Trading schemes for greenhouse gas emissions from European agriculture: A comparative analysis based on different implementation options

Ignacio PÉREZ DOMÍNGUEZ*, *Wolfgang* BRITZ**,
Karin HOLM-MÜLLER**

* **Corresponding author:** Agricultural Economics Research Institute (LEI), Alexanderveld 5, 2585DB, The Hague (Netherlands)
e-mail: ignacio.perez@wur.nl

** Institute for Food and Resource Economics, University of Bonn, Bonn (Germany)

Summary – *A rational negotiation strategy for coming multilateral negotiations regarding climate change requires knowledge about possible social, economic and environmental effects of policy instruments for the abatement of greenhouse gas emissions. With this purpose, an agricultural sector model is expanded to cover greenhouse gas emissions from agricultural sources in Europe and policy instruments for their reduction. This modelling approach concentrates on the application of a permit trade scheme for emission abatement within the Kyoto Protocol 'first commitment' baseline. The effects derived of three alternative schemes are described in detail: the EU 'burden sharing' agreement option defined as regional emission standards, emission trading between regions inside each Member State, and finally, emission trading between all European regions. The analysis shows the importance of selecting an adequate combination of instruments of emission abatement for the design of efficient emission reduction policies.*

Keywords: *Kyoto Protocol, agricultural policy, economic modelling, tradable emission permits*

Systèmes d'échange de droits d'émissions de gaz à effet de serre d'origine agricole en Europe : une analyse comparative de différentes options

Résumé – Une stratégie rationnelle pour les négociations multilatérales à venir sur le changement climatique requiert la connaissance des effets possibles des instruments politiques pour la réduction des émissions des gaz à effet de serre sur le plan social, économique et environnemental. A cet effet, un modèle sectoriel agricole est développé afin de couvrir les émissions de gaz à effet de serre d'origine agricole en Europe et les instruments politiques visant à leur réduction. Cette approche de modélisation est basée sur l'application d'un système d'échange de droits des émissions comparé au scénario de référence de la première période d'engagement du Protocole de Kyoto. Les effets dérivés de trois systèmes alternatifs sont décrits en détail : l'option EU d'accord de partage de la charge (définie comme standards régionaux), les crédits d'échange entre les régions à l'intérieur de chaque Etat-membre et, finalement, les crédits d'échange entre toutes les régions européennes. L'analyse montre l'importance de sélectionner une combinaison adéquate d'instruments de réduction des émissions pour définir une politique environnementale efficace.

Mots-clés : Protocole de Kyoto, politique agricole, modélisation économique, crédits d'émission échangeables

JEL descriptors: C15, Q18, Q54

1. Introduction

In October 2003 the EU adopted a proposal for a directive on CO_2 emission trading to be operable by January 2005 (Council of the European Union, 2003), establishing a coordinated GHG (Greenhouse Gas) emission allowances Trading Scheme (ETS) over all Member-States (MS). Applying to a list of energy and industrial production activities covering all GHGs included in Annex A of the Kyoto Protocol (KP), the legislation aims at reductions of GHG emissions in a cost-effective and economically efficient manner (article 1). However, according to the categories of polluting activities defined in Annex 1, only CO_2 emissions are effectively covered by the directive. 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] through possible amendments (article 30). This is an important point with regard to the potential extension to the agricultural sector.

The possible inclusion of agriculture in a carbon-based ETS is a controversial issue. Saddler and King (2008) highlight the current debate in Australia and stress the need to include incentives to adopt best-practice methods of emission abatement in the agricultural sector, without effectively taxing production through any rigid emission abatement mechanism. The Australian Government is expected to take a decision on the inclusion of agriculture in its Carbon Pollution Reduction Scheme in 2013, which would raise the coverage of emissions through the scheme to 90%. Lennox *et al.* (2008) and Kerr and Sweet (2008) describe the main characteristics of the New Zealand ETS, where agriculture is foreseen to be included in a 'cap and trade' scheme by January 2013, covering then 90% of total GHG emissions in year 2005. Breen (2008) motivates the importance of targeting GHG emission from agriculture in Australia and New Zealand, countries where this sector shows considerably larger emissions shares (16% and 48% in 2006 respectively) than in the EU (10% in 2006). On these grounds, he justifies the introduction of Irish agriculture in a ETS, since methane and nitrous oxide emissions represent 25% of total GHG emissions. Radov *et al.* (2007) analyse the scope and feasibility of a ETS for the UK, but do not include a quantitative assessment of its relative merits relative to other regulatory approaches. Reilly and Asadoorian (2007, pp. 192-194) claim that ETS in agriculture seem to perform better than simple regulatory systems (*i.e.* 'cap' on emissions), but they justify this with the nature of the emission allowances (*i.e.* perceived as tangible assets by regulators) and not on economic reasoning. They also consider measurement, monitoring and enforcement costs as a key issue for the design of policies targeting emission sources and sinks in agriculture.

In order to analyse the quantitative effects of an EU-wide ETS for the agricultural sector, a novel methodological approach is presented in the next section of this paper. The scenario construction process and main model assumptions are described in section 3. Section 4 discusses the main results and section 5 highlights the main limitations of the methodological approach selected. Section 6 summarises the main

---

[1] The list of activities included in the Directive might be subject to future revision.

findings and draws some reflections on the relevance of this study for the European decision making process.

2. Modelling emission trading in CAPRI

2.1. Overview of the CAPRI Model

The CAPRI modelling system (Common Agricultural Policy Regional Impact Analysis) is a large-scale comparative-static agricultural sector model with a focus on EU27, Norway and Western Balkans, but covering global trade with agricultural products as well (Britz and Witzke, 2008). Developed since 1996, it is now used by different institutions, including the European Commission, for policy impact assessment. From a technical perspective, CAPRI is split into two major modules.

The **supply module** consists of about 250 independent aggregate optimisation models representing all regional agricultural activities as defined by the Economic Accounts for Agriculture, each model representing the aggregate choices of farmers in a Nuts 2 region (EuroStat regional classification). These supply models combine a Leontief technology for intermediate inputs covering a low and high yield variant for the different production activities with a non-linear cost function which captures the effects of labour and capital on farmers' decisions. This is combined with constraints relating to land availability, animal requirements, crop nutrient needs and policy restrictions (production quotas and set-aside restriction). The non-linear cost function allows for perfect calibration of the models and a smooth simulation response rooted in observed behaviour [2]. The supply models feature a high differentiation in production activities (28 crop and 13 animal activities), capture the premiums paid under the CAP in high detail and use an expected utility approach from stochastic revenues to model the EU sugar quota regime.

The **market module** consists of ***a* spatial, non-stochastic global multi-commodity** model for 40 primary and processed agricultural products, covering 40 countries or country blocks in 18 trading blocks. Bi-lateral trade flows and attached prices are modelled based on the Armington assumption of quality differentiation (Armington, 1969). The behavioural functions for supply, feed, processing and human consumption in the market module apply flexible functional forms, so that calibration algorithms ensure full compliance with micro-economic theory. This module allows for market analysis at global, EU and national scale, including a welfare analysis.

