Applied Economic Perspectives and Policy (2021) volume 43, number 4, pp. 1503–1519.
doi:10.1002/aepp.13092

Featured Article

Coupled Agricultural Subsidies in the EU Undermine Climate Efforts

Torbjörn Jansson, Ida Nordin*, Fredrik Wilhelmsson, Peter Witzke, Gordana Manevska-Tasevska, Franz Weiss, and Alexander Gocht

Torbjörn Jansson, Ida Nordin and Gordana Manevska-Tasevska are Analyst at the Agrifood Economics Centre and Department of Economics, Swedish University of Agricultural Sciences, Uppsala, Sweden. Fredrik Wilhelmsson is a Policy Analyst at Agrifood Economics Centre, Lund University, Lund, Sweden. Peter Witzke of European Centre for Agricultural, Regional and Environmental Policy Research, Bonn, Germany. Franz Weiss of European Commission, Joint Research Centre, Ispra, Italy. Alexander Gocht of Thünen Institute, Braunschweig, Germany.
Editor in Charge: Chris McIntosh
*Correspondence may be sent to: E-mail: ida.nordin@slu.se

Submitted 24 May 2018; editorial decision 26 August 2020.

Abstract *Subsidizing polluting industries generally leads to increased pollution locally. However, given the diversity of production technologies across countries and international trade, the global impact of unilateral policies is not* a priori *clear. We use the agricultural sector model CAPRI to simulate the impact of removing the voluntary coupled support for ruminants, presently permitted under the EU Common Agricultural Policy. We find that this reduces greenhouse gas emissions in the EU. However, emissions leakage significantly diminishes the global mitigation effect since about 3/4 of the reduction in the EU is offset by increased emissions in the rest of the world.*

Key words: Agricultural Policy, Climate Change, Coupled Support, Emissions Leakage, EU.

JEL codes: Q18, Q54, Q17.

Introduction

A significant proportion of all greenhouse gas (GHG) emissions in the EU come from the agricultural sector,[i] which has a largely untapped potential to reduce these emissions (Allen and Maréchal 2017; Grosjean et al. 2016).

[i] *About 11% of net GHG emissions in the EU in 2017 according to the EEA. That number excludes land use and land use change and energy use in agriculture.*

Therefore, emission reductions in agriculture can be vital in helping the EU achieve its 40% target for reduction in domestic GHG emissions by 2030 (European Environment Agency 2015). Indeed, the European Commission emphasizes the need for the future Common Agricultural Policy (CAP) support to farmers to be conditioned on adoption of climate-friendly practices (European Commission 2017a).

Despite the potential to reduce emissions, the agricultural sector is exempt from the EU emissions trading system (EU-ETS)—the cornerstone of EU efforts to limit global warming. The sector is exempt from the EU-ETS due to concerns about emissions leakage, i.e., reallocation of production to other countries, and due to difficulties monitoring emissions in the sector (European Commission 2016). Even though the livestock sector (ruminants in particular) has the highest GHG emission intensity and highest total emissions within agriculture (*e.g*. Lesschen et al. 2011; Golub et al. 2013), the current CAP allows countries to subsidize ruminant production using Voluntary Coupled Support (VCS, described below in more detail).

Removing production subsidies for polluting production, such as VCS to ruminants, is a potentially cost-effective climate policy. Removing VCS would mean fewer ruminants in the EU and consequently less GHG emissions there. However, it may result in increased production and thus higher emissions in other countries, both within and outside the EU, particularly if the emissions per unit of product (emission intensities) are relatively higher in these countries. This *emissions leakage* (Markusen 1975; Zhang 2012) could limit or even reverse the positive impact on global warming that could come from removing VCS in the EU. Does the risk of emissions leakage justify the existence of VCS if GHG emission intensities are lower in the EU than in other countries? In other words, does more agricultural production in the EU reduce production abroad and thereby reduce the global emissions of GHG?

