Mitigating GHG emissions from EU agriculture – what difference does the policy make?

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Abstract

The contribution of the agricultural sector to climate change is gaining more and more visibility and therewith, interest is growing on policy options to induce agricultural GHG mitigation. However, so far only little is known about the different impacts of specific policies on GHG mitigation on the one hand and agricultural production and markets on the other hand. This paper provides an empirical analysis of the impact of three alternative abatement policies (implementing an emission standard, tradable emission permits and a livestock emission tax) to reduce agricultural GHG emissions in the EU. The policy scenarios are designed to achieve a 20% reduction of EU agricultural GHG emissions in 2020 compared to 2004.

Projection results show that emission reduction effects per EU Member State in each scenario are quite different from the EU average, depending on the production level and the composition of the agricultural activities. Moreover, the policy instrument chosen makes a considerable difference with regard to effects on production, cost-effectiveness and income redistribution within the agricultural sector. It is also highlighted that an effective emission reduction commitment in the EU would be diminished due to a shift of emissions from the EU to the rest of the world (emission leakage), mainly as a result of higher net imports of feed and animal products. The estimates provided can feed the discussion on the feasibility of integrating the agricultural sector in multi-sectoral emission abatement policies currently in place (e.g. EU emission trading directive) or under consideration.

Keywords: GHG emissions, EU, agricultural sector, mitigation policies, CAPRI model

1 Background

Agricultural greenhouse gas (GHG) emissions account for almost 14% of global emissions. The agricultural sector is especially a large contributor of non-CO2 GHG emissions, namely methane (CH_4) from ruminants and nitrous oxide (N_2O) from fertilizer application and management. In the European Union (EU) GHG emissions reported in the agriculture sector represent 9.2% of total EU emissions, with methane and nitrous oxide accounting for around 5% and 4.2% of total European GHG emissions respectively (European Commission, 2009). In general, the contribution of the agricultural sector to climate change is gaining more and more visibility and therewith interest is growing on policy options to reduce agricultural GHG emissions (FAO 2006; Smith et al. 2007; FAO 2010). To design reasonable mitigation policies it is important to understand the impact of such policies on GHG mitigation on the one hand and agricultural production and trade on the other hand. However, so far there is hardly any empirical evidence on the possible impacts of specific agricultural GHG abatement policies on production and agricultural commodity markets.

Against this background this paper assesses the implications of three alternative policy options (implementing an emission standard, tradable emission permits and a livestock emission tax) to reduce agricultural GHG emissions in the EU. The policy scenarios are designed to achieve a 20% reduction of agricultural GHG emissions in 2020 compared to 2004, following the latest non-binding emission reduction proposal of the Copenhagen Accords in 2009.[1]

[1] Note: The policy scenarios presented in this paper were conducted in course of the study “Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS)” (see Leip et al., 2010). It has to be mentioned that in the meantime the CAPRI model used for the GGELS study and the paper at hand has been further elaborated and some of the policy scenarios have been adjusted. Thus, latest results may be obtained from Pérez Domínguez et al. (2012).

2. Specification of the modelling approach and overview on the simulation scenarios

In order to calculate the emission scenarios, the CAPRI modelling system (Common Agricultural Policy Regional Impact Analysis) was applied. CAPRI is an economic large-scale comparative-static agricultural sector model with a focus on EU-27, but covering global trade of agricultural products as well. CAPRI consists of two interacting modules: the supply module and the market module. The supply module consists of about 250 independent aggregate optimisation models representing all regional agricultural activities in a Nuts 2 region (28 crop and 13 animal activities). 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 (e.g. production quotas). The non-linear cost function allows for perfect calibration of the models and a smooth simulation response rooted in observed behaviour[2] (cf. Britz and Witzke, 2008; Pérez Dominguez et al., 2009)

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. 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. The link between the supply and market modules is based on an iterative procedure (cf. Britz and Witzke, 2008; Pérez Dominguez et al., 2009).

The regional supply models in CAPRI capture links between agricultural production activities in detail. The modelling system was adapted to be able to calculate activity based agricultural emission inventories. Based on the differentiated lists of production activities, inputs and outputs define GHG emission effects of agriculture in response to changes in the policy or market environment. CAPRI incorporates a detailed nutrient flow model per activity and region (including explicit feeding and fertilizing activities, i.e. balancing of nutrient needs and availability) (for more information see Pérez Dominguez 2006; Leip et al., 2010). With this information, CAPRI is able to calculate endogenously GHG emission coefficients following the IPCC guidelines (mostly Tier 2, cf. IPCC, 2008). Furthermore the optimization structure of the supply module enables CAPRI to conduct detailed mitigation policy scenarios for the EU-27 regional aggregate (i.e. emission limits introduced as constraints within the existing non-linear optimization framework).