As the supply models are solved independently at fixed prices, **the link between the supply and market modules** is based on an iterative procedure. After each iteration, during which the supply module works with fixed prices, the constant terms of the behavioural functions for supply and feed demand of the market module are

---

[2] The supply behaviour of CAPRI for the most important annual crops is based on Jansson (2007), a further development of Heckelei and Wolf (2003). For animals, perennials and annuals crops not covered by the estimation, exogenous own supply elasticities are used, which are as far as possible based on typical mean supply elasticities.

calibrated to the results of the regional aggregate programming models aggregated to MS level. Solving the market module then delivers new prices. A weighted average of the prices from past iterations then defines the prices used in the next iteration of the supply module. Equally, in between iterations, CAP premiums, differentiated according to the different decoupling schemes adopted by MS, are re-calculated to ensure compliance with national ceilings (Pérez Domínguez and Wieck 2006, pp.113-114 ; Britz *et al.*, 2006, p. 218).

The specific structure of CAPRI renders it especially suitable for agri-environmental analysis. The regionalized programming models capture links between agricultural production activities in detail, and allow, based on the differentiated lists of production activities, inputs and outputs, to define environmental effects of agriculture in response to changes in the policy or market environment. They allow for the integration of different types of environmental policy instruments (pollution standards/taxes and technical emission abatement options). As opposed to many other regionalized agricultural sector models, the transparent link with the large-scale global market model in CAPRI allows to model different trade policies capturing price feedbacks for agricultural products from the rest of the world (Wieck *et al.*, 2006). A specific market module for young animal trade ensures a plausible mix of pig and cattle activities.

2.2. Methodological approach selected

Different methodological approaches to the analysis of trading schemes for GHG emission abatement can be found in the literature. Springer (2003, p. 528) classifies these models into five categories: integrated assessment models, computable general equilibrium models (CGEs), neo-Keynesian macroeconomic models, emission trading models and energy system models. From this classification, Springer groups economic models into three broad layers: (*i*) top-down economy-wide approaches, which include CGEs and macroeconomic models, (*ii*) bottom-up sector-specific models and (*iii*) pure emission trading systems.

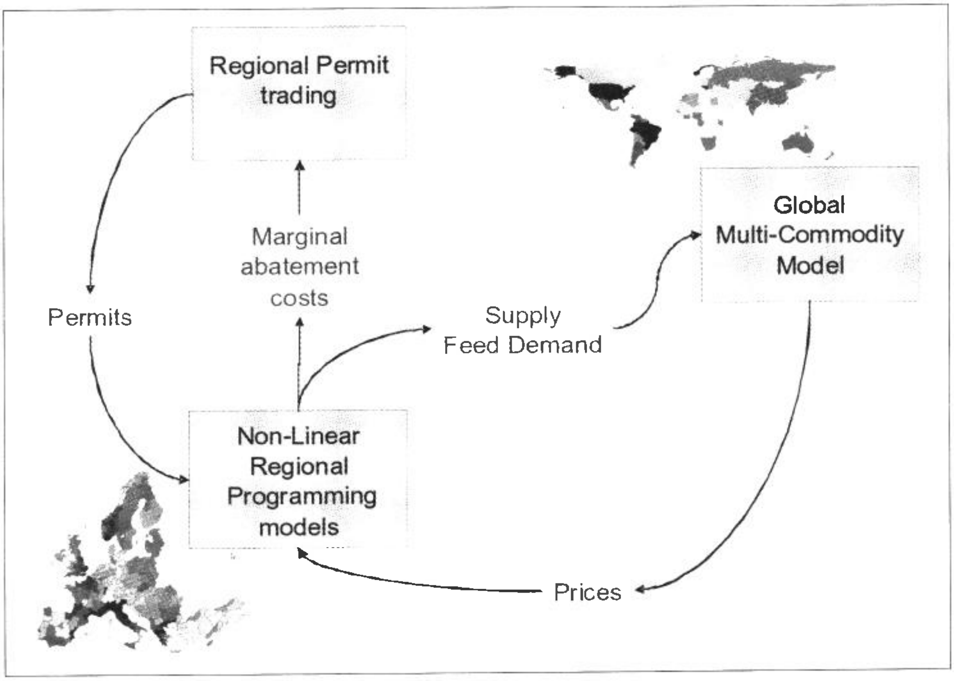
The methodological approach proposed in this paper builds on features of the last two groups. On the one hand, the emission trading scheme analysed in the paper includes different GHGs calculated from a bottom-up perspective for different agricultural processes (*e.g.* production activities), based on specific interactions of nitrogen flows in agriculture and an implicit technological choice (*e.g.* current agricultural management, fertilizing and feeding practices). Whereas energy and transport models are widely used for modelling trade of GHG emissions from a sectoral perspective, agricultural models can also play an important role here, especially linked to the potential extension of existing emission trading schemes to this sector (opt-in clause, article 30 of the KP). On the other hand, the methodology presented includes an explicit emission trading scheme based on marginal abatement cost curves (MACC) linked to regional emission constraints. Similar approaches can be found in Holtsmark and Maestad (2002, p. 208), Jotzo and Michaelowa (2002, pp. 182-183), Löschel and Zhang (2002, p. 720), Stevens and Rose (2002), Jorgenson *et al.* (2009, p. 366). In this type of models, emitters interact with each other in order to find a market clearing point where prices for permits are equal to marginal abatement costs.

Beyond the identified common features to other model systems, our modelling approach opens up new possibilities that are described in detail below. We have implemented the modelling of tradable emission permits in CAPRI in a separate module[3] as shown in figure 1. The advantage of this modular approach is that it requires no structural changes in the overall system and fits well to the existing system based on a transparent combination of different components, allowing to a large extent their independent maintenance and further development. Basically, besides the two modules dealing with markets for final agricultural products and young animals comprised in the system, a new regional trade module for GHG emission permits is linked into the system. It updates permit prices and regional emission ceilings within the overall iterative framework until a fix point is found.

Depending on the scenario selected, Nuts 2 regions are allowed to trade emission permits with each other and face different transaction costs (TC) depending on whether trade is taking place between agents in the same or in different MS[4]. Moreover, additional costs for setting up the necessary institutions for emission trading (fixed TC) are also included in the decision-taking process.

The new module consists of two elements. Firstly, a new constraint in the supply model defines GHG emissions from agriculture at regional level according to the

Figure 1. **CAPRI model flow with explicit consideration of regional emission permit trading**



---

[3] CAPRI Modelling system; revision version 498 of 30/05/2007.

[4] 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.

UNFCCC[5] emission accounting scheme. By setting an upper bound on GHG emissions, effects of a standard or permit distribution for GHG emissions on agricultural supply and intermediate demand at regional level can be simulated. The related marginal abatement costs are derived as the shadow prices of the constraint. These abatement costs enter in each iteration the second element: the newly developed permit trade module. Based on a second order approximation of the marginal abatement cost curve, it defines market clearing prices for emission permits and their regional distribution in the EU27. Clearly, the iterative feedback from the global market module allows simulating impacts on demand, trade and prices of the emission ceilings, but also, impacts on the marginal abatement costs in agriculture resulting from price changes.

