Economic Incentives and Technological Options to Global Warming Emission Abatement in European Agriculture

I. Pérez, K. Holm-Müller[1]

[1] Institute for Agricultural Policy, Bonn University, Germany

Contribution appeared in Arfini, F. (Ed.) (2005) "Modelling Agricultural Policies: State of the Art and New Challenges", proceedings of the 89th EAAE Seminar, pp. 413 - 425

February 2-5, 2005

Parma, Italy

Economic Incentives and Technological Options to Global Warming Emission Abatement in European Agriculture

I. Pérez, K. Holm-Müller

Institute for Agricultural Policy, Bonn University, Germany

Abstract

In this paper, a brief overview on different economic aspects of greenhouse gas emission abatement in European agriculture is given. Three different typologies of emission mitigation approaches are defined and analysed from a modelling perspective: structural, management and technological measures. Their practical implementation in the CAPRI model is then presented and some selected model results used to analyse the following questions: what is the effect of emission abatement regulation on European agriculture? Are there any indirect environmental benefits to be expected from current CAP reform?

Keywords: climate change, agricultural modelling, CAP Reform, emission abatement measures.

Introduction

The climate change externality is nowadays increasingly seen as a relevant issue which encompasses cause and effect relationships in almost all sectors of the economy (inter-sectoral dimension) and world regions (inter-regional dimension). With the ratification of the Kyoto Protocol (KP) to the United Nations Framework Convention on Climate Change (UNFCCC) by Russia on the 4th of November 2004, the implementation of the currently most ambitious time plan towards the reduction of anthropogenic greenhouse gas (GHG) emissions by industrialised countries has been formally initiated. The future environmental and economic effects of this international regulation are, however, uncertain, particularly regarding their distribution along the afore-mentioned dimensions.

This paper concentrates on the contribution of European agriculture to the global warming effect, through indirect emissions of methane (CH_4) and nitrous oxide gases (N_2O), and its abatement possibilities. A partial analysis is justified by the singularities of this sector, which is highly isolated from the rest of the economy (CAP policy umbrella). Moreover, some other reasons justify the analysis of this environmental externality. First of all and according to the estimates of the Intergovernmental Panel on Climate Change (IPCC), agricultural activities contribute in Europe to about 10% of European total GHG emissions, playing therefore an important role in the concentration of GHGs in the atmosphere. Additionally, the complex agricultural policy network and the relative high availability of data in Europe with respect to other world regions offer a chance for modelling approaches in this field.

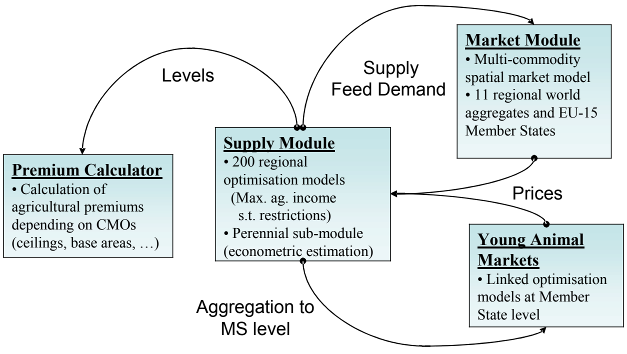
Modelling Issues

The CAPRI Model

In this paper several emission abatement approaches are analysed within a consolidated agricultural model, the CAPRI Model (Institute for Agricultural Policy, Bonn University). CAPRI is a spatial economic agricultural model. It makes use of mathematical programming tools to maximise regional agricultural income with explicit consideration of the main CAP policy variables in an open-economy. This model is designed as a complex projection and simulation tool for the agricultural sector based on: *an activity-based breakdown of regional agricultural production* (50 activities) *and farm and market balances* (60 products and 35 inputs), *economic accounting principles* (according to the definition of the Economic Accounts for Agriculture), *a detailed policy description* (direct payments and their respective ceilings, set-aside obligations, sales quotas, tariff rate quotas, intervention purchases, subsidised exports) and *behavioural functions and allocation mechanisms strictly in line with micro-economic theory* (Britz et al., 2003).