The emission mitigation scenarios for this paper are constructed by selecting a restricted number of policy options, including regulatory tools and market based instruments for emission abatement. The presented analysis explores what could happen if policies that explicitly force farmers in the EU-27 to reach certain GHG emission reduction targets would be implemented[3]. For this, three main sets of emission abatement scenarios are examined: the implementation of an emission standard, an emission tax on livestock and tradable emission permits. Apart from the reference scenario, which assumes that GHG emissions continue to be determined as in the past (i.e. trend-based), the policy scenarios are characterised by a target of 20% GHG emission reduction in the year 2020 compared to EU-27 emissions in the base year 2004, which in CAPRI is represented as the three-year average of 2003-2005. An overview on the reference and mitigation policy scenarios is given in Table 1.

[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 annual crops not covered by the estimation, exogenous own supply elasticities are used, which are based on typical mean supply elasticities.

[3] These policy scenarios are rather hypothetical and do not reflect mitigation policies that are already agreed on, or are under formal discussion.

Table 1: Overview on the reference and mitigation policy scenarios (projection year is 2020)

Scenario acronym	Scenario Name	Policy Instrument	GHG abatement
REF	Reference Scenario	No specific policy measures implemented for GHG emission abatement in agriculture	Trend-driven
STD	Emission Standard Scenario	Emission standard with a regionally homogeneous cap (no trade in emission rights)	20% reduction with respect to EU-27 emissions in the year 2004
ETSA	Emission Trading Scheme for Agriculture	Tradable emission permits (regionally homogenous cap, with trade in emission rights at regional and EU-wide level)	
LTAX	Livestock Emission Tax Scenario	Emission tax on livestock (regionally homogenous taxes per cow, sheep and non-ruminants)	

3 Definition and major results of the scenarios

In this chapter the reference and mitigation policy scenarios are briefly described and major scenario results are delineated.[4]

Reference Scenario (REF)

The reference scenario (also called baseline) can be interpreted as a projection in time that does not intend to constitute a forecast of what the future will be, but represents a description of what may happen under a specific set of assumptions and circumstances, which at the time of projections were judged plausible. The REF Scenario serves as comparison point in the year 2020 for counterfactual analysis of the mitigation policy scenarios.

The REF scenario assumes status quo policy and includes future policy changes already agreed and scheduled in the current legislation, based on the information available at the end of summer 2010. Hence, the reference scenario incorporates a full implementation of the Health Check and the biofuels directive, as well as the sugar and milk market reforms. However, although the agricultural sector is included in the GHG emission reduction obligation of the so-called climate and energy package of 2009, no explicit policy measures are considered for GHG emission abatement in the REF scenario.[5]

The development of emissions of individual gases and carbon dioxide equivalents (CO2-eq) for all EU Member States from the 2003-2005 base period to the projection year 2020 are presented in Table 2. Overall reduction in CO2-eq is projected to be -6.8% in the EU-27, with a decrease in methane emissions of -15% while the reduction in nitrous oxide is projected to remain at -0.4%. With the exemption of Malta, Spain and the Netherlands, a reduction in total emissions can be observed in all countries. The current baseline implies a somewhat higher reduction in the EU-12 compared to EU-15. However, given that GHG emissions in EU-15 in the base year are almost five times higher than in EU-12, the reduction in EU-15 from 2004 to 2020 is more significant in absolute terms.

For the EU-15 the reduction of methane emissions in the reference scenario is projected at -11.7%, with highest reductions achieved in Denmark (-21.3%), Germany (-21.1%) and Sweden (-31.8%) whereas Spain and the Netherlands are projected to increase methane emissions by 0.6 and 3.3% respectively. The EU-10 and Bulgaria/Romania are projected to experience methane emission reductions of -34.3% and -31% respectively, with Malta being the only Member States (MS) increasing methane emissions (+5.3%) and Cyprus (-1.3%) and Slovenia (-18.6%) being the only MS achieving reductions less than -20%.

[4] Tables with complete information could be presented upon request.

[5] While MS actually have binding GHG emission abatement targets that also include agriculture, there are so far no explicit policy measures implemented that would specifically force GHG emission abatement in the agricultural sector. Consequently, no explicit policy measures for GHG emission abatement are considered in this reference scenario.

The changes in emissions of nitrous oxide are projected to be -0.4% for the EU-10, -10.2% for Romania/Bulgaria and +0.4% for the EU-15. However, in the EU-10, Estonia, Hungary, Lithuania and Malta are projected to increase nitrous oxide emissions. From the EU-15, the only countries projected to experience nitrous oxide emission increases are France, Germany, Ireland and Spain.