In the permit trading module, interregional trade of permit allowances is simulated by maximising the **total rent from trading** under a constant sum of regional permits. At the market clearing point TC should account for the remaining differences in regional permit prices[6], which should reflect the regional marginal abatement costs. For the modelled multi-regional case, the permit trading module is analytically constructed as a maximisation problem:

$$\begin{aligned} Max\ Obje = [\sum_r \frac{1}{2}(PermitP_r^i - PermitP_r^f) * (AllowP_r^f - AllowP_r^i) \\ +(AllowP_r^f - AllowP_r^i) * PermitP_r^f \\ -(BuysIn_r + BuysOut_r) * VarTC\_Inst \\ -(BuysIn_r * VarTCIn + BuysOut_r * VarTCOut)\Big] \end{aligned} \tag{1}$$

Subject to the following restrictions:

$$AllowP_r^f = AllowP_r^i + (BuysIn_r + BuysOut_r) - (SalesIn_r + SalesOut_r) \tag{2}$$

$$\sum_r [SalesOut_r] = \sum_r [BuysOut_r] \tag{3}$$

$$\sum_{r \in MS} [SalesIn_r] = \sum_{r \in MS} [BuysIn_r] \tag{4}$$

$$PermitP_r^i = \alpha_r + \beta_r * AllowP_r^i \tag{5}$$

$$PermitP_r^f = \alpha_r + \beta_r * AllowP_r^f \tag{6}$$

Where:

- $Obje$ = surplus from emission trade
- α, β = intercept and slope of the regional permit demand function

---

[5] United Nations Framework Convention on Climate Change.

[6] Assuming rational behavior of the agents in the market and in the absence of transaction costs a uniform permit price would be achieved at the optimum (equi-marginality principle).

- $AllowP^i$ = initial distribution of permits (initial upper-bound imposed on emissions)
- $AllowP^f$ = final distribution of permits for the region (after trading)
- $PermitP^i$ = initial permit price (shadow price of the emission restriction)
- $PermitP^f$ = final permit price (after trading)
- $BuysIn$ = permits bought by region r from regions in the same MS
- $BuysOut$ = permits bought by region r from regions in other MS
- $SalesIn$ = permits sold by region r to regions in the same MS
- $SalesOut$ = permits sold by region r to regions in other MS
- $VarTC\_Inst$ = per unit TC linked to the pre-implementation and implementation of the scheme (institutional TC)
- $VarTCIn$ = per unit TC directly linked to trade within the same MS (*e.g.* brokerage fees)
- $VarTCOut$ = per unit TC directly linked to trade with regions in other MS (*e.g.* brokerage fees)

In the optimisation problem presented in equation (1) the sum of the areas below the regional permit demand functions between the initial and the final market clearing situation is maximised. This is achieved by moving away from the initial permit distribution$AllowP_r^i$ to the final distribution $AllowP_r^f$. The area change below the permit demand functions is comprehended by the objective function and divided in two terms: $(0.5*(PermitP_r^i - PermitP_r^f)*(AllowP_r^f - AllowP_r^i))$ and $((AllowP_r^f - AllowP_r^i)*PermitP_r^f)$. Variable TC are charged to the permit buyers and are subtracted from the obtained rent.

The constraints of the problem are:

1. *Equation (2):* the total amount of permits allocated to a region in the market has to be equal to the initial allocation plus purchases and sales, inside and outside of the MS.
2. *Equation (3):* total permit sales from regions in other MS has to be equal to total permit purchases from other MS (international permit trade balance).
3. *Equation (4)*: total permit sales and permit purchases between regions in the same MS have to be equal (national permit trade balance).
4. *Equation (5)*: the initial regional permit price lays on the permit demand function and is defined through the intercept, the slope and the initial permits allocated to the region.
5. *Equation (6):* the permit demand function has to pass through the simulated regional permit price, which is defined through the intercept, the slope and the new amount of permits allocated to the region.

This approach is analogous to a consumer rent maximisation problem: Agricultural producers demand permits according to their marginal willingness to pay given by the individual permit demand functions, which reflect the marginal profits attached to the emission constraint. With fixed prices for agricultural outputs, trade of emission allowances must lead to income gains or at least to no change in income in each region compared to a no-trade situation.

Given the structure of the non-linear programming models, there exists no closed-form representation of the marginal abatement cost curve. That is especially true under changing output prices which impact marginal abatement costs. Accordingly, only a second order approximation of the marginal abatement cost curves was implemented through **linear** permit demand functions, designed to go in each iteration through the initial regional permit price ($PermitP_r^i$) which results from the application of the uniform regional emission standard at the starting point and that estimated in the final situation ($PermitP_r^f$). Therefore, the optimal demand for permits per region (*i.e.* convergence to a point of the real Marginal Abatement Cost Curve, MACC) is achieved within an iterative approach.

During the first iteration, permit allowances are distributed to regions based on an equal percentage reduction of the GHG emissions in the baseline, and the shadow price on the emission ceiling derived by solving the regional models deliver one point on the regional MACC to which the permit trade models need to be calibrated. Therefore, the permit trade module works during this first iteration with a vector of assumed parameters α_r and β_r [7] of the MACC.

In the second and following iterations, the information delivered by the trading module in the form of regional permit allowances ($AllowP_r^f$) is used in the regional supply models to update the emission ceilings and calculate an updated vector of shadow values. With this information, intercepts and slopes for the linear permit demand functions can be updated, since at least two equilibrium points coming from the supply model (points on the real MACC) are available. This is shown in the following equation.

$$\begin{aligned} \beta_r &= (\mu_r^{step-2} - \mu_r^{step-1}) / (emission_r^{step-2} / emission_r^{step-1}) \\ \alpha_r &= \mu_r^{step-1} - \beta_r * emission_r^{step-1} \end{aligned} \tag{7}$$

The iteration process is repeated until no noticeable price changes are observed between the results delivered by the supply model and the permit trading module for a vector of permit allowances (the value of the objective function of the permit trading module is at its maximum). At this stage, the final equilibrium is achieved.

3. Scenario construction

3.1. Baseline

CAPRI combines expert judgements and trend analysis to provide a scenario baseline, used as comparison point for counterfactual analysis. The baseline may be interpreted as a projection in time covering the most probable future development of the European agricultural sector under the *status quo* policy and including all future changes already foreseen in the current legislation. Expert data on future trends are obtained from internationally reliable sources doing forecasting research at EU level (Commission of

---

[7] Please note that these slopes are only selected as a starting point as to allow for fast convergence of the emission trading module, they do not influence the final equilibrium stage.

the European Communities, 2005) and for non-EU regions and exogenous drivers (FAO, 2003). This information and own trend projections using time series from the current CAPRI database are fed into an estimator which chooses the most likely combination of forecast values subject to a larger set of consistency restrictions (*e.g.* closed area and market balances, feed requirements, production quotas, set-aside restriction, composition of cattle herds).

Similar to CGEs, calibration of the non-linear programming models is based on the definition of a parameter set fulfilling first-order conditions at the pre-defined baseline results, including both parameters of the non-linear costs function and technical coefficients. On the market side, the projection results at EU27 level plus Norway and Western Balkans are taken as given for calibration. In the calibration step bilateral import and export flows from these countries to other trade blocks are defined, as well as development of agricultural production, feed use, processing activities and human consumption. In this paper the CAPRI baseline comprehends all the changes foreseen in the Common Agricultural Policy until 2013.

Table 1. **Exogenous drivers considered for the baseline construction**

Exogenous drivers	Value
Inflation	1.9% per annum
Growth of GDP per capita	20% nominal per annum for the EU 10.5% for India, 1.5% for USA, 4% for Russia, 1.5% for Least Developed countries and ACPs, and 1% for the rest.
Demographic changes	EUROSTAT projections for Europe and UN projections for the rest of countries in the world
Technical progress	0.5% input savings per annum (affecting exogenous yield trends), with the exemption of N, P, K needs for crops where technical progress is trend forecasted.
Domestic Policy	National decisions on coupling options and premium models, with their expected implementation date for the EU25 MSs (25 different premium schemes, compilation by Massot Martí, 2005).
Common Market Organisations	Supply and demand shifted according to the expert forecasts (Commission of the European Communities, 2005).
Trade policy	Final implementation of the 1994 Uruguay round plus some further elements as NAFTA.
World markets	Supply and demand forecasts (FAO, 2003).