We analyze the likely impact on global GHG emissions resulting from removal of the current VCS in the EU. Our analysis is carried out with the CAPRI model (Britz and Witzke 2014), which is an agricultural sectoral simulation model. The model is extended with the inclusion of VCS for each of the EU member states (MS) to facilitate the analysis. The overall emission change is decomposed into production-level effects and reallocation effects in order to identify the causes and size of emissions leakage. An extensive and systematic sensitivity analysis with respect to key model parameters confirms the robustness of the main results.

A deeper understanding of the global effect on emissions and emissions leakage of unilateral removal of production subsidies harmful to the environment can facilitate better-designed agricultural policies. That is, policies that align with the climate policy objectives and effectively reduce global GHG emissions, not just domestic emissions. Thus, this article contributes by: (i) quantifying and assessing the climate impact of production subsidies for ruminants in EU MS and the emission leakage resulting from removing VCS; (ii) extending the CAPRI model with the inclusion of all VCS for all EU MS, which will enable further analysis of the increased use of coupled support and *de facto* nationalization of the agricultural policies; and (iii) developing a systematic sensitivity analysis for model parameters in the CAPRI model so that the robustness of the results and importance of key model parameters can be assessed in simulations with the model.

The remaining part of the paper is structured as follows. The next section reviews other studies of emissions leakage in agriculture. Then, there is a section on data and methods where we describe relevant parts of the CAPRI model, the estimation of GHG emissions, the European agricultural policy context and the scenarios applied. The results are presented in the fourth section and discussed in the fifth.

Previous Simulations of Climate Policy and Emissions Leakage in Agriculture

A few previous studies have considered emissions leakage within the agricultural sector, but to the best of our knowledge, the impact on global GHG emissions of EU production subsidies within the CAP has not previously been analyzed. Fellmann et al. (2012) and Fellmann et al. (2018) used CAPRI to simulate EU-wide reductions in GHG emissions of 20% and 28% by 2020 and 2030, respectively, relative to 2005, in response to global climate agreements. Specific policy changes were not investigated, however. One of the findings in these studies was that the reductions in GHG emissions in the EU were accompanied by significant emission leakage. Lee et al. (2007) used the GHG version of the US Agricultural Sector Model (ASMGHG) to simulate the welfare impact and emission leakage from unilateral, partial global, and full global implementation of mitigation policies related to emissions reduction actions on agricultural production and international trade. They found that under a unilateral policy, total GHG emissions decline, but substantial emission leakage occurs. Van Doorslaer et al. (2015) found that emission leakage can significantly reduce the benefits of emission reductions in the EU, depending on how climate policies are implemented in the EU. This implies that a policy effective at reaching regional climate objectives (*e.g.*, reducing GHG in the EU) may not be the best way to reduce global emissions. Reviewing the literature on carbon leakage, Zhang (2012) found that most models predict significant leakage effects, though mostly well short of 100%. When comparing *ex-ante* to *ex-post* results, they found that the predicted leakage was difficult to verify empirically, suggesting that models tend to overestimate leakage. However, none of the studies surveyed looked specifically at agricultural markets, and the models used were mostly computable general equilibrium models, and hence Zhang's observations, albeit interesting, are not directly transferable to our case.

Theory and Method

Based on economic theory we expect that removing production subsidies, in our case VCS in the EU, will reduce domestic production. The decline in domestic production causes an increase in import demand in the EU, a reduction in export supply from the EU, and a consequent rise in prices on the world market. This in turn provides incentives to increase production outside the EU. In other words, part of the EU's ruminant production and associated emissions would reallocate abroad, causing emission leakage, as discussed by Markusen (1975) and Zhang (2012). This emissions leakage might be expected to offset emissions reductions obtained in the EU, or even lead to an increase in total global emissions. Therefore, the effect of policy changes—specifically the effect of removing VCS—on global GHG emissions is not a priori clear, but needs to be quantified.