Further scenario results reveal that the general emission reduction at EU level is mostly based on reduced emissions linked to reductions in the number of ruminants (which leads to reductions of CH_4 from digestion and N_2O from grazing). With the exception of the Netherlands, all countries are projected to decrease their dairy herd size (EU-15: -10%; EU-12: -35%). The decrease in dairy herd size can be mostly attributed to pressure of declining prices on the one hand, and increases in milk yields on the other hand. For the beef and the sheep sectors also significant decreases in herd sizes are projected. These reductions are mainly due to reduced policy incentives for beef cattle and sheep after the conversion of coupled supports for beef production into (mainly) decoupled payments, and the reform in the dairy market. For the crop sector scenario results show that crop yields continue to grow moderately, provoking an increase in GHG emissions linked to crop residues, and to lesser extent, to the application of mineral nitrogenous fertilizers.

Table 2: Change in emissions per EU Member State between 2004 and 2020

	Base Year (2004)			REF Scenario (2020)		
	CH_4 [MMt CO2eq]	**N_2O** [MMt CO2eq]	**CO_2eq** [MMt CO2eq]	**CH_4** [% to BAS]	**N_2O** [% to BAS]	**CO_2eq** [% to BAS]
Austria	4.3	3.9	8.2	-15.9	0.0	-8.4
Belgium-Lux.	5.5	5.6	11.2	-4.9	0.6	-2.1
Denmark	5.3	6.9	12.2	-21.3	-11.6	-15.8
Finland	2.0	7.7	9.7	-14.7	-3.9	-6.2
France	37.5	45.3	82.8	-14.5	4.5	-4.1
Germany	32.2	34.3	66.6	-21.1	4.4	-8.0
Greece	3.3	3.3	6.5	-7.3	-15.1	-11.2
Ireland	11.8	11.5	23.3	-6.3	6.3	-0.1
Italy	17.7	17.0	34.8	-6.3	-5.0	-5.6
Netherlands	9.0	10.6	19.6	3.3	-2.7	0.0
Portugal	3.6	3.2	6.8	-13.8	-9.6	-11.9
Spain	18.7	20.8	39.5	0.6	7.5	4.2
Sweden	3.8	6.4	10.2	-31.8	-3.4	-14.0
United Kingdom	22.0	39.4	61.4	-12.1	-4.7	-7.3
EU-15	176.8	215.9	392.8	-11.7	0.4	-5.1
Cyprus	0.3	0.2	0.5	-1.3	-1.3	-1.4
Czech Republic	2.9	4.4	7.3	-53.7	-8.0	-25.9
Estonia	0.6	0.7	1.2	-47.8	6.8	-17.7
Hungary	2.0	5.8	7.8	-42.2	2.1	-9.5
Latvia	0.8	1.5	2.2	-42.1	-2.1	-16.0
Lithuania	1.8	3.1	4.8	-34.9	5.9	-9.1
Malta	0.0	0.0	0.1	5.3	14.3	8.6
Poland	11.2	21.8	33.1	-27.5	-2.5	-11.0
Slovac Republic	1.1	1.5	2.6	-49.1	-8.4	-25.4
Slovenia	0.9	0.9	1.8	-18.6	-5.6	-12.2
EU-10	21.5	39.9	61.5	-34.3	-1.9	-13.3
Bulgaria	2.2	2.8	5.0	-34.2	-12.0	-21.8
Romania	8.7	8.1	16.8	-30.2	-9.6	-20.2
BUR	10.9	10.9	21.8	-31.0	-10.2	-20.6
EU-27	209.3	266.8	476.1	-15.0	-0.4	-6.8

BAS: Base year 2004 (3-year average 2003-2005). REF: Reference Scenario. MMt: Million Tons

Emission Standard Scenario (STD)

Command and control (CAC) policy instruments are the most commonly used instruments to address environmental negative externalities such as urban air pollution, nitrogen leaching or methane emissions. CAC regulation commonly uses the setting of standards, i.e. a mandated level of performance that is enforced by law. There are different types of standards, however in this scenario we focus on emission standards that put a 'cap' on the level of GHG emissions.

In this STD scenario a regionally homogenous 'cap' is set on GHG emissions from agriculture in the EU-27. The level of GHG emissions will be reduced by 20% in the year 2020 compared to emissions in the year 2004. The emission reduction targets are equally applied across all regions at Nuts 2 level and are assumed to be binding in year 2020 on top of the legislation lined out in the reference scenario.

Table 3 presents the changes in GHG emissions between the STD scenario and the REF scenario (changes in year 2020). The first figure to look at is the total reduction of GHG emissions for the EU-27 measured in CO_2eq (-13.7%), which is about the additional emission reduction commitment necessary to achieve an overall -20% 'cap' on GHG emissions (keeping in mind that the reduction in GHG emissions in REF is already -6.8%).[6]

Table 3: Change in cow milk, beef and cereals production per EU Member State according to the Emission Standard Scenario