3.2. Emission restriction scenarios

In this scenario block, an 8% emission reduction on GHG emissions from agriculture is analysed. This emission reduction target covers all EU27 MS and is projected to happen in year 2013 (end of the first commitment period of the Kyoto Protocol) on top of the current legislation. In order to implement it, two policy options have been selected:

- A **regional homogeneous emission standard** of 8% with respect to the baseline. The reduction is equal in relative terms in all European regions, and thus independent from differences in abatement costs (see column 2 of table 2).

Table 2. GHG emissions in 2013: baseline and different emission restriction scenarios [a]

	2013 Baseline MM tonnes CO_2^{eq}	8% Restriction no trade % change w.r.t. baseline	8% Restriction BSAA % change w.r.t. baseline	8% Restriction optimal distribution % change w.r.t. baseline
EU27	578 518	– 8.0	– 7.6	– 7.7
EU25	559 880	– 8.0	– 7.8	– 7.8
EU15	487 671	– 8.0	– 7.2	– 7.7
EU10	72 210	– 8.0	– 11.9	– 4.6
Belgium/Luxemboug	10 791	– 8.0	– 5.0	– 4.6
Denmark	12 828	– 8.0	– 5.0	– 5.1
Germany	87 314	– 8.0	– 5.0	– 5.8
Greece	8 046	– 8.0	0.0	– 3.8
Spain	67 690	– 8.0	– 10.0	– 10.2
France	125 290	– 8.0	– 5.0	– 4.5
Ireland	24 592	– 8.0	– 10.0	– 11.2
Italy	46 542	– 8.0	– 5.0	– 4.5
Netherlands	15 066	– 8.0	– 5.0	– 4.6
Austria	8 881	– 8.0	– 10.0	– 6.2
Portugal	6 312	– 8.0	– 5.0	– 5.1
Sweden	8 193	– 8.0	– 5.0	– 4.4
Finland	6 264	– 8.0	– 5.0	– 3.3
United Kingdom	59 862	– 8.0	– 15.0	– 16.9
Czech Republic	12 690	– 8.0	– 10.0	– 8.2
Estonia	986	– 8.0	– 10.0	– 6.7
Hungary	12 033	– 8.0	– 5.0	– 6.8
Lithuania	7 201	– 8.0	– 15.0	– 11.8
Latvia	2 223	– 8.0	– 15.0	– 11.6
Poland	29 801	– 8.0	– 15.0	– 9.5
Slovenia	2 418	– 8.0	– 10.0	– 10.8
Slovakia	4 122	– 8.0	– 10.0	– 6.6
Cyprus	664	– 8.0	– 10.0	– 2.7
Malta	71	– 8.0	– 10.0	– 10.9
Bulgaria	5 261	– 8.0	– 10.0	– 9.5
Romania	13 377	– 8.0	0.0	– 4.1

[a] Emission inventories for MS have been cross-checked ex post for year 2001 (calibration point of the version of CAPRI used for this study) and the development of emissions up to year 2013 (baseline) directly linked to exogenous drivers (see table 1) affecting activity data and emission factors. Therefore, emission inventories in the baseline might deviate from historival trends on emissions.

Source: CAPRI Modelling System; projection to year 2013

The baseline emissions in CAPRI are calculated based on the emission coefficients published by the Intergovernmental Panel on Climate Change (IPCC), the nutrient content per activity and the projections responding to the most-likely development of the international agricultural markets (see column 1 of table 2).

- In order to find a more suitable solution for balancing the burden of emission abatement, an *ad hoc* **burden sharing agreement for agriculture** (BSAA) is proposed for the EU27, where percentage reductions differ between MS, but are identical for regions inside the same MS. The purpose is to analyse a regionally differentiated emission standard by building 4 clusters of MS with different emission reduction targets (no change, – 5%, – 10% and – 15%, see column 3 in table 2). This clustering is done by trying to close the gap to the actual marginal costs of abatement in the regions, derived from a hypothetical situation of perfect convergence of marginal costs through permit trade with no TC (see column 4 in table 2). With this rationale, the efficiency of the policy measure in terms of welfare is increased.

3.3. Trade of emission permits

In this scenario block, the scenario analysis is enhanced by the explicit implementation of a European market of GHG emission permits from agriculture. With this purpose, information on TC[8] related to existing trading schemes is explicitly considered, since they are meant to have an important effect on the economic performance of such an instrument. Similar to Jorgenson *et al.* (2009), two policy implementation options based on different scopes for trading are considered here:

- **Unrestricted emission trading**. In this scenario, an 8% emission reduction target is enforced for the aggregate of all EU27 regions while trade across regions is allowed without restriction. The original permit distribution is based on the regional emissions in the baseline minus 8%. Variable and fixed TC are introduced, increasing marginal abatement costs. Variable TC are mainly brokerage fees and are paid by permit buyers. In the current study, they are assumed to be 5 € per ton of CO_2 equivalent for purchases within a MS (trade between national agricultural producers) and 10 € per ton for purchases from abroad (trade between agricultural producers in different EU MS). These values are based on estimates from various studies which report handling fees in international trading schemes to be between 2 and 10 % of the transaction value (compilation by Eckermann *et al.*, 2003, p. 16). For the selection of the 'appropriate' values in relation to the final permit price, a simple 'sensitivity analysis' for different values is carried out with the model. Moreover, a further 10 MM € are assumed as institutional costs of the trading scheme (2 MM € per year with 5 years of amortisation). These are also assumed to be paid by permit buyers and therefore distributed over transactions. They are defined based on

---

[8] Transaction costs are those 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).

information found in the literature for clean development mechanism (CDM) and joint implementation (JI) projects in different economic sectors and size of the markets (compilation by Eckermann *et al.*, 2003, pp. 6-8)[9].

- **Restricted emission trading**. In this scenario, an 8% emission reduction target is enforced for all regions within the EU27 but trade is only allowed within countries. The idea is to mimic existing trading schemes in the EU (*e.g.* different trading schemes of milk quotas). The original permit distribution remains the same as in the previous case.

3.4. Model assumptions

The results provided by this emission trading model are linked to some general model assumptions. First of all, full rational behaviour of regional agricultural producers is assumed in CAPRI. Whereas agricultural profit is maximized subject to economic and agronomic constraints, supply and market balances in an open economy have to be cleared out. Secondly, the calculation of GHG emission indicators root in (*a*) the basic economic behaviour of the model, *i.e.* optimal cropping patterns at regional level, (*b*) a balanced nitrogen flow model based on explicit energy requirements and deliveries per agricultural activity, and (*c*) a set of emission factors derived from the literature (IPCC, 2006). Total emissions per MS are, therefore, the result of these three factors. Thirdly, it is important to stress that the information on permit prices is directly linked to the shadow values of the emission constraints included in the regional supply models. Since no additional information on emission prices for the proposed EU trading scheme was available, no additional calibration efforts were done here (contrary to *e.g.* explicit calibration of land prices in certain MS where information was available). Last but not least, TC are assumed to be additional costs for agricultural producers and are linked to the size of the modelled emission trading scheme, as estimated by PriceWaterhouse-Coopers (2000).