The CAPRI Modeling System

The present analysis was based on CAPRI Stable Release 1.3 (STAR 1.3, publicly available from www.capri-model.org), but with updated data in the area of GHG emission estimates. The CAPRI model is a partial equilibrium simulation model covering the agricultural sector (Britz and Witzke 2014). The model simulations provide results for the global impact on production and trade in the agricultural sector, aggregated to about forty trade blocks, and detailed results for NUTS2 (Nomenclature of Territorial Units for Statistics) regions within the EU. Countries outside the EU are represented in a more simplified fashion than EU countries (EU+), and therefore less detailed information on production and emissions is available for these. Trade flows between the forty regions are modeled based on the Armington assumption of product differentiation by origin. With regard to global trade, the model includes policy data on tariffs, tariff rate quotas, and the trigger price system of the EU. For EU countries, the model also contains a detailed representation of the CAP's policy measures, thus making it suitable for analyzing the impacts of agricultural policy reform scenarios. In addition, we have added VCS measures for all EU MS to the model in order to better represent the production coupling of the CAP and simulate the impact of VCS on GHG emissions.

CAPRI is a comparative static model, meaning the policy impact is inferred from a comparison of a baseline and a policy scenario at a specific point in time. In the present study, this point in time was set as 2030, after the end of the next multiannual financial framework.[ii] The CAPRI model is frequently used to assess the impact of changes in the CAP on aspects such as production, trade, and selected environmental indicators. Recent examples include: simulations of the impact of currently proposed EU free trade agreements and carbon taxes on GHG emissions (Himics et al. 2018); simulations of the impact of the so-called "greening" measures in the 2013 CAP reform (Gocht et al. 2017); and, used together with other models, simulations of the impact of climate change on agriculture (Blanco et al. 2017).

GHG Emissions in CAPRI

CAPRI's coverage of GHG emissions is global, but the method used to calculate emissions varies depending on the availability of detailed production data from the simulations. For EU+ countries,[iii] more details on production are available than for other regions, allowing a bottom-up computation of emissions based on production technology. For all regions, the main direct and indirect emissions of methane (CH_4) and nitrous oxide (N_2O) from agriculture are covered[iv] (representing agricultural emissions according to the UNFCCC classification). The CO_2 emissions from land use, land use change, fertilizer production, and energy use on farms are omitted from our analysis, as they are not yet covered globally in the CAPRI model. Gerber et al. (2013) estimate that about 75% of emissions from beef production are in the form of N_2O and CH_4, and about 25% are CO_2 emissions from land use and land use

[ii] *The duration of the multiannual financial framework has not yet been decided, but could be 5–10 years after 2020 (European Commission 2017c).*

[iii] *The twenty-eight countries of the EU before Brexit plus the Western Balkans, Turkey, and Norway.*

[iv] *The following emissions categories are included in our study: Methane: Enteric fermentation, Manure management (housing and storage), Manure application on soils except pastures, and Rice cultivation. Di-nitrous oxide: Manure deposition on pastures, Inorganic fertilizer application, Crop residues, Indirect from ammonia volatilization, Indirect from leaching and runoff, and Cultivation of organic soils.*

change, but with large uncertainties. The effect on our results of omitting emissions from land use and land use change are unclear, as the importance of omitted emissions and production methods varies across regions.

To compare emissions of different gases, Global Warming Potential (GWP) was used to convert all gases into carbon dioxide equivalents[v] (CO_2-eq.). The climate change induced by the change in emissions would also have an impact on agricultural systems. That feedback is not modeled in CAPRI.

For EU+ regions, emissions are computed endogenously in the CAPRI model based on detailed input and output data. This means, for example, that changes in the feed mix for animals due to a policy change can be captured and thus result in changes in emissions. For the main emission sources, the calculation is performed using a more detailed method (Tier 2 in the 2006 IPCC 2006 guidelines), while for some sources with lower total contributions to emissions, a simplified method (Tier 1) is used. Emissions are calculated per hectare of land or per animal production activity, and then allocated to commodities associated with those agricultural activities. A more detailed description of the method is available in Leip et al. (2010), Pérez Domínguez (2005), and Pérez Domínguez et al. (2012).

The high level of detail on production technology used to compute emissions in the EU+ is not available for other regions. For these regions, computations of GHG emissions are based on estimated emission intensities (EI) per tonne (metric ton) of product, without