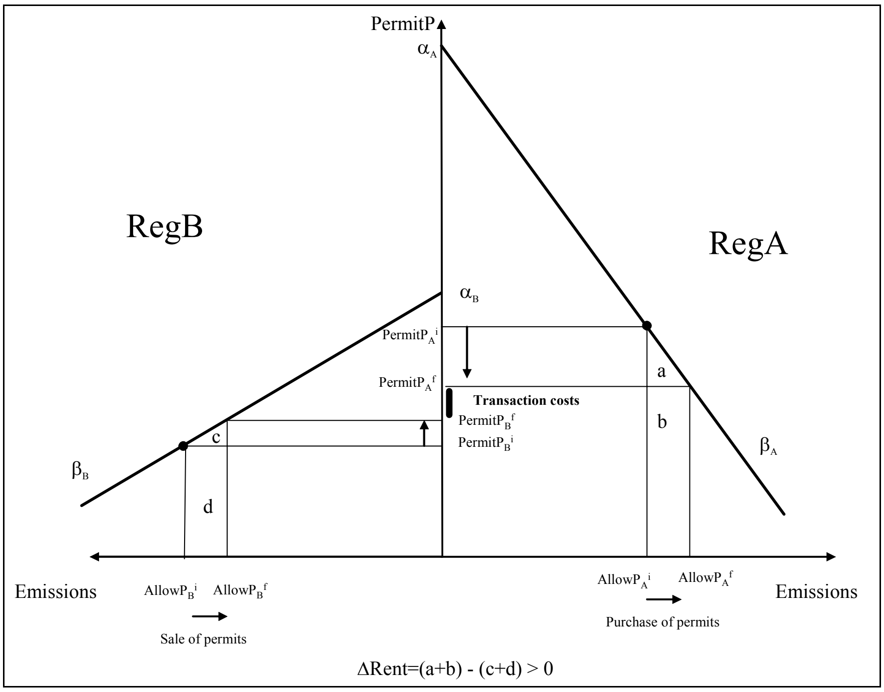
[11] As STRONZIK recognises in the additional report to Working Group 4 (STRONZIK, 2001), almost no work has been done in the estimation of transaction costs for ETSs since this is a relatively new instrument. For that reason, estimations for specific evaluated CDM and JI projects are used as proxies in this study.

[12] It is considered realistic to assume lower transaction costs in the first case since trade between emitters 'within a country' is comparably cheaper in terms of the administrative burden.

[13] Note that these 'permit demand functions' are linked to the previously presented 'marginal abatement cost curves' through the equality permit price = marginal abatement cost.

[14] In the absence of transaction costs, a uniform permit price for all regions would be achieved at the optimum (*equi-marginality principle*).

Figure 2. Graphical representation of a permit trade model for 2 regions



Source: based on PEREZ, 2004

$PermitP_r$: permit price for region r before trade (i) or after trade (f)

α_r , β_r : intercept and slope parameters of the permit demand function for region r

In this instance, the ETS modelled in CAPRI is simplified and presented for two agents (regions A and B) with two different permit demand functions defined by parameters α_r and β_r. In the initial situation (before trading), each region receives a number of permits representing a binding limit on emissions ($AllowP_r^i$) and has to pay a positive price for the last emission unit abated ($PermitP_r^i$). Through the trading mechanism an optimum is achieved where the total variation in the area below both individual permit demand functions is at its maximum: (a+b)-(c+d) in the graph. At this point the 'consumer rent' from permit trading is maximised.[15] The regional permit allowance moves in the final situation to $AllowP_r^f$ at the cost of $PermitP_r^f$ per emission certificate. At the optimum the remaining differences in regional permit prices correspond to variable transaction costs, which are assumed to be paid by the permit buyer (in this case region A).

As mentioned above, *variable and fixed transaction costs* are introduced in this modelling exercise as marginal costs. *Variable transaction costs* are mainly brokerage fees and are paid by permit buyers. In the current study, they are assumed to be €5 for purchases within a member state (trade with national agricultural producers) and €10 for purchases from abroad (trade with foreign agricultural producers). These values are based on estimates from various studies reporting handling fees in international trading schemes to be between 2 and 10% of the transaction value (compilation by ECKERMANN et al., 2003: 16). To select the 'appropriate' values in relation to the final permit price, a simple 'sensitivity analysis' for different values was carried out with the model.[16]

Moreover, a further €10m is assumed as the institutional cost of the trading scheme (€2m per year with 5 years amortisation). This cost is also assumed to be borne by permit buyers and therefore distributed over transactions. This is based on information found in the literature for CDM and JI projects in different economic sectors and project sizes (compilation by ECKERMANN et al., 2003: 6-8).