4. Selected Results

The overall effect of emission abatement measures on agricultural markets is a reduction in production. This is not very surprising since the emission target mainly leads to a structural response in the regional supply models. Changes in intensity of crop production by adjustment of yields play a far minor role in the current set-up of the supply models. Nevertheless, this effect can vary across activities depending on the emission weight attached by the 'emission accounting system' (income/emission relationship) and regions depending on the substitution possibilities found in each regional model (*i.e.* agricultural income is always maximised subject to constraints). Therefore, we can distinguish the availability of regional resources, such as land (arable,

---

[9] The reader should be aware of the fact that the initial distribution of the permits has an impact on the final distribution if transaction costs are taken into account, so that the Coarse Theorem does not hold. This theorem implies that all parties in a trading scheme can achieve the social optimum if the transaction cost is low, property rights clearly defined and enforced and everyone has full information.

grass and fallow land), the intensity of production and the regional cost structures as the main drivers for results.

The supply effects resulting from the reduction in GHG emissions have a sizeable impact especially on agricultural prices where (*a*) demand elasticities are low, (*b*) EU border protection is high and market access falls under a tariff rate quota, and (*c*) GHG emissions per unit of product are high. All these factors are found in beef markets, where price increases by 16% at EU level in the scenarios. This price increase is also due to the fact that methane emissions from ruminants are an important part of the overall GHG emissions from agriculture, leading to a drop in beef production by around – 5%. The strong impacts for the beef production chain are also due to the milk quota system, *i.e.* milk production and dairy cow herds do not change, instead, milk quota prices drop.

Whereas adjustments for sheep and goat are somewhat smaller, with production falling in the range of – 3%, pork production remains almost stable and poultry production even increases due to substitution effects on the demand side. Supply of cereals also drops in the range of – 6%: On the one hand due to a reaction of lower demand when meat output drops and, on the other hand, due to high opportunity costs for fertilization. The high global warming potential of nitrous oxide, emission restrictions put a higher burden on production of fertilizer-intensive crops. Moreover, the reduced number of ruminants leads to an extensification effect on grasslands, with yields dropping by – 12%, and a reduction in silage maize production by – 6%.

In map 1, the regional abatement costs attached to the imposition of a regional homogeneous emission standard of 8% with respect to the baseline are presented.

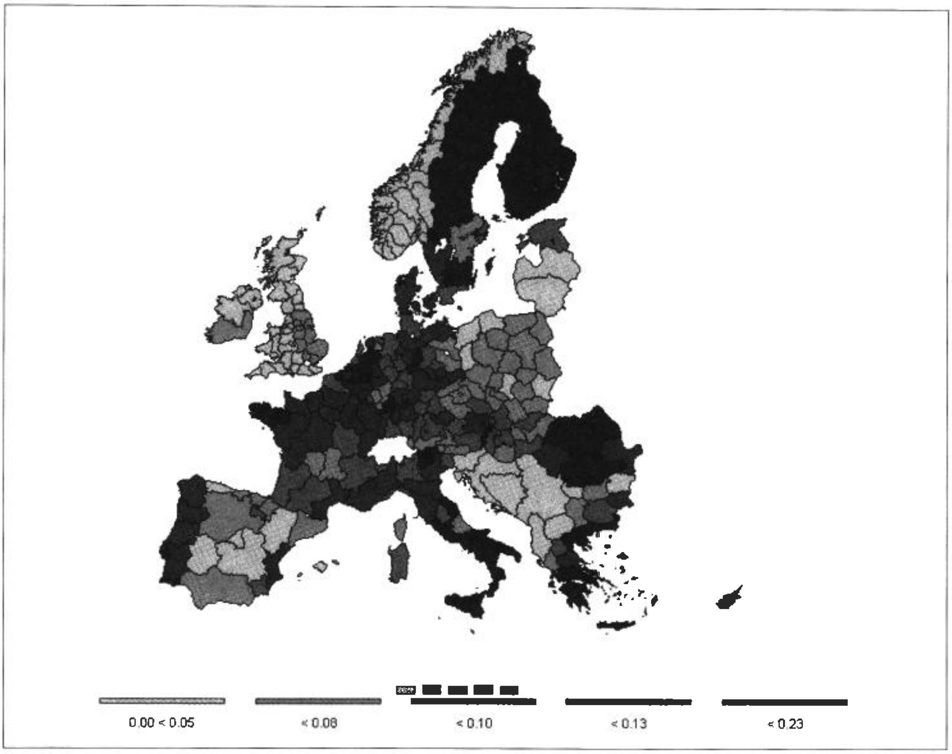
With a homogeneous emission standard at a regional level, the average marginal abatement cost for the EU27 is 95 euros per tonne (€/t) of CO$_2$-equivalents (CO$_2^{eq}$). The regional costs vary between 30 and 230 €/tCO$_2^{eq}$. These results are consistent with the literature. Under similar assumptions, De Cara *et al.* (2005) estimate for the EU15 marginal abatement costs of 123 €/tCO$_2^{eq}$ for an 8% emission standard on methane and nitrous oxide emissions from agriculture in year 2001. By introducing emission taxes their estimates go down to 55.8 €/tCO$_2^{eq}$ (*i.e.* results comparable to an unrestricted permit trading scheme without TC, see table 3).

With a burden sharing agreement at a MS level (see map 2), the average marginal abatement cost for the EU27 drops to 77 €/tCO$_2^{eq}$. The regional variation in marginal abatement costs is reduced with respect to the previous case, as the burden sharing was defined based on marginal abatement costs.

If permit trading is introduced, the average marginal cost for the abatement of a CO$_2^{eq}$ emission in the EU27 varies between 73 € (in the case of no TC), and 89 € in the case of intra-national trade. In table 3, the convergence of prices at MS level is presented. Increases beyond the burden sharing solution are due to taking TC of the trading scheme into account.

This is achieved after several iterations and with the consideration of endogenous market prices for agricultural products. Slight differences in total abatement in the first column of table 3, are due to a lack of full convergence between the emission ceilings

Map 1. **Marginal abatement costs with an emission standard (in thousand €/t CO_2^{eq})**



Source: CAPRI Modelling System; projection to year 2013

implemented in the programming models and the allocation of permits generated by the permit trade module. These differences, however, were considered minimal and did not affect the results. The third column of table 3 actually shows the differences in marginal abatement costs amongst countries (*i.e.* here convergence of permit prices is only achieved within the Nuts 2 regions of a MS). For instance, the EU15 presents considerably higher marginal costs than the EU10 (90 € *versus* 70 €), what is dampened when trade of permits is allowed (77 € *versus* 73 €, see column 2, table 3).

If emission trading is introduced under explicit consideration of TC, the purchases and sales of permits go up to 8.2 MM tCO_2^{eq}. Of this amount, around 90% of the purchases come from abroad and 10% due to trade within national borders, which is explained by the higher differences in marginal abatement costs between different MS. As shown in map 3, most of the regions in France, Netherlands, Denmark and Italy are a net permit buyers, whereas Eastern European regions are permit providers (due to lower marginal abatement costs).