STD Scenario (2020), % change to REF						
	Production			GHG emissions		
	Milk	Beef	Cereals	CH_4	N_2O	CO_2eq
Austria	-3.8	-17.5	4.2	-13.6	-11.1	-12.3
Belgium-Lux.	-4.7	-18.9	-5.1	-16.3	-16.9	-16.6
Denmark	-1.9	-24.6	4.3	-4.3	-3.2	-3.6
Finland	-2.3	-13.6	-9.6	-6.8	-16.4	-14.6
France	-3.4	-14.3	-9.3	-15.1	-16.4	-15.9
Germany	-2.5	-22.5	-10.8	-9.1	-14.9	-12.5
Greece	-3.7	4.0	-4.4	-9.8	-8.9	-9.4
Ireland	-3.1	-20.3	-7.2	-20.3	-18.7	-19.5
Italy	-5.1	-15.6	-10.8	-14.2	-15.0	-14.6
Netherlands	-8.4	-15.0	-18.4	-16.2	-21.4	-18.9
Portugal	-2.9	2.5	18.9	-7.4	-10.7	-9.0
Spain	-4.0	-20.8	-14.4	-23.1	-22.0	-22.5
Sweden	-1.0	-6.8	-0.9	-3.4	-8.1	-6.7
United Kingdom	-1.7	-7.9	2.1	-8.6	-15.2	-12.9
EU-15	-3.6	-15.9	-8.0	-13.8	-15.9	-15.0
Cyprus	-8.8	-5.4	-7.6	-20.6	-14.7	-17.6
Czech Republic	0.1	8.6	8.9	3.4	1.9	2.3
Estonia	-2.9	-8.3	7.3	-3.9	0.0	-1.3
Hungary	-4.4	-1.6	-6.6	-8.1	-11.4	-10.9
Latvia	-3.1	3.9	8.8	-1.1	-3.7	-3.2
Lithuania	-5.1	-5.2	-0.7	-4.9	-12.3	-10.4
Malta	-14.0	-21.1	-79.3	-28.0	-25.0	-25.2
Poland	-6.7	-16.9	-9.4	-11.0	-11.3	-11.2
Slovac Republic	1.0	17.3	5.5	6.8	2.5	3.8
Slovenia	-2.5	6.1	-1.6	-7.7	-8.5	-8.0
EU-10	-4.9	-8.4	-4.2	-7.8	-9.0	-8.7
Bulgaria	-0.1	2.6	3.3	0.8	-0.9	-0.2
Romania	-0.5	0.0	2.9	-1.2	-0.7	-0.9
BUR	-0.4	0.6	3.0	-0.8	-0.7	-0.8
EU-27	-3.6	-14.8	-6.4	-12.8	-14.4	-13.7

REF: Reference Scenario. STD: Emission Standard Scenario

It is interesting to see in Table 3 how the model allocates the emission 'cap' differently to gases and MS after clearance of agricultural markets. First of all, higher emission reductions are observed in the EU-15 than in the EU-10 and BUR. This is due to the fact that several EU-10 countries do not need to face the full 'cap' (on average -8.7%), since their baseline emissions are considerably lower than the base year emissions (e.g. the Czech and Slovak Republic are even allowed to increase emissions compared to the baseline projections). Within the EU-15 aggregate, higher emission

[6] The three defined GHG emission abatement policy scenarios could be designed to almost achieve the reduction goal of 20% emission reduction compared to the reference year (+ 0.01 error margin tolerated).

reductions are coupled to lower degree of production substitution possibilities and lower production margins (e.g. beef production in Spain and Ireland). Secondly, in EU-27 the N_2O emissions (-14.4%) are on average more affected than CH_4 emissions (-12.8%). This has to do with the fact that on average it is more costly for farmers to achieve the emission standard through the reduction of CH_4 emission activities compared to N_2O-emitting activities. Further modelling results indicate that the highest reductions (taking absolute terms into account) are achieved in N_2O emissions from mineral fertilizer application. Therefore, an optimal strategy for farmers to cope with the emission standard is to move to more extensive arable and fodder production (less nitrogen input required).

Taking into account the considerable emission cap introduced, cereal areas are expected to decrease only moderately (-7%) in the EU-27, with proportionally higher decreases in the EU-15 than the EU-12. With almost no changes in yields at EU-27, the reduction in cereals area results in a decrease in cereal production of -6.4%. The net exporter position of the EU-27 (mostly coming from the EU-15) is weakened since demand drops less than supply; imports of cereals decrease by -3 MM t cereals and exports by -10.6 MM t (net effect of -7.6 MM t).

Dairy herds decrease by 4% on average for the EU-27. When taking absolute size of dairy herds into account, highest changes are projected to be in the Netherlands (-9%) and in Poland (-7%). The main two drivers for these results are the high profitability of cattle systems (the emission standard puts a higher burden on high productive systems) and the composition of the cattle herd in the respective MS. For instance, the Netherlands has a much larger dairy herd than beef herd, and consequently production losses are higher for dairy cattle. Milk production follows the dairy cattle changes, with a decrease of 3.6% at EU-27 level.