In CAPRI a supply and a market module are distinguished. On the one side, in the **supply module**, regional agricultural supply of annual crops and animal outputs is modelled by an aggregated profit function approach under a limited number of constraints: land, policy restrictions, and feeding restrictions based on requirement functions. The underlying methodology assumes a two-stage decision process. In the first stage, producers determine optimal variable input coefficients per hectare or head (nutrient needs for crops and animals, seed, plant protection, energy, pharmaceutical inputs, etc.) for given yields, which are determined exogenously by trend analysis (data from EUROSTAT). Nutrient requirements enter the supply models as constraints and all other variable inputs, together with their prices, define the accounting cost matrix. In the second stage, the profit-maximising mix of crop and animal activities is determined simultaneously with cost-minimising feed and fertiliser in the supply models. Availability of grass and arable land, as well as the presence of quotas, impose a restriction on acreage or production possibilities. Moreover, crop production is influenced by set-aside obligations and animal requirements (e.g. gross energy and crude protein) are covered by a cost minimised feeding combination. Fertiliser needs of crops have to be met by either organic nutrients found in manure (output from animals) or in purchased fertiliser (traded good). On the other side, the **market module** introduces price-endogeneity in the system. It breaks down the world into

12 country aggregates or trading partners, each one featuring systems of supply, human consumption, feed and processing functions (constrained system of equations). The parameters of these functions are derived from elasticities borrowed from other studies and modelling systems, and calibrated to projected quantities and prices in the simulation year. Regularity is ensured through the choice of the functional form (a normalised quadratic function for feed and supply, and a generalised Leontief expenditure function for human consumption) and some further restrictions (homogeneity of degree zero in prices, symmetry and correct curvature). Policy instruments in the market module include bilateral tariffs and producer or consumer subsidy equivalent price wedges. Tariff rate quotas, intervention sales and subsidised exports under WTO commitment restrictions are explicitly modelled for the EU (Junker, Wieck, Pérez, 2003). Both supply and market modules interact towards the achievement of the optimum (iterative equilibrium) as presented in the following figure:



Source: Britz et al. 2003.

Figure 1. Link of modules in CAPRI

In the supply module, the relevant parametric information needed for the calculation of regional GHG emission factors is estimated. It comprehends the main determinants of regional nutrient flows in the model: feeding-mix, manure output, fertiliser application, etc. An accounting system for the estimation of methane and nitrous oxide emissions based on the IPCC methodology is implemented at a regional level. National greenhouse gas inventories (NGHGIs) are then endogenously estimated and validated through comparison with current reports provided by EU-15 Member States to the UNFCCC (Pérez, forthcoming).

The profit-maximising problem and definition of modelling parameters

As previously mentioned, the supply part of the CAPRI model consists of an agricultural income maximisation problem subject to several restrictions. It can be simplified by the following expression:

$$\begin{array}{l} \max \quad AgInc = f(x) \\ s.t.\ g(x) \leq G \end{array} \quad \Leftrightarrow \quad \frac{\partial AgInc}{\partial x} = 0 = \frac{\partial f}{\partial x} + \lambda \frac{\partial g}{\partial x} \qquad \text{Equation (1)}$$

Where:

AgInc= profit or agricultural income
f = objective function (revenues plus premiums minus costs)
x = activity level (vector of activities)
g = generic expression for all constraints in the model (physical or economic)
G = allowed level of the corresponding restriction
λ = shadow value of the corresponding restriction

In the design of simulation scenarios, this problem is solved ex-post by introducing different shocks in the system. Nevertheless, in order to obtain the necessary information to specify these functions a previous step has to be taken, namely the **calibration of the model**. For this purpose, the whole modelling system is forced to run back through a base year period (costs are calibrated by using classical positive mathematical programming techniques in order to ensure that 'regional revenue is exhausted'). In this calibration stage the model is constrained to meet the information found in the statistics (mainly from the NEWCRONOS and REGIO domains of EUROSTAT), so that activity levels are held constant, and functional parameters are variable. These parameters are then consistently estimated at regional level. This step is quite important in the estimation of static emission factors, since it delivers most of the parametric information needed, as defined by the IPCC (IPCC, 1997 and 2000).