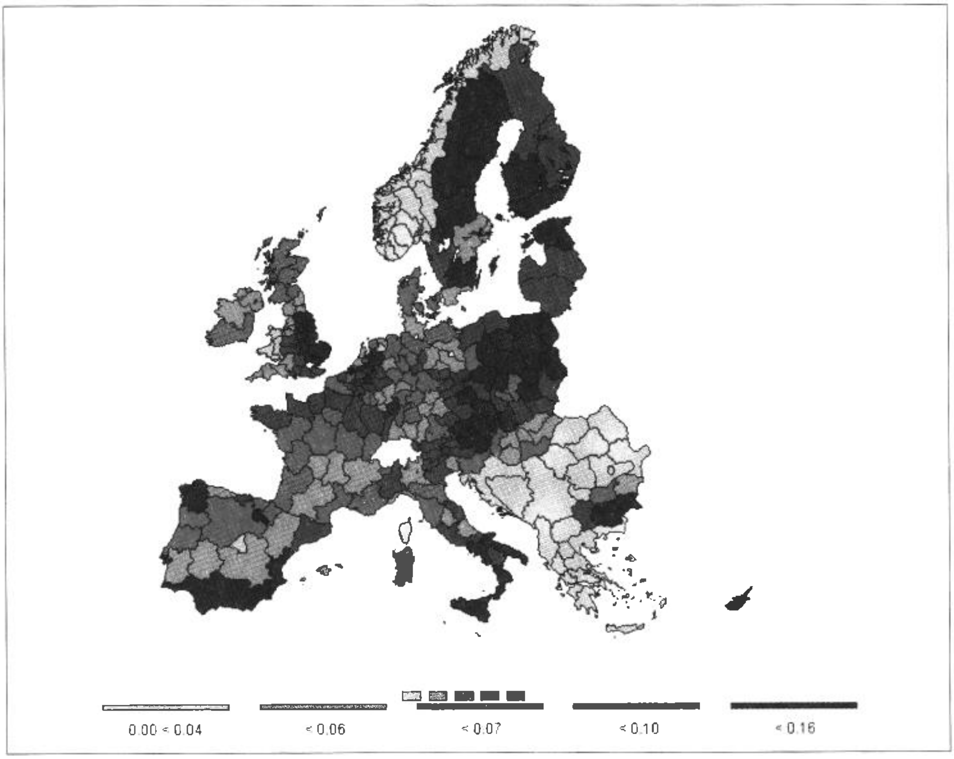
This picture changes when permit trade is restricted and only agricultural producers within a MS are allowed to trade (see map 4). In this case only 3.2 MM tCO_2^{eq} are traded, what also leads to a much less smooth convergence of permit prices between regions (see column 3 in table 3), along with higher average abatement costs for the EU as a whole.

Table 3. **Evolution of regional permit prices under different trade schemes (€/t CO_2^{eq})**

	8% Restriction Trade, No TCs	8% Restriction unrestricted trade, TCs	8% Restriction restricted trade, TCs
EU27	72.9	76.5	85.9
EU25	73.0	77.0	88.0
EU15	73.0	77.0	90.0
EU10	72.0	73.0	70.0
Belgium/Luxemboug	73.0	80.0	121.0
Denmark	73.0	80.0	109.0
Germany	72.0	80.0	98.0
Greece	73.0	82.0	135.0
Spain	73.0	71.0	61.0
France	72.0	80.0	104.0
Ireland	73.0	70.0	56.0
Italy	72.0	80.0	117.0
Netherlands	76.0	80.0	137.0
Austria	72.0	79.0	93.0
Portugal	73.0	81.0	113.0
Sweden	72.0	80.0	127.0
Finland	72.0	80.0	159.0
United Kingdom	73.0	70.0	37.0
Czech Republic	73.0	72.0	72.0
Estonia	73.0	80.0	85.0
Hungary	73.0	79.0	86.0
Lithuania	73.0	70.0	51.0
Latvia	73.0	70.0	52.0
Poland	71.0	72.0	64.0
Slovenia	72.0	70.0	55.0
Slovakia	72.0	78.0	87.0
Cyprus	75.0	80.0	190.0
Malta	72.0	68.0	31.0
Bulgaria	72.0	72.0	65.0
Romania	73.0	80.0	143.0

Source: CAPRI Modelling System, projection to year 2013

Map 2. **Marginal abatement costs with a burden sharing agreement for agriculture (in thousand €/t CO_2^{eq})**



Source: CAPRI Modelling System; projection to year 2013

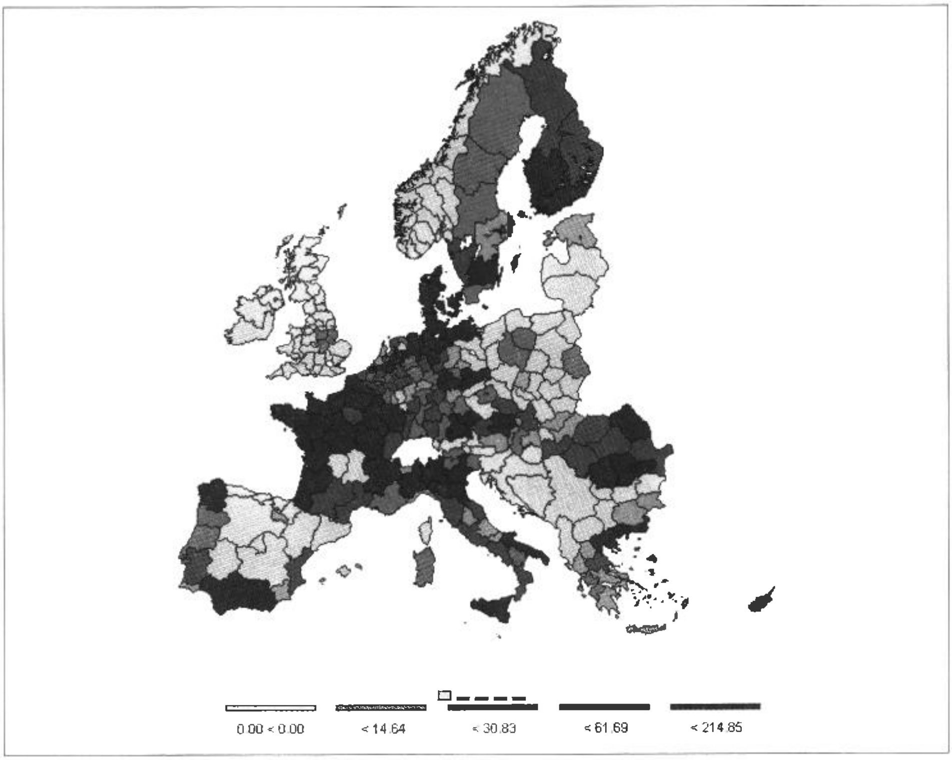
5. Limitations of the study and further research

There are several effects which are not covered in the current analysis worth to be mentioned. Firstly, emission abatement in our model is related strictly to agricultural direct emissions [10] and does neither cover indirect emissions, like *e.g.* related to fertilizer production, nor emissions from other pollutants, like *e.g.* SO_2, nor changing carbon sequestration resulting from changes in land management techniques and introduction of alternative crop rotations (as in Lal, 2004; Reilly and Asadoorian, 2007, p. 178). Secondly, the analysis is restricted to agricultural GHG emissions in EU27, excluding emission leakage due to changes in production in other parts of the world substituting reduced EU production (as in Laurijssen and Faaij, 2009). Accordingly, due to our restriction to agriculture changes in the forestry or energy sectors resulting from adjustment in agricultural production are not considered (as in Böhringer, 2000, p. 780 ; Truong *et al.*, 2007). Moreover, agricultural processing activities for explicit mitigation of GHG emissions, *e.g.* biofuel or biogas production (Gielen *et al.*, 2003, pp. 179-180; Pathak *et al.*, 2009, p. 408) are subject to further

---

[10] As included in paragraph 4 of the official reporting to the UNFCCC by MS.