Beef cattle is the activity most affected by the emission standard. The reductions in herd sizes are in the range of -26% for the EU-27 (with -40% for Denmark, -38% for Spain and Ireland -36% as highest values). Beef meat yields also contract by about -3% and beef production is projected to decrease by about -15%. However, the large production decline in the cattle sector leads to higher prices and also to higher incomes for all (remaining) cattle activities. This is also the case for the arable sector, with utilised agricultural area decreasing by -5% (the increase in fallow land does not fully compensate the losses in fodder and arable areas) and cereal production by -6.4%, whereas income for the cereal sector is procjected to increase on average by 18.5%.

Tradable Emission Permits Scenario (ETSA)

In 2005 the EU launched a coordinated Emission Trading Scheme (ETS) over all MS within the EU. To date, the EU ETS is only applied to industrial and energy producing activities, but other sectors might be included in the future with a view to further improving the economic efficiency of the scheme through possible amendments (European Council, 2009).

The possible inclusion of agriculture in an existing Emission Trading Scheme (ETS) or alternatively the implementation of an ETS explicitly for the agricultural sector is an issue that is already controversially discussed in several countries (cf. Breen, 2008; Kerr and Sweet, 2008; Lennox et al., 2008; Saddler and King, 2008). In an ETS GHG emissions of all participants are limited and target amounts (‘caps’) are decided on, usually amounting to less emission than encountered at present. According to the allocation procedure participants are assigned a certain amount of emission rights for a certain period. Each participant can then decide to either make use of the permits to emit or trade them with other participants.

This tradable emission permits scenario assumes the explicit implementation of an Emission Trading Scheme for Agriculture (ETSA) in the EU-27, with the target to achieve a 20% GHG emission reduction in the year 2020 compared to 2004. Therefore a regionally homogeneous emission 'cap' is set on total GHG emissions in all Nuts 2 regions. According to this 'cap' and historical emission levels the emission permits are allocated to agricultural producers (1 permit equals 1 ton of CO_2^{eq}, where CH_4 and N_2O emissions from agricultural sources are considered). Trade of emission permits is allowed between regions (i.e. Nuts 2 level), MS and EU-27 wide level. Hence, regions specialised in livestock production are allowed to trade with regions specialised in arable production.

For this ETSA scenario we explicitly consider additional information on transaction costs (TC) related to existing emission trading schemes, since TC are expected to have an important effect on the economic performance of such a policy instrument as tradable permits.[7] In the ETSA, farmers would be directly trading emissions with each other, but not with other sectors (isolated market). Although we are talking about fairly small entities, EU farms are already subject to large reporting obligations in terms of nutrient loads and activity numbers. Thus in a hypothetical stock market for emissions, additional TC could be kept at reasonable levels. In our exercise, variable TC consist of mainly brokerage fees and are paid by permit buyers. In the scenario TC are assumed to vary around 5% of the transaction value (cf. Eckermann et al., 2003). For the selection of the 'appropriate' TC value in relation to the final permit price, a sensitivity analysis for different values was carried out with the model. Moreover, institutional costs of the trading scheme (approximately 50 Million Euro) are assumed as fix costs for setting up and maintaining the emission trading market. These fix costs are also assumed to be paid by permit buyers and therefore distributed over transactions (cf. Eckermann et al., 2003; Pérez Dominguez et al., 2009).

Table 4: Change in cow milk, beef and cereals production per EU Member State according to the Emission Trading Scheme for Agriculture Scenario

	ETSA Scenario (2020), % change to REF					
	Production			GHG emissions		
	Milk	Beef	Cereals	CH_4	N_2O	CO_2eq
Austria	-2.5	-11.7	2.9	-9.2	-7.8	-8.5
Belgium-Lux.	-2.0	-9.5	-3.4	-8.4	-9.8	-9.1
Denmark	-2.9	-25.1	1.0	-8.4	-6.7	-7.4
Finland	-3.2	-15.8	-20.4	-11.1	-26.4	-23.5
France	-1.4	-5.6	-3.3	-6.7	-9.2	-8.2
Germany	-2.2	-18.8	-6.3	-7.8	-11.0	-9.6
Greece	-1.8	4.1	-4.8	-7.3	-7.6	-7.5
Ireland	-3.3	-20.2	-9.9	-20.4	-18.6	-19.5
Italy	-1.4	-4.0	-5.0	-5.8	-7.8	-6.8
Netherlands	-2.2	-5.8	-1.2	-5.1	-7.9	-6.6
Portugal	-2.9	-3.1	-0.9	-12.9	-18.2	-15.5
Spain	-3.0	-12.0	-7.7	-12.7	-14.9	-13.9
Sweden	-2.1	-13.0	-11.4	-8.5	-16.4	-14.0
United Kingdom	-3.3	-18.2	-0.8	-19.5	-37.8	-31.6
EU-15	-2.2	-11.3	-4.7	-10.3	-16.2	-13.8
Cyprus	-5.9	1.6	6.0	-12.9	-9.3	-10.8
Czech Republic	-4.2	-17.4	-8.0	-11.3	-13.6	-13.0
Estonia	-8.6	-36.0	-6.0	-19.4	-16.6	-17.4
Hungary	-4.5	-2.1	-5.2	-8.2	-10.6	-10.2
Latvia	-10.4	-15.7	-16.1	-15.3	-22.2	-20.6
Lithuania	-7.8	-7.6	-7.3	-9.0	-18.0	-15.6
Malta	-6.7	-2.7	-41.4	-12.4	-12.5	-11.5
Poland	-7.4	-18.3	-7.3	-11.7	-11.1	-11.3
Slovac Republic	-2.5	4.8	0.8	-2.6	-5.8	-4.8
Slovenia	-3.4	-1.0	4.9	-13.4	-11.8	-12.5
EU-10	-6.6	-14.2	-6.5	-11.2	-12.2	-11.9
Bulgaria	-8.3	-8.6	-7.3	-10.1	-12.8	-11.8
Romania	-7.9	-9.3	-3.0	-11.5	-9.4	-10.4
BUR	-8.0	-9.2	-4.2	-11.2	-10.3	-10.7
EU-27	-2.9	-11.5	-5.0	-10.4	-15.4	-13.4