In the first modelling exercise described in section 3, market effects are further excluded so that prices remain exogenous and efficiency effects derived from the use of instruments of abatement can be directly observed in the regional supply models ("efficiency model"). In section 4, this modelling approach is extended to consider price effects, so that trade between the EU and the most important trade blocks in the world is included ("price model").

4. Results from the "Efficiency Model"

By implementing the afore-mentioned parameters model, a market of 271 million permits is simulated.[17] Of these, 6.9 million permits are effectively traded between Nuts 2 regions, i.e. 2.5 % of the total. This defines the size of the trading market and is linked to the disparity of marginal abatement costs and the level of transaction costs. The distribution of allowances and trade flows between member states is highlighted in table 3.

There is a group of member states that face very high initial MACs and act only as buyers in the market: Denmark, the Netherlands, Finland and Austria. It is rational for these

15 Technical note: in this modelling approach the change in the total area below the 'permit demand functions' between the initial and final emission levels is maximised, which leads to a minimisation of total emission abatement costs (these functions are actually cost functions). This approach differs from the one taken in a conventional quota trade model, where the quota rent is maximised as the total area below the quota demand function at the final emission level ('consumer rent'). Moreover, it allows explicit modelling of transaction costs and prices without requiring bilateral permit trade flows and additional spatial arbitrage conditions (net trade approach).

16 For this sensitivity analysis, the model was shocked with 4 differentiated sets of transaction costs varying between 0 and 50€ for each permit purchased within national borders or from abroad (16 simulations in total). The resulting traded quantity of permits and price were than compared with the estimates found in the literature (see ECKERMANN et al., 2003: 16).

17 Exactly 85% of 2001 estimated global warming emissions in the EU-15 (319 million tonnes of CO_2^{eq}).

Table 3. Permit transactions between EU-15 member states

	Initial Permit Price * (Std 85%)	Final Permit Price	Total amount of permits	Purchases inland **	Purchases abroad	Sales abroad	Total purchases	Total Sales
	Euro	Euro	1000 Units	1000 Units	1000 Units	1000 Units	1000 Units	1000 Units
European Union	**171.3**	**157.6**	**271393**	**952**	**5984**	**5984**	**6936**	**6936**
Denmark	260.4	161.2	7448	0	469	0	469	0
Netherlands	259.0	161.2	13554	0	786	0	786	0
Finland	245.6	161.2	3546	0	198	0	198	0
Austria	215.3	161.2	5714	0	240	0	240	0
Italy	215.2	160.9	27573	37	1205	0	1242	37
Belgium	210.0	160.8	7119	4	276	0	279	4
Germany	195.0	160.8	48496	5	1704	0	1709	5
France	175.7	159.5	68821	690	1102	0	1792	690
Sweden	159.9	159.1	4714	12	5	0	17	12
Greece	149.0	154.2	5999	33	0	52	33	85
Portugal	130.5	151.9	5091	5	0	163	5	168
Spain	120.8	151.8	28358	90	0	1681	90	1771
United Kingdom	108.0	151.2	33141	76	0	2982	76	3058
Ireland	105.9	150.9	11819	0	0	1106	0	1106

* Initial permit prices are in line with the $MAC_{15\%}$ results in figure 1.
** Purchases inland are equal to sales inland for a member state.

Source: own calculations; simulation scenario 85% emission standard and emission trade; year 2001; Luxembourg is modelled together with Belgium

countries to increase emissions in order to reduce abatement costs. These countries end up using 4 to 6% more permits than in the initial allocation.

A second group of countries is comprised by Italy, Belgium, Germany, France, Sweden and Greece. Purchases also take place but in smaller proportions than in the initial situation (1 to 4% more permits than in the initial allocation). However, the picture in these countries is not homogeneous since several regions face lower MACs than the national weighted average and sell permits. Some Nuts 2 regions sell permits at national level (e.g. Sardinia in Italy and Midi-Pyrenées in France) and even to foreign regions (e.g. Ipeiros in Greece).