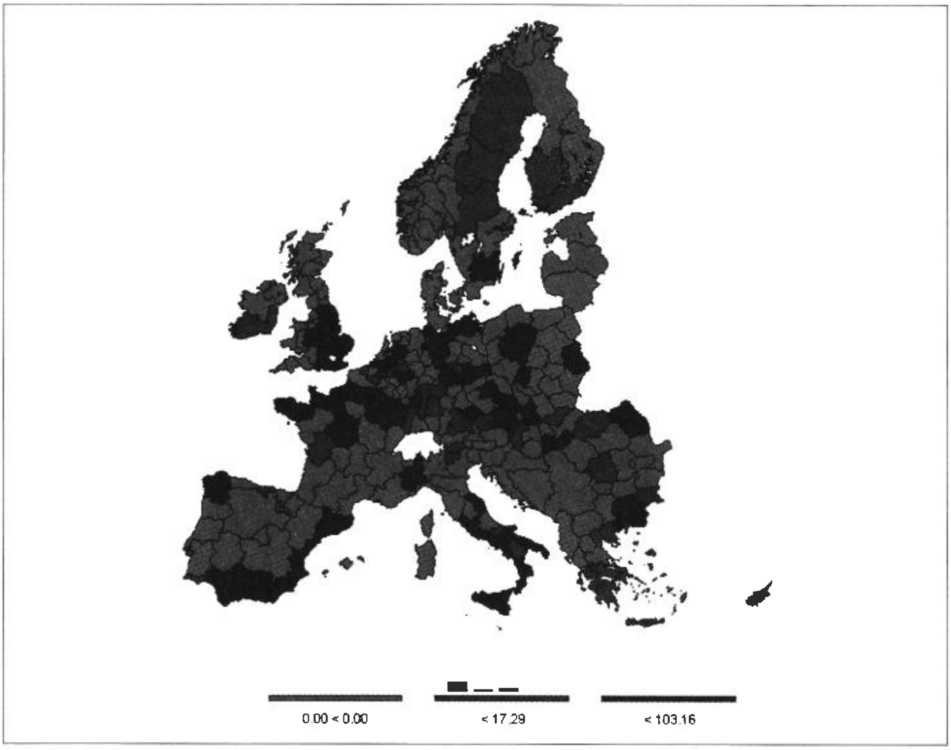
Map 3. **Purchases of emission permits at the regional level with unrestricted trade (trade of permits allowed across Member State borders) (in thousand units)**



Source: CAPRI Modelling System

research. Therefore, in our model emission abatement is mostly related to changes in the farm production program and not to improved process management. The analysis hence builds on a rather simple and straightforward emission accounting scheme and not on on-farm measurements of emissions or more elaborated emission coefficients depending on single processes (as in Moran *et al.*, 2009). However, given the high numbers of agents involved, the high control and administration costs to include in Pan-European Legislation, the presented simplified approach could be more suitable for agriculture (opt-in solution for agriculture, so that farmers or groups of farmers can take part in the climate control schemes based on a rather simple accounting scheme). This is in line with Monni *et al.* (2007, p. 530), who warn of increasing uncertainties and marginal emission reduction costs linked to a too complex extension of the current EU-wide ETS to other sectors and gases.

Map 4. **Purchases of emission permits at the regional level with restricted trade (trade of permits only allowed within Member State borders) (in thousand units)**



Source: CAPRI Modelling System

6. Conclusions

In this paper an EU-wide trading scheme of GHG emission permits from agriculture is proposed. The characteristics are: (*1*) full coverage of EU27; (*2*) distribution of permits between handed out to agricultural producers free of charge and linked to historical emission records, *i.e.* grandfathering; (*3*) regional [11] emission trading only within each country, *i.e.* restricted trade, or also across MS borders, *i.e.* unrestricted trade; (*4*) explicit consideration of TC in trading; and (*5*) no enforcement penalties considered. With this purpose a partial equilibrium model CAPRI has been used.

Moreover, in this paper a burden sharing agreement between the EU27 Members in order to meet a certain target for agricultural GHG emissions in 2013 at EU27 level is explicitly simulated, *i.e.* different emission reduction rates per country. Such an

---

[11] Here it is important to remind the reader that the Nuts 2 spatial aggregation level is the highest resolution available in the CAPRI modeling system and, therefore, used in this study. A higher resolution in space (*e.g.* Nuts 3) could improve the analysis if reliable information would be available. However, EuroStat did not provide time series on yields and activity levels at NUTS 3 level at the time when the model was parameterized.

agreement already exists for the EU at economy wide-scale. The burden sharing agreement analyzed here for agriculture is based on economic efficiency solely, *i.e.* country with low abatement costs must achieve higher reductions. In real world negotiations agreements, other aspects such as "fairness" (*e.g.* regarding chances for economic growth for the poorer MS) and historical events (*e.g.* different industrialization processes in Eastern European countries) play an at least equally important role.

Our analysis sheds light on three different aspects of the GHG emission abatement debate. The first one adds an agricultural perspective to the general discussion. It has been shown that at least when applying a rather simple accounting scheme, abatement costs in agriculture are in a similar or even higher magnitude than in other sectors (70-90 €/tCO_2^{eq} for an 8% emission reduction).

The second important aspect relates to the economic consequences of including agriculture in any GHG abatement scheme. Given in many cases prohibitive most favourite nation (MFN) import tariffs for agricultural and food products, environmental legislation forcing large-scale reduction of agricultural production in Europe leads to sizeable price increases for agricultural products, given a rather inelastic demand. An EU-wide GHG emission ceiling for agriculture, as simulated in our analysis, acts as an implicit supply control for agricultural production as a whole. Analogously to a quota regime, it may lead to a positive quota rent for farmers and agricultural profits could hence increase. The latter will typically come at the cost of an even higher increase in the food bill due to net economic welfare losses from the additional market interventions.

GHG abatement in agriculture via emission restrictions let production costs and food prices increase. With their high expenditure share for food, the highest relative burden will be carried by poorer households. Alternatively, abatement measures in agriculture might be financed by tax regimes, *e.g.* in form of support to farmers for implementing GHG saving technologies. Effects on households of such programs will depend on the direct and indirect tax shares of household income, and probably put a higher burden on richer households.

The increasing effect on price and farm income may be dampened at higher world prices for agricultural products observed during the so-called food crisis in 2007/2008, where EU border protection is no longer such a definitive factor. Equally, the EU agricultural tariffs are to a larger extent specific ones which are slowly being eroded by inflation. Even if thus probably small, the farm income increasing effect should render it attractive to include agriculture in GHG emission strategies as long as supporting farming income is still a major policy objective of the CAP. Design of GHG legislation for agriculture is further eased by the fact that we deal with a global externality linked to many different economic activities. It can hence draw on comparing agricultural MACC to those in other sectors already operating under a trading scheme.

The third aspect relates to implementation issues of policy abatement measures. Whereas there is no doubt that market solutions are superior to standards in a hypothetical world without implementation costs, the picture is far less clear when public and private TC come into play. For the analysis at hand, it is obvious that the control costs for the emission standard or permit trade options would be probably rather similar: crop shares, animal herds and fertilizer sales would need to be monitored at farm level. However, if actual emissions were to be monitored the costs of implementing and controlling the market – public and private ones –, could drastically reduce welfare gains.