REF: Reference Scenario. ETSA: Emission Trading Scheme for Agriculture

In Table 4 projected changes of GHG emissions in 2020 under the ETSA Scenario compared with the reference scenario in 2020 are presented. These projections show that EU-10 and

[7] General transaction costs related to the GHG mitigation policies examined in this paper are not explicitly considered, because EU farms are already subject to large reporting obligations in terms of nutrient loads and activity numbers. Thus we can assume only very minor additional transaction cost related to the burden of reporting, monitoring and controlling. In contrast, transaction costs as defined in the ETSA scenario are those costs that arise from setting up and maintaining the emission trading system, initiating and completing transactions, such as finding partners, holding negotiations, consulting with lawyers or other experts, etc. Transaction costs include also monitoring/verification costs as part of fix costs.

Bulgaria/Romania are projected to reduce GHG emissions of CO_2eq more than in the STD scenario (by 11.9% and 10.7% respectively), after selling emission allowances to several EU-15 MS. The EU-15 is projected to reduce GHG emissions of CO_2eq by 13.8% in the ETSA scenario compared to the reference, i.e. 1.2% less emission reduction than in the STD scenario (cf. Table 3).

Projection results show that the major reductions of methane emissions are projected in the emissions coming from the enteric fermentation. The indirect nitrous oxide emissions from leaching and the direct nitrous oxide emissions from cultivation of histosols account for the major reductions of nitrous oxide emissions. Significant potential for further emission reductions compared to the reference are projected by the direct nitrous oxide emissions from mineral fertilizer and from crop residues.

The production effects of the ETSA scenario vary with respect to the STD scenario. The effects across activities are more homogeneous, with beef meat activities being less affected and arable crops in turn more affected. Utilizable agricultural area is expected to decrease by -6% and fallow land to increases by 12% and an overall effect of decreasing cereal production by -5%.

Regarding beef meet activities in the EU-27, an overall reduction in herd size of -21% and -11.5% in production can be observed. While in the EU-15 these reductions are again most pronounced (and in a similar range as in the STD scenario) in Denmark and Ireland, it is striking that the reductions in the Netherlands are only projected to be -5.8% for beef herd size and production. It is also noticeable that in the EU12 all MS (except Cyprus) show reductions in meat activities higher than in the STD scenario.

In the dairy sector, herds decrease by -3.3% on EU-27 level, with the EU-15 and EU-10 projected to experience decreases in dairy herds by -2.3% and -7.1% respectively. In absolute terms, highest reductions in cows are projected for Poland and Rumania. Milk production in the EU is projected to decline by -2.9% at EU level, with decreases of -2.2% in the EU-15, -6.6% in the EU-10 and -8% in Bulgaria/Rumania.

When looking at the market for GHG emission permits, results confirm that the EU-15 is the main buyer of permits in the ETSA. On average, 26 MM tonnes of permits are traded in the market, under the prevailing assumptions on transaction costs.

Livestock Emission Tax Scenario (LTAX)

Livestock is the major contributor to GHG emissions in the agricultural sector, and therefore much attention is given to specific options on how to reduce the GHG emissions in the livestock sector (cf. FAO, 2006; Leip et al., 2010). One possibility to reduce the contribution of livestock on GHG emissions would be to indirectly affect livestock emissions through the implementation of livestock emission taxes.

For this LTAX scenario the livestock tax is set at an amount so that a GHG emission reduction of 20% would be met in the year 2020 in the EU-27. Therefore we modelled the effect of an EU-wide livestock tax of 300€ per ton of CO_2^{eq} emissions from ruminants and 160€ for non-ruminants, including not only CH_4 but also N_2O from manure management activities.