The last group of countries is formed by Portugal, Spain, the United Kingdom and Ireland, where mainly permit selling takes place. Regions in these countries face MACs below the average equilibrium point of the EU-15. Some permit purchases are still observed but only from national regions.

By plotting the internal solution path on an aggregated level for member states, the average weighted MAC in the European Union falls from €171.3 to €157.6 through emission trade. The results at member state level are shown in table 4.

The first three columns represent the 85% emission standard simulation scenario (no trade). All member states suffer income losses from the implementation of the emission standard (between -€1412m for Germany and -€9m for Portugal) compared to the base year situation (no emission restriction). As already mentioned, these income losses are very disparate percentage-wise and depend on the marginal abatement costs faced by regions. In this first scenario, total income equals agricultural income since no revenues or costs from trading take place (middle column).

With the implementation of emission trading between Nuts 2 regions, income losses still remain with respect to the base year situation (the emission cap is still binding) but efficiency gains are achieved with respect to the uniform application of the emission standard (agricultural income increases by €630m). These revenues are dampened, however, by the costs of the trading scheme, i.e. negative rents coming from transaction costs (-€66m), as defined above. For the EU-15 as a whole, €564m is estimated to be the total efficiency gains.[18] On the one hand, *sellers* are able to compensate income losses from production substitution effects through permit rents: for example, the United Kingdom moves from potential losses of -€302m to gains of €147m through permit sales). On the other hand, *buyers* cover purchase costs of permits through higher revenues from production: for example, Germany moves from potential income gains of €412m to €138m through permit purchases. All member states are "better off" through permit trading, which is consistent with the microeconomic theory underlying the model.

5. Results from the price model

The price model is constructed similar to the efficiency model, but prices are now considered as endogenous variables. Again there are two scenarios: 15% emission reduction from 2001 emissions without emission trading (scenario 1) and with emission trading (scenario 2).

Table 5 shows the regional emission abatement targets endogenously obtained after reaching an optimum in the emission permit market. These 'optimal' regional emission abatement targets are aggregated for member states in this table and should be closest to the expected situation when introducing the ETS.

[18] Note that in this comparison between instruments prices are kept constant, meaning that efficiency gains and income gains are the same (no price interference).

Table 4. Income effects of emission trading for EU-15 member states

	85% emission standard [2001] *differences to : GHG Inventories Base Year [2001]*			85% emission standard + trade [2001] *differences to : 85% emission standard [2001]*		
	Agricultural income [1] Mio Euro	Revenues/costs from emission trade* Mio Euro	Total Income Mio Euro	Agricultural income Mio Euro	Revenues/costs from emission trade [2] Mio Euro	Total Income [3] Mio Euro
European Union	165567.54 *-5920.67*	0	165567.54 *-5920.67*	166198.21 *630.67*	-66.6	166217.9 *564.06*
Belgium	3697.18 *-108.34*	0	3697.18 *-108.34*	3735.19 *48.01*	-44.4	3737.7 *3.61*
Denmark	4112.55 *-261.73*	0	4112.55 *-261.73*	4208.47 *95.92*	-75.7	4211.6 *20.27*
Germany	21766.98 *-1412.37*	0	21766.98 *-1412.37*	22179.44 *412.46*	-274.7	22217.0 *137.72*
Austria	2848.98 *-174.13*	0	2848.98 *-174.13*	2898.51 *49.53*	-38.6	2901.3 *10.89*
Netherlands	10903.64 *-356.64*	0	10903.64 *-356.64*	11052.07 *148.43*	-126.6	11056.5 *21.83*
France	34831.65 *-992.78*	0	34831.65 *-992.78*	35070.56 *238.91*	-181.2	35089.1 *57.71*
Portugal	3953.94 *-9.21*	0	3953.94 *-9.21*	3933.24 *-20.70*	24.5	3930.4 *3.79*
Spain	26104.67 *-565.27*	0	26104.67 *-565.27*	25912.43 *-192.24*	253.3	25887.3 *61.06*
Greece	8953.98 *-215.54*	0	8953.98 *-215.54*	8949.72 *-4.26*	7.7	8946.9 *3.44*
Italy	30383.43 *-836.80*	0	30383.43 *-836.80*	30638.28 *254.85*	-194.4	30652.2 *60.45*
Ireland	3093.61 *-143.11*	0	3093.61 *-143.11*	2959.46 *-134.15*	166.9	2945.3 *32.76*
Finland	1534.15 *-111.00*	0	1534.15 *-111.00*	1578.31 *34.16*	-31.9	1580.1 *2.22*
Sweden	1970.51 *-175.07*	0	1970.51 *-175.07*	1972.7 *2.19*	-0.9	1975.1 *1.25*
United Kingdom	11412.27 *-558.67*	0	11412.27 *-558.67*	11109.85 *-302.42*	449.5	11087.5 *147.08*