Modelling greenhouse emission mitigation from the CAPRI perspective

Once an economic model is specified and the accounting of GHG emissions defined, mitigation becomes an issue. From a wide perspective, emission mitigation can be achieved through different measures. Oenema et al. differentiate between **structural**, **management** and **technological** mitigation measures. First of all, **structural measures** imply indirect changes in land use caused by the explicit introduction of policy incentives to emission abatement (substitutive effects between agricultural activities). This category comprehends the classical policy abatement instruments: emission standards, carbon taxes and tradable permits (abatement mechanisms foreseen by the KP). **Management measures** imply, however, changes in farming which directly affect agricultural yields (e.g. different tillage or crop rotation, different pasture periods) and require in most cases new investment (e.g. change to organic farming). Finally, **technological mitigation measures** imply explicit investment on abatement technologies, yields not having to be affected (e.g. nitrification inhibitors, manure injection in the field, application of filters in stables). This latter typology of measures might have some external effects on other economic sectors (e.g. 'emission recycling' through bio-gas production).

Modelling structural measures to emission abatement (policy incentives): state of the art

Instruments of emission abatement have gained importance in the last decade due to their consideration by the KP to the UNFCCC, the only serious effort at international level to mitigation of GHG emissions from developed countries. These can be categorized in command-and-control instruments and market-based instruments. The typical command-and-control instrument is the **emission standard**. It has been used by governments to address most environmental negative externalities, such as urban air pollution, nitrogen leaching or methane emissions. As the name indicates, they consist of a 'command' and a 'control' variables. Whereas the former sets a standard or maximum level of permissible pollution, the latter monitors and enforces the implementation of this standard. On the other side, market-based or economic instruments use market signals in form of a modification of relative prices, or a financial transfer, to influence behaviour and get environmental performance rewarded by the market. The typical economic instrument of abatement is the **carbon tax**.

In the following paragraphs the empirical implementation of these two mentioned basic instruments of emission abatement is defined from a modelling perspective:

- Regional emission standards

Emission standards can be modelled by including an additional restriction in the regional supply models. An upper-bound on regional emissions (political emission objective) is included as a constraint in the regional supply models:

$$\begin{array}{l} \max \quad AgInc = f(x) \\ s.t.\ g(x) \le G \\ e(x) \le E \end{array} \quad \Leftrightarrow \quad \frac{\partial AgInc}{\partial x} = 0 = \frac{\partial f}{\partial x} + \lambda \frac{\partial g}{\partial x} + \mu \frac{\partial e}{\partial x} \qquad \text{Equation (2)}$$

Where:

e = greenhouse gas emission (conversion to global warming potentials of methane and nitrous oxide emissions)

μ = shadow value of the emission restriction

E = allowed regional emission level

By following this approach, a percentage emission abatement objective (e.g. Kyoto commitment of 8% for the EU) can be simulated with respect to a historical period. The result is a **non-uniform regional emission standard**, which depends on base year emissions of each regional unit. At the optimum production shifts might occur depending on the emission factors attached to single agricultural activities, so that emission sources are differently affected. The differences in abatement costs faced by producers are reflected on the marginal values of the restriction (μ).

- Emission taxes

From a different perspective incentives to emission abatement can be introduced by taxing polluting activities, i.e. regulation of a tax on carbon-equivalent emissions. Carbon taxes can be modelled by introducing a slight modification of the objective function, as stated in the following equation:

$$f(x) = r(x) - c(x) - e(x) * CarbP \qquad \text{Equation (3)}$$

Where:
r = revenue
c = costs (quadratic functions)
CarbP = carbon price

The carbon tax enters as an additional input cost in the objective function ($CarbP$). By choosing a different carbon price, a different abatement response is achieved at the optimum. Polluters in the regulated region are then assumed to face a **uniform emission tax**, the modelling response being different between them, since production costs are not the same (different emission targets achieved).