References

Armington P.S. (1969) A theory of demand for products distinguished by place of production, IMF Staff Papers 16, 159-178.

Böhringer C. (2000) Cooling down hot air: A global CGE analysis of post-Kyoto carbon abatement strategies, *Energy Policy* 28, 779-789, DOI: 10.1016/S0301-4215(00)00060-4, Elsevier.

Breen J.P. (2008) Simulating a market for tradable greenhouse gas emissions permits amongst Irish farmers, 82nd annual conference of the Agricultural Economics Society, Royal Agricultural College, 31stMarch-2nd April.

Britz W., Witzke H.P. (2008) CAPRI modelling system documentation, University of Bonn, *http://www.capri-model.org/docs/capri_documentation.pdf*.

Britz W., Heckelei T. and Pérez Domínguez I. (2006) Effects of decoupling on land use: An EU wide, regionally differentiated analysis, *Agrarwirtschaft* 55(5-6), 215-226.

Coase R. (1937) The nature of the firm, *Economica, New Series* (4), 386-405.

Commission of the European Communities (2005) Prospects for agricultural markets and income 2005-2012 – Update for EU markets, Brussels, Directorate-General for Agriculture.

Council of the European Union (2003) Council Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, *Official Journal of the European Communities* L275.

De Cara S., Houzé M. and Jayet P.A. (2005) Methane and nitrous oxide emissions from agriculture in the EU: A spatial asessment of sources and abatement costs, *Environmental and Resource Economics* 32, pp. 551-583, DOI: 10.1007/s10640-005-0071-8, Springer.

Eckermann F., Hunt A., Stronzik M. and Taylor T. (2003) The role of transaction costs and risk premia in the determination of climate change policy responses, Diskussionspapier No. 03-59, Zentrum für Europäische Wirtschaftsforschung, pp. 28.

FAO (2003) World agriculture: Towards 2015/2030. A FAO perspective, Rome, Food and Agriculture Organisation.

Gielen D., Fujino J., Hashimoto S. and Moriguchi Y. (2003) Modeling of global biomass policies, *Biomass and Bioenergy* 25, 177-195, DOI: 10.1016/S0961-9534(02)00188-5, Elsevier.

Heckelei T., Wolff H. (2003) Estimation of constrained optimisation models for agricultural supply analysis based on generalised maximum entropy, *European Review of Agricultural Economics* 30(1), 27-50.

Holtsmark B., Maestad O. (2002) Emissions trading under the Kyoto Protocol. Effects on fossil fuel markets under alternative regimes, *Energy Policy* 30, 207-218, DOI: 10.1016/S0301-4215(01)00090-8, Elsevier.

IPCC (2006) 2006 IPCC guidelines for national greenhouse gas inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H., Biennia L., Miwa K., Negara T. and Tanabe K. (eds), Published: IGES, Japan.

Jansson T. (2007) Econometric specification of constrained optimization models, PhD Dissertation, Bonn University, *http://hss.ulb.uni-bonn.de/diss_online, Bonn.*

Jorgenson D., Goettle R., Sing Ho M. and Wilcoxen P. (2009) Cap and trade climate policy and US economic adjustments, *Journal of Policy Modeling* 31, 362-381, DOI: 10.1016/j.jpolmod.2008.09.006, Elsevier.

Jotzo F., Michaelowa A. (2002) Estimating the CDM market under the Marrakech accords, *Climate Policy* 2, 179-196, DOI: 10.1016/S1469-3062(02)00035-9, Elsevier.

Kerr S., Sweet A. (2008) Inclusion of agriculture and forestry in a domestic emissions trading scheme: New Zealand's experience to date, Motu Economic and Public Policy Research, Working Paper 08-04, Wellington, New Zealand.

Lal R. (2004) Agricultural activities and the global carbon cycle, *Nutrient Cycling in Agroecosystems* 70, 103-116.

Laurijssen J., Faaij A.P.C. (2009) Trading biomass or GHG emission credits?, *Climatic Change* 94, 287-317, DOI: 10.1007/s10584-008-9517-7, Springer.

Lennox J.A., Andrew R. and Forgie V. (2008) Price effects of an emission trading scheme in New Zealand, Paper prepared for presentation at the 107th EAAE Seminar 'Modelling of Agricultural and Rural Development Policies', Seville, Spain, 29th January - 1st February.

Löschel A., Zhang Z.X. (2002) The economic and environmental implications of the US repudiation of the Kyoto Protocol and the subsequent deals in Bonn and Marrakech, *Review of World Economics* 138, 711-746, DOI: 10.1007/BF02707659, Springer.

Massot Martí A. (2005) Hacia una nueva PAC: Condicionantes para los mercados de materias primas, ASFAC – IV Seminario de análisis de mercados de materias primas, Barcelona.

Monni S., Syri S. and Pipatti R. (2007) Extensions of EU emissions trading schemes to other sectors and gases: Consequences for uncertainty of total tradable amount, *Water, Air and Soil Pollution: Focus* 4-5, 529-538, DOI: 10.1007/s11267-006-9111-9, Springer.

Moran D., McLeod M., Wall E., Eory V., McVittie A., Barnes A., Rees B., Smith P. and Moxey A. (2009) Marginal abatement cost curves for UK agriculture, forestry, land-use and land-use change sector out to 2022, Paper presented at the Agricultural Economics Society 83rd Annual Conference, Dublin, 31 March – 1 April.

Pathak H., Jain N., Bhatia A., Mohanty S. and Gupta N. (2009) Global warming mitigation potential of biogas plants in India, *Environmental Monitoring Assessment* 157, 407-418, DOI: 10.1007/s10661-008-0545-6, Springer.

Pérez Domínguez I., Wieck C. (2006) Welfare distribution between EU member states through different national decoupling options – Implications for Spain, *Economía Agraria y Recursos Naturales* 6(11), 109-137.

PriceWaterhouseCoopers (2000) A business view on key issues relating to Kyoto mechanisms, UK Department of the Environment, Transport and Regions, London UK.

Radov D., Klevnas P. and Skurray J. (2007) *Market mechanisms for reducing GHG emissions from agriculture, forestry and land management*, London, NERA Economic Consulting.

Reilly J.M., Asadoorian M.O. (2007) Mitigation of greenhouse gas emissions from land use: Creating incentives within greenhouse gas emission trading systems, *Climatic Change* 1-2, 173-197, DOI: 10.1007/s10584-006-9151-1, Springer.

Saddler H., King H. (2008) Agriculture and emissions trading. The impossible dream?, The Australia Institute, Discussion Paper 102.

Springer U. (2003) The market for tradable GHG permits under the Kyoto Protocol: A survey of model studies, *Energy Economics* 25, 527-551, DOI: 10.1016/S0140-9883(02)00103-2, Elsevier.

Stevens B., Rose A. (2002) A dynamic analysis of the marketable permits approach to global warming policy: A comparison of spatial and temporal flexibility, *Journal of Environmental Economics and Management* 44, 45-69, DOI: 10.1006/jeem.2001.1198, Elsevier.

Truong T.P, Kemfert C. and Burniaux J.M. (2007) GTAP-E: An energy-environmental version of the GTAP model with emission trading, Deutsches Institut für Wirtschaftsforschung, Discussion Paper 668, Berlin.

Wieck C., Pérez Domínguez I. and Junker F. (2006) Combining global trade analysis with regional impact assessment: Effects of trade liberalisation under the recent CAP reform, WSU Technical Working Papers, TWP-06-116.