Differently than in the other scenarios, the burden of GHG emissions reduction falls on animal numbers. Thus in this scenario reductions in methane emissions are generally bigger in almost all MS than in the other policy scenarios (cf. Table 5).

Projection results show that on the one side CH_4 emissions from enteric fermentation fall by -20.7%, whereas on the other side mineral fertilizer emissions are not much affected (-2.1%). The introduced tax increases the costs per animal activity in the supply model depending on their emission intensities, which leads to a reduction in livestock, with a particular high impact on ruminants. The additional tax costs for cattle and beef production causes a reduction of land use (grassland) by around -4.2% in EU-15 and -4.5% in EU-10. Arable land does not compensate this reduction, indicating that it is mainly reduced in areas with high grassland share and that land is not anymore used for agricultural production. However, overall EU cereals production is not much affected and would be reduced by about 1.3%.

The cut of herd sizes and although prices for beef and milk products increased, drastic income losses for farming in EU-15 by –15% and in EU-10 by -18% are projected. Producer prices increase for beef by +20% in EU-15 and by +10% in EU-10 and prices for dairy products increase by +7% in the EU-15 and by +10% in the EU-10. This is the outcome from a rather moderate reduction of the demand, on the one hand, and the deep cut of supply for beef, sheep and goat meat on the other hand. Total meat supply is reduced by -5.4% in EU-15 and by –4% in EU-10, whereas meat supply from ruminants such as beef, sheep and goat meat is even more affected. Beef meat supply declines by -23% in EU-15 and -28% in EU-10. For sheep and goat meat the reduction range is similar. The supply for dairy products such as butter or fresh milk products is also reduced, in EU-15 less strong (between -1% and -17%) than in EU-10 (between -7% and -27%). As consequence of the supply drop and higher prices, imports into EU-27 increase for meat by +49% and for dairy products by +7%, while at the same time exports decrease in EU-27 by -9% for meat and -8% for dairy products.

While there are no severe changes in dairy cow supply in the EU-15 (-4% in herd size and production), reductions in the EU-10 are more pronounced (with -13% in herd size and -12% in production), resulting in an overall EU-27 reduction in herd size by -6% and -5% in production. As expected, the livestock emission tax results in very drastic production costs and income losses for European livestock farmers. As already mentioned, decreases in beef meat activities are very high in almost all MS, with the EU-27 being projected to face a reduction in beef herd by -40% and -23% in production.

Table 5: Change in cow milk, beef and cereals production per EU Member State according to the Livestock Emission Tax Scenario

LTAX Scenario (2020), % change to REF						
	Production			GHG emissions		
	Milk	Beef	Cereals	CH_4	N_2O	CO_2eq
Austria	-4.0	-25.8	-0.8	-17.9	-11.0	-14.3
Belgium-Lux.	-3.3	-20.6	5.5	-14.7	-10.3	-12.4
Denmark	-6.9	-41.7	-0.1	-17.3	-9.1	-12.5
Finland	-3.6	-27.6	0.0	-16.7	-2.3	-5.0
France	-2.8	-18.1	-2.2	-16.7	-7.4	-11.2
Germany	-4.1	-34.1	0.8	-15.1	-5.1	-9.2
Greece	-2.9	-4.5	-4.4	-16.4	-6.9	-11.8
Ireland	-2.4	-25.7	2.1	-25.4	-20.7	-23.0
Italy	-2.5	-13.7	-3.9	-13.2	-8.6	-10.9
Netherlands	-4.2	-16.8	2.4	-8.9	-6.8	-7.8
Portugal	-5.1	-10.9	3.6	-25.5	-27.4	-26.4
Spain	-4.6	-24.1	-3.2	-25.6	-14.5	-19.5
Sweden	-3.8	-29.1	-1.7	-18.9	-6.8	-10.4
United Kingdom	-3.7	-25.7	1.3	-25.5	-14.5	-18.2
EU-15	-3.7	-22.5	-1.1	-18.6	-10.0	-13.6
Cyprus	-6.3	2.1	-4.1	-6.1	-2.7	-4.3
Czech Republic	-8.1	-38.4	-0.2	-20.5	-5.9	-9.5
Estonia	-8.8	-41.8	6.6	-18.3	-10.2	-12.5
Hungary	-9.5	-12.3	-1.6	-16.5	-3.8	-5.9
Latvia	-14.9	-18.7	7.1	-19.6	-11.1	-13.2
Lithuania	-14.4	-16.2	4.6	-17.0	-5.1	-8.2
Malta	-7.7	-0.6	-13.8	-7.3	-6.3	-6.5
Poland	-13.7	-32.8	-1.7	-20.4	-6.1	-10.0
Slovac Republic	-6.8	-5.4	-0.4	-9.9	-2.9	-4.8
Slovenia	-6.4	-13.2	30.6	-21.1	-7.4	-13.9
EU-10	-12.0	-27.7	-0.4	-19.1	-5.8	-9.3
Bulgaria	-18.9	-12.7	-3.2	-18.3	-11.1	-13.8
Romania	-17.1	-21.2	-5.9	-20.3	-12.5	-16.0
BUR	-17.5	-19.4	-5.1	-19.9	-12.1	-15.5
EU-27	-5.1	-22.8	-1.3	-18.7	-9.5	-13.2