It is important to relate both emission standards and taxes. From a modelling perspective, the marginal value of the emission restriction (see equation (2)) is nothing else than an endogenous tax on emissions (non-uniform tax). By applying an economic instrument, such as a carbon tax, marginal abatement costs equalise across polluters and efficiency gains are achieved. The close relationship between these two instruments can be observed by modelling **emission permits**, a further developed economic instrument of emission abatement that follows the equi-marginality principle of taxes (similar abatement costs across polluters) but keeps an environmental target in sight (Pérez, 2004). All these instruments have been already tested and implemented in the CAPRI model.

Modelling management measures to emission abatement: state of the art

As already mentioned, management mitigation measures refer to indirect emission reduction achieved by changes in farming practices. Differently than in the case of structural measures, management measures might just affect a single agricultural activity (no substitution effects between activities) and do not necessary imply a reduction in acreage or number of animals produced but in the yield response of the corresponding activity. In practice, the original maximisation problem does not have to be modified, since the management options considered (e.g. organic farming) imply a splitting of activities (also in the calibration stage). The response of the supply model is therefore more flexible, since farmers/regions are allowed to choose between different bundles of inputs-outputs combinations. In the current version of CAPRI a restricted yield variation is allowed, with emission factors, and therefore emissions per activity, indirectly linked to it. Nevertheless, in order to cover the specific management mitigation instruments found in the literature, an explicit modelling of different management options would be necessary.

Modelling technological abatement options: state of the art

Similarly to the previous case, specific technological abatement options are also available in agriculture. The difference is that these measures usually require important investments in new technology and that the link between the activity and the emissions emitted/abated through the applied measure is not always defined. Moreover, they pretend to reduce GHG emissions, affecting neither land use (structural measures) nor yields (management measures).

A non-exhaustive list of potential technological measures aggregated per agricultural emission sources is provided in the following table.

Emission source	Technological instrument of abatment	Comments
Enteric fermentation (CH_4)	Optimisation of cows lifetime (higher replacement rate)	Investments in production restructuring
	Improvement of feeding (diet manipulation)	Yields might be affected (crossed effect with management measures)
Manure management (CH_4 and N_2O)	Manipulation of storage systems (promotion of aerobic digestion by high C additives)	Calculation at farm or regional level (manure indistinctly coming from different animal activities)
	Introduction of end-pipe systems (filters or ventilation systems)	The additional investment can be attributed to the corresponding activities (if all animals affected)
Rice production (CH_4)	Shortening of flooding period	Yields might be affected
Manure excretion on grazings (N_2O)	Restrictions of cattle grazing	Emission factors depending on climate regions
Synthetic fertiliser application (N_2O)	Application of nitrification inhibitors	Costs directly applicable at activity level
	Improvement of soil drainage	Difficult allocation of investments, calculation at farm or regional level

Source: own representation based on Oenema et al., 2004

Table 1. Technological mitigation measures

The implementation of technological measures in an agricultural model is not as straightforward as in the previous cases. It presents the problem that technologies cannot always be attributed to a single activity (see comments in the previous table) and therefore emissions cannot be defined per activity, what is an advantage since it allows a differentiated response of the model to different emission abatement targets. Moreover, new activities play a very important role in the system, such as bio-energy crops (which are not that well represented in statistics) and a closer link to other economic sectors has to be considered, such as the co-generation of electricity through bio-gas production.

In order to model technological GHG emission mitigation measures in CAPRI, an *endogenous regional technological abatement frontier* could be constructed. Regional specific emission targets should be achieved through the exhaustive application of the available technological abatement options (restricted use per emission source and region), the production level remaining constant. With this purpose emission factors for different technological options at activity, emission source and regional level would have to be defined. At the optimum the minimum costs of abatement for the achievement of a predetermined emission target could be obtained (selection of cost-efficient technological options). Alternatively, by applying the available technological options to the maximum (emission factors not variable) the maximum regional emission abatement potential and its costs could be estimated, as done in other models (e.g. ASMGHG for tillage options).

For the application of this approach, several problems have been detected: lack of regional data at European level for abatement technologies in agriculture (still high uncertainty about their effect on emission reduction), high interaction between activities and sources (additional constraints are necessary), difficult aggregation between emission factors at activity level, farm level and regional level (abatement '*parcelling*') and necessary implementation of new agricultural activities (energy crops). Moreover, the problem of combining structural, management and technological mitigation options is not yet solved.

Effects of emission abatement policy on European Agriculture

In CAPRI, to date, only structural mitigation measures have been consistently modelled at European level (EU-15 disaggregated at a Nuts 2 regional level). In the following figure some estimates of the effects on agricultural supply of a Kyoto-like emission standard (8% emission abatement) on some activity aggregates are given:

Table 2. Supply details for activity aggregates for a 92% uniform regional emission standard (average for the EU-15, year 2001)

	92% GWP emission standard [2001]						
	% deviation to : NGHGIs base year [2001]						
	Hectares or herd size 1000 ha or heads	**Yield** kg /ha or head	**Supply** 1000 t	**Revenues** Euro/ha or head	**Total costs** Euro/ha or head	**Premiums** Euro/ha or head	**Income** Euro/ha or head
Cereals	35306.2	5637.11	199024.85	658.97	302.92	327.42	683.47
	-5.88%	*-0.52%*	*-6.37%*	*3.16%*	*-0.67%*	*2.76%*	*4.76%*
Oilseeds	5012.75	2952.85	14801.9	517	262.03	301.66	556.63
	-5.59%	*-0.04%*	*-5.63%*	*3.74%*	*-1.00%*	*1.66%*	*4.95%*
Other arable crops	6837.75	35577.73	243271.57	3110.65	729.54	355.52	2736.62
	-1.27%	*-0.11%*	*-1.38%*	*1.88%*	*0.33%*	*1.22%*	*2.21%*
All cattle activities	73188.68	2152.72	157554.64	1342.88	792.76	71.26	621.38
	-10.49%	*8.21%*	*-3.14%*	*31.61%*	*18.93%*	*6.63%*	*47.73%*
Beef meat activities	22799.56	209.49	4776.25	916.76	777.5	185.23	324.49
	-16.10%	*6.00%*	*-11.06%*	*37.89%*	*24.12%*	*12.34%*	*59.55%*

Source: CAPRI modelling system, own calculations
In cursive % differences in hectares/herd size, yield and supply w.r.t. to the base year situation
'Cereals': soft wheat, durum wheat, rye, barley, oats, grain maize, other cereals and paddy rice. 'Oilseeds': rape, sunflower, soya, other oils. 'Other arable crops: pulses, potatoes, sugar beet, flax and hemp, tobacco, other industrial crops and other crops. 'All cattle activities': dairy cows high and low yield, heifers breeding, raising calves, fattening calves, heifers fattening low and high weight, male cattle low and high weight and suckler cows (the latter five activities also under the aggregate 'beef meat activities').

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 in the fulfilment of the emission target. Nevertheless, this effect can vary across *activities*, depending on the emission weight attached by the 'IPCC emission accounting system' (income/emission relationship), and *regions*, depending on the substitution possibilities found in each regional model (agricultural income is always maximised subject to constraints). A slight extensification effect can be observed for cereals (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 accused for 'other arable crops' such as pulses, potatoes and sugar beet. For cattle activities, however, higher yields are modelled, so that from an 'emission accounting perspective' it is optimal to increase yields (8%) and further reduce the cattle herd (-10%). Through this intensification effect animals become more efficient in terms of GHG emissions (higher income obtained per emission unit).

Moreover, it can be observed how, parallel to this effect on supply, producer and consumer prices increase, especially for animal products. This is due to the market barriers applied by the European Union on agricultural markets: amongst other measures, tariff rate quotas for cereals and beef remain binding in the different simulation scenarios (MFN tariffs are quite restrictive compared to preferential tariffs). These make imports quite 'steaky' and indirectly transfer the burden to exports, which drop heavily in order to fulfil internal demand. The effect on income is positive, production losses per activity being therefore over-compensated by increases in prices. In the previous table, it can be observed that, whereas revenues increase between 2 to 3% for crop activities, input costs remain more or less constant. For animal activities this effect is even stronger. For example, cattle activities experiment income gains over 40% with respect to the base year situation.