[1] Differences in italics to original income data in the base year situation: no emission restriction (in € million).
[2] Differences in italics to original income data in the 85% emission standard scenario (in € million).
[3] Total income is equal to agricultural income (from the supply regional models) plus revenue minus costs from emission trading.
Source: own calculations; year 2001; Luxembourg is modelled together with Belgium

The overall effect of emission abatement measures on agricultural markets is a reduction in production. This is not very surprising since only a structural response is allowed from regional supply models to meet the emission target. Nevertheless, this effect can vary across *activities*, depending on the emission weight attached by the 'emission accounting system' (income/emission relationship), and across *regions*, depending on the substitution possibilities found in each regional model (agricultural income is always maximised subject to constraints). Table 6 presents the supply effects on the main activity aggregates for the EU-15:

A slight extensification effect can be observed for cereals in all three scenarios (reduction in yields). At the optimum, it is profitable for agricultural producers to reduce the amount of fertiliser applied (and indirectly N_2O emissions) and maintain some production on land which otherwise would have been abandoned, i.e. the drop in supply is higher than the drop in hectares of cultivation. This effect is less pronounced for 'other arable crops' such as pulses, potatoes and sugar beet. For cattle and beef meat activities, however, higher yields are modelled. For the latter group, it is optimal from an 'emission accounting perspective' to heavily increase yields (up to 18%) and further reduce the cattle herd (up to -17%). Through this intensification effect, animals become more efficient in terms of GHG emissions (higher income obtained per emission unit).

The previous table also shows that in scenario 1 (85-STD) higher drops in crop production are estimated. The introduction of non-uniform standards through emission trading

Table 5. Final emission abatement targets with emission trading (EU-15 member states)

	85% emission standard + trade [2001]
European Union	**-15.0%**
Austria	-9.8%
Belgium	-7.0%
Denmark	-6.8%
Finland	-8.5%
France	-13.9%
Germany	-11.8%
Greece	-6.0%
Ireland	-26.8%
Italy	-7.5%
Netherlands	-8.0%
Portugal	-21.6%
Spain	-17.4%
Sweden	-11.8%
United Kingdom	-28.3%

Measurement units: % reduction of CO_2^{eq}.

Source: own calculations; year 2001; Luxembourg is modelled together with Belgium

simulation scenarios (MFN tariffs are quite restrictive compared to preferential tariffs). These make imports quite inelastic and indirectly transfer the burden to exports, which drop heavily in order to meet internal demand. Consequently, demand slightly shrinks and consumer prices increase.

At this stage, the analysis on supply and prices indicates: (1) that consumers suffer high economic losses through the implementation of an emission constraint on agricultural production (consumer prices increase) and (2) that these losses are lower in the case of 'non-uniform' emission abatement scenarios (85-TRD) than in the case of a 'uniform' standard (85-STD). Nothing conclusive can, however, be said about how agricultural producers are affected, since they produce less but at higher prices. For further analysis of the welfare effects of emission abatement measures, these two variables are combined in the following section and agricultural income per activity estimated. Public sector expenditure (welfare losses from taxpayers) and profits from the dairy and oil-crushing processing industry are also considered.

Welfare effects

The welfare measure in CAPRI is based on production and consumption shifts of agricultural primary goods, and on an aggregate of 'all other goods',[19] driven by price changes. The main factors are producer surplus, consumer surplus and budgetary expenditures (paid by taxpayers). Additionally, profits from the oil-crushing and dairy processing industry are included (PEREZ and WIECK, 2004):

- *Consumer surplus* is calculated by using the money-metric indirect utility function (VARIAN, 1992: 110). The money-metric measure is the minimal expenditure consumers need to incur in order to reach the utility level of the simulation year at reference situation prices (= calibration point). Final consumption is modelled by a generalised Leontief expenditure function, allowing explicit derivation of this indirect utility function. Changes in consumer prices from the implementation of an emission