REF: Reference Scenario. LTAX: Livestock Emission Tax Scenario

4 Concluding remarks

In order to design mitigation policies it is important to understand the impact of such policies on GHG mitigation on the one hand and agricultural production and trade on the other hand. In this paper we first analyse in a reference scenario the development of EU GHG emissions from 2004 to 2020, when no specific GHG abatement policies would be implemented. We then compare this scenario with mitigation policy scenarios, where we assess the implications of three alternative policy options (implementing an emission standard, tradable emission permits and a livestock emission tax) to reduce agricultural GHG emissions in the EU by 20% in 2020.

According to the projections of the reference scenario, agricultural GHG emissions in the EU would decrease by 6.8% in 2020 compared to the base year 2004 (3-year average 2003-2005). Thus, the EU would not achieve a GHG emission reduction of 20% without implementing specific policy measures. Additional measures would be needed in almost all EU-15 MS. In the EU-12 the situation is different, since several countries autonomously already reduce emissions in the reference scenario below the 20% objective. Furthermore, the emission projection results indicate that an emission reduction commitment based on historical emissions would not be necessarily binding for all MS.

The three defined GHG emission abatement policy scenarios could be designed to almost achieve the reduction goal of 20% emission reduction compared to the reference year (+-0.01 error margin tolerated). The emission reduction effect per country in each scenario is quite different from the EU average, depending on the production level and the composition of the agricultural activities. MS that are projected to already achieve a 20% GHG emission reduction in the baseline (i.e. without additional policy measures) would clearly benefit from an emission permit trading scheme as they are free to decide if they would increase their emissions at no additional costs or sell their emission permits to other MS.

For the scenarios STD and ETSA the projected decrease in production activities leads to higher producer prices and therefore a higher agricultural income per production unit could be expected. In all policy scenarios the largest decreases in agricultural activities are projected to take place in beef meat activities, with EU beef meat production decreasing by about 15% (STD), 11,5% (ETSA) and 23% (LTAX) respectively. Beef and also milk activities are especially affected in the LTAX scenario, with strong decreases not only in production but also in herd sizes and income.

For the interpretation of the overall effects on GHG emissions it is important to assess and account not only for those emissions resulting from production changes within the EU but also outside the EU (cf. Lee et al., 2006). Therefore the CAPRI model was adapted and includes now a module where per-commodity emission coefficients are estimated for traded agricultural commodities (for details on the methodology see Jannson et al., 2010). Thus the trade model is able to account for agricultural GHG emission leakage (expressed in CO_2^{eq}) due to policy changes in the EU. When emission leakage is included in the calculation, it can be observed that the effective emission reduction commitment in the EU is diminished due to a shift of emissions from the EU to the rest of the world (mainly as a result of higher net imports of feed and animal products). Emission leakage is projected to be highest in the LTAX scenario. This is due to increased beef production in the rest of the world in order to meet demand in the EU. The following table summarises the GHG emissions (MMt CO_2^{eq}) and emission reductions (%) for all scenarios including emission leakage.

Table 6: Overview on GHG emission reductions when emission leakage is taken into account (2020)

	Reference	Emission Standard	Emission Trading	Livestock Tax
% reduction compared to 2004	-6.8%	-19.6%	-19.3%	-19.1%
Emission leakage: Net emission increase in rest of the world due to mitigation policy in the EU (CO_2^{eq} in Million Tons)		9.2	6.0	19.9
% reduction compared to 2004, incl. leakage	-6.8%	-17.7%	-18.1%	-14.9%

When looking at the results of the emission mitigation policy scenarios it has to be kept in mind that technological responses to policy measures, like the adaptation of stables or livestock keeping methods, are currently not considered in the CAPRI model. Therefore, the system responds only in form of price and production quantity changes, i.e. farmers react to the mitigation policies only by adjusting their production (e.g. by decreasing the number of cows or their intensity) but not their production management techniques. However, in reality it is very likely that farmers would also try to reduce their GHG emissions by changing their production techniques (i.e. using technical measures like introducing low-nitrogen feeding, covering of manure storage, or switching to minimum tillage or no-till techniques). Such changes in production techniques would certainly alter the results of the mitigation policy scenarios. Nonetheless, our scenario results provide valuable insights for policy making, as they clearly reveal the differences of how the policy instruments impact on the one hand the GHG emissions per EU Member State and on the other hand production, cost-effectiveness and income redistribution within the agricultural sector. To this end, the estimates provided can feed the discussion on the feasibility of integrating the agricultural sector in multi-sectoral emission abatement policies currently in place (e.g. the EU emission trading directive) or under consideration.

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