Trends in greenhouse gases after the CAP Reform 2003

For modelling purposes the year 2009 is selected. The CAP Reform 2003 or Luxembourg agreement (LA) is then assumed to be fully implemented (partial decoupling of premiums and modulation of premiums), the WTO current agreements are kept constant and several additional assumptions are incorporated to the model: (1) exogenous development of yields according to DG-Agri market outlooks, (2) rate of input saving technical progress is 0.2% p.a., (3) inflation is 1.9% p.a. and growth of nominal Gross Domestic Product (GDP) for the EU-15 2.7% p.a. and (4) shifts in demand not linked to income or prices changes are trended using ex-post time series on per capita consumption, in most cases in line with data found in the EU Prospects for Agricultural Markets.

After the reduction of intervention prices for subsidised activities (mainly cereals) and the implementation of environmental regulations (set-aside, afforestation, nitrate directive, etc.) in Agenda 2000, some extensification effects have been observed. Moreover, the decoupling options introduced by the CAP Reform are expected to intensify this effect: whereas agriculture in rural areas is protected from abandonment for its environmental benefits, subsidisation leading to over-production is avoided. The effect of this reform on supply and income for the main activity aggregates is shown in the following table:

Table 3. Supply details for activity aggregates (average for the EU-15, year 2009)

	CAP Reform 2003, possible implementation [2009] ***percent deviation to: NGHGIs base year [2001]***						
	Hectares or herd size	**Yield**	**Supply**	**Revenues**	**Total cost**	**Premiums**	**Income**
	1000 ha or hds	kg or 1/1000 head/ha or head	1000 t	Euro /ha or head	Euro /ha or head	Euro /ha or head	Euro /ha or head
Cereals	33272.14	6215.64	206807.59	723.55	359.94	263.35	626.96
	-11.30%	*9.69%*	*-2.71%*	*13.27%*	*18.02%*	*-17.35%*	*-3.90%*
Oilseeds	4831.85	3260.61	15754.75	547.08	311.2	241.45	477.33
	-8.99%	*10.37%*	*0.45%*	*9.78%*	*17.57%*	*-18.63%*	*-10.01%*
Other arable crops	6794.74	41036.54	278832.46	3734.22	892.18	454.62	3296.66
	-1.89%	*15.22%*	*13.04%*	*22.30%*	*22.69%*	*29.43%*	*23.13%*
All cattle activities	80450.88	2046.83	164669.51	937.16	657.92	26.99	306.23
	-1.61%	*2.89%*	*1.24%*	*-8.15%*	*-1.30%*	*-59.61%*	*-27.19%*
Beef meat activities	28550.89	190.45	5437.64	600.66	589.17	58.84	70.33
	5.07%	*-3.63%*	*1.25%*	*-9.66%*	*-5.94%*	*-64.32%*	*-65.42%*

Source: CAPRI Modelling System, own calculations

Supply and income is especially affected for agricultural activities receiving direct payments in Agenda 2000 (oilseeds, cereals and cattle activities). Income losses are less than expected (under premium losses) due to producer price increases. This is mainly caused by a higher pressure on demand (see explanations in the previous section). Although the overall effect is similar (less production) the distribution of changes across activities is different than the one obtained by introducing policy incentives to emission abatement ('highly subsidised activities' are not the same as 'high-emitting activities').

Moreover, the LA has also a relevant side-effect on the shrinking of greenhouse gas (GHG) emissions from agricultural emission sources, as accounted in the CAPRI model.

The following table gives an idea of the effect of policy reform on greenhouse gas emissions. Actually, by implementing the 2003 CAP reform, global warming emissions in agriculture are reduced by 1.8%. This is mainly due a shrinking effect of agricultural production and is differently distributed across gases and sources: since crop activities are more affected by the reduction in premiums, nitrous oxide emissions from mineral fertiliser are further reduced (-10%). This indirect effect of agricultural policy on the evolution of GHG emissions should be taken into account by any targeted measure on emission abatement (e.g. Kyoto Protocol).

Table 4. GHG emissions from agricultural sources in the EU-15 (2001 and 2009)

	Base year: NGHGIs [2001]			**CAP Reform 2003, possible implementation [2009]** ***percent deviation to : NGHGIs base year [2001]***		
	Total	**Amount per ha**	**Impact in GWP**	**Total**	**Amount per ha**	**Impact in GWP**
CH4 enteric fermentation	5820.87	43.1	122238.37	5761.95 *-1.01%*	42.73 *-0.86%*	121000.93 *-1.01%*
CH4 manure management	1758.15	13.02	36921.22	1792.39 *1.95%*	13.29 *2.07%*	37640.13 *1.95%*
CH4 rice production	79.8	0.59	1675.81	80.28 *0.60%*	0.6 *1.69%*	1685.78 *0.59%*
N2O manure management	44.23	0.33	13710.21	45.05 *1.85%*	0.33 *0.00%*	13966.98 *1.87%*
N2O manure on grazings	93.79	0.69	29074.64	93.22 *-0.61%*	0.69 *0.00%*	28897.96 *-0.61%*
N2O from synthetic fertiliser	180.93	1.34	56087.68	161.17 *-10.92%*	1.2 *-10.45%*	49961.33 *-10.92%*
N2O from animal waste	104.88	0.78	32511.8	107.14 *2.15%*	0.79 *1.28%*	33212.74 *2.16%*
N2O crop residue decomposition	30.92	0.23	9583.92	29.61 *-4.24%*	0.22 *-4.35%*	9178.47 *-4.23%*
N2O biological fixation	7.67	0.06	2376.79	7.41 *-3.39%*	0.05 *-16.67%*	2297.51 *-3.34%*
N2O from atmospheric deposition	48.73	0.36	15105.57	49.37 *1.31%*	0.37 *2.78%*	15304.24 *1.32%*
N2O total emissions	511.13	3.78	158450.62	492.97 *-3.55%*	3.66 *-3.17%*	152819.23 *-3.55%*
CH4 total emissions	7658.83	56.71	160835.4	7634.61 *-0.32%*	56.61 *-0.18%*	160326.84 *-0.32%*
Global Warming Potentials	319286.02	2364.24		313146.07 *-1.92%*	2322.12 *-1.78%*	

Source: CAPRI Modelling System, own calculations

Conclusions

In this paper, the contribution of agriculture to the European Climate Change Program (ECCP) in its current and future policy framework is briefly highlighted by implementing an emission accounting system in an economic programming model. Moreover, different approaches to emission mitigation in agriculture are briefly analysed from a modelling perspective and the main problems found in their implementation highlighted. Results show how current policy incentives might have relevant income effects on European agriculture and how current reform efforts indirectly contribute to the objectives set by the Kyoto Protocol. This crossed-effects should be taken into account in the future negotiations on climate change mitigation.

References

Junker F., Wieck C., Jansson T. and Pérez I. (2003): *Policy Description in the CAPRI Model*, Working Paper 03-03, CAP-STRAT Project, Institute for Agricultural Policy, Bonn.

Britz W., Pérez I. and Wieck C. (2003): "Mid-Term Review Proposal Impact Analysis with the CAPRI Modelling System", in *Mid-Term Review of the Common Agricultural Policy*, July 2002 Proposals Impact Analyses, European Commission, Directorate-General for Agriculture ed., pp. 111-140, Brussels.

Pérez I. (forthcoming in 2005): *Greenhouse Gases: Inventories, Abatement Costs and Markets for Emission Permits in European Agriculture: A Modelling Approach*, PhD Thesis, Institute for Agricultural Policy, Bonn University.

Pérez I. (2004): "Europaweite Reduktion des Ausstoßes klimarelevanter Emissionen durch handelbare Emissionsrechte. Eine Analyse mit dem regionalisierten Agrarsektormodell CAPRI", Paper presented at the Conference of the German Association of Agricultural Economists (GeWiSoLa), Hohenheim, Germany.

IPCC (1997): *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, *Workbook and Reference Manual*, Paris.

IPCC (2000): *Good Practice Guidance and Uncertainty Management in National Greenhouse gas Inventories*, Japan.

Oenema O., Kukman P., and Velthof G. (2004): "Assessment and Mitigation of Greenhouse Gas Emissions at Farm Level", Paper presented at the International Conference on *Greenhouse Gas Emissions from Agriculture – Mitigation Options and Strategies*, February 10-12: 172-178, Leipzig.