Table 6. Supply details for activity aggregates (average for the EU-15)

	85% emission standard [2001] *% differences to: GHG Inventories base year [2001]*			85% emission standard + trade [2001] *% differences to: GHG Inventories base year [2001]*		
	Hectares or herd size 1000 ha or heads	**Yield** kg /ha or head	**Supply** 1000 t	**Hectares or herd size** 1000 ha or heads	**Yield** kg /ha or head	**Supply** 1000 t
Cereals	33003.36	5601.91	184881.75	33282.27	5621.65	187101.14
	-12.02%	*-1.14%*	*-13.02%*	*-11.28%*	*-0.79%*	*-11.98%*
Oilseeds	4697.04	2954.25	13876.26	4754.1	2963.58	14089.15
	-11.53%	*0.00%*	*-11.53%*	*-10.46%*	*0.32%*	*-10.17%*
Other arable crops	6740	35686.7	240528.62	6763.87	35829.4	242345.15
	-2.68%	*0.20%*	*-2.49%*	*-2.34%*	*0.60%*	*-1.75%*
All cattle activities	66328.47	2305.29	152906.34	66303.65	2300.67	152542.78
	-18.88%	*15.88%*	*-6.00%*	*-18.91%*	*15.65%*	*-6.22%*
Beef meat activities	19849.43	228.42	4533.93	19433.14	229.14	4452.91
	-26.95%	*15.58%*	*-15.57%*	*-28.48%*	*15.94%*	*-17.08%*

Source: own calculations; year 2001; % differences in italics in hectares or herd size, yield and supply with respect to the base year situation

(85-TRD) implies a relaxing of the emission constraint at regional level and indirectly production is less affected.

As prices are now endogenous, world markets have an influence on European agricultural markets and, therefore, monetary variations in supply are no longer equivalent to variations in income. The following two tables show the effect on agricultural prices (consumer and producer prices) for the modelled abatement mechanisms:

Table 7 shows the main variations in consumer and producer prices for primary products. Producer and consumer prices increase for the main activities in all three scenarios, especially for animal products. This effect has to be considered parallel to the supply effects explained in the previous section and is due to the market barriers applied by the EU on agricultural markets. Amongst other measures, tariff rate quotas for cereals and beef remain binding in the different

[19] This 'bundle of goods' closes the demand balance.

abatement instrument affect the money metric, giving an indirect measure of consumer welfare change.

- *Producer surplus* is calculated as agricultural income in accordance with the gross value added concept of the Economic Accounts of Agriculture (output revenues minus input costs). The current analysis explicitly includes direct payments and revenues/costs from permit trading (scenario 85-TRD).

Table 7. Variation in consumer and producer prices for selected primary products (average for the EU-15)

	85% emission standard [2001]		85% emission standard + trade [2001]	
	Consumer Price	Producer Price	Consumer Price	Producer Price
Soft wheat	0.80%	15.57%	0.79%	15.25%
Durum wheat	0.98%	7.90%	0.96%	7.89%
Rye and meslin	0.70%	19.66%	0.68%	19.29%
Barley	0.30%	7.49%	0.29%	7.29%
Oats	0.85%	19.46%	0.84%	19.20%
Grain maize	0.17%	2.81%	0.16%	2.71%
Paddy rice *		22.51%		21.84%
Pulses	0.03%	2.98%	0.03%	2.75%
Potatoes	0.39%	15.54%	0.38%	17.56%
Sugar beet *		8.81%		8.38%
Beef	0.00%	3.43%	0.00%	2.93%
Veal	45.54%	99.36%	44.13%	97.63%
Pork meat	42.47%	100.13%	41.18%	98.29%
Sheep and goat meat	6.74%	21.79%	6.66%	21.65%
Poultry meat	41.67%	78.95%	40.88%	81.26%
Cow and buffalo milk *		2.48%		2.60%
Sheep and goat milk *		49.35%		48.76%

* These products are processed in the model.

Source: own calculations; year 2001; differences with respect to prices in the base year situation

Table 8. Welfare effects (average for the EU-15)

	NGHGIs base year [2001]	85% emission standard [2001]	85% emission standard + trade [2001]
		% differences to: GHG Inventories base year [2001]	*% differences to: GHG Inventories base year [2001]*
Budgetary expenditure	37498.51	35542.07	35464.59
		-1956.44	*-2033.92*
Money metric	4397054.81	4354880.43	4356338.21
		-42174.38	*-40716.6*
Output revenues	276654.8	330326.12	334291.92
		53671.32	*57637.12*
Input costs	135626.88	146042.86	150025.26
		10415.98	*14398.38*
Premiums	30460.29	27928.57	27880.7
		-2531.72	*-2579.59*
Transaction costs from permit trading			95.07
			95.07
Agricultural income	171488.21	212211.84	212052.3
		40723.63	*40564.09*
Profit of processing industry	70071.25	64219.98	64325.9
		-5851.27	*-5745.35*
TOTAL WELFARE	4601115.76	4595770.18	4597251.82
		-5345.58	*-3863.94*

Measurement units: € million (differences in italics with respect to the base year)

NB: total welfare is defined in the table as positive transfers to consumers (money-metric) + agricultural income (output revenues - input costs + premiums - transaction costs from permit trading) + profits from the processing industry - budgetary expenditures (transfers from taxpayers).

Source: own calculations (2001)

- *Profits of the processing industry.* Processed products from the dairy and oilseed industry are modelled in CAPRI through the derivative of a normalised quadratic profit function (one input product and several processed products). Production of milled rice is calculated through fixed processing factors (one raw product and one processed product).
- *Budgetary expenditure* comprises all direct payments for agricultural commodities (premiums) and export subsidies and costs for intervention purchases.

The main welfare effects observed for the EU-15 are summarised in table 8:

Agricultural income (= producer surplus) increases in all simulation scenarios. Whereas in the 85-STD scenario €40.7bn is estimated as economic transfers to producers, in the 85-TRD €40.6bn is achieved (transaction costs of permit trading included for the latter). This positive effect is due to the general increase in producer prices. On the other hand, transfers to consumers (money-metric utility measure) diminish due to an increase in consumer prices: -€42.2 and -40.7bn, respectively, in the scenarios defined. Since public expenditure remains more or less constant (-€2bn), the effect on total welfare is mainly determined by the difference between gains achieved by producers and losses suffered by consumers and the processing industry.

The total welfare effect is estimated as being negative for all simulation scenarios: -€5.3bn in 85-STD and -€3.8bn in 85-TRD. It is interesting to see that, whereas agricultural income is highest in the 85-STD scenario ('quota effect'), welfare losses are minimised with the introduction of tradable emission permits. It can, therefore, be concluded from an overall perspective that the introduction of emission permits achieves a more efficient solution than emission standards. Nevertheless, it is important to note that the welfare analysis presented does not take account of the environmental benefits obtained by future generations. Welfare effects derived from the reduction of GHG emissions do not enter into this calculation since their estimation goes beyond the scope of this study.

6. Conclusions

The main finding of this paper is that if significant greenhouse gas emission abatement is to be achieved in the agricultural sector, efficiency gains from expanding the current emission trading scheme to this sector (through the existing voluntary opt-in clause) can be appreciable. According to our modelling approach, and assuming a 15% reduction on the 2001 baseline, marginal abatement costs in Europe are reduced from about €171 to about €157 through the use of emission trading. The proposed emission trading system seems feasible, as similar trading systems already exist in Europe and the necessary information is already incorporated in the data any farmer eligible for agricultural support has to provide. Nevertheless, according to the literature there will be substantial transaction costs linked to this instrument. Assuming that these transaction costs are to be paid by the permit buyer, the MACs do not balance out in our model across regions, nevertheless, the reduction in abatement costs is quite significant.

An additional finding of this paper is that under the current support to agriculture, and in the absence of a successful WTO reform round, emission reduction does not result in a net income loss for the agricultural sector because of the 'production quota effect'. This is caused by the isolation of European agricultural markets from world markets through effective barriers to trade (import tariffs, export subsidies and tariff rate quotas). The decrease in domestic production plus a parallel restriction on imports exerts some pressure on internal demand, with higher producer and consumer prices as a consequence. From an overall perspective, total 'private' welfare is – of course – declining. It is not possible to balance this loss with positive welfare effects derived from the reduction of GHG as – to our knowledge – in the presence of high uncertainties robust monetary estimates for GHG emissions do not exist. But it can be shown that the cost of reaching certain emission reduction targets can be considerably reduced by the introduction of tradable emission permits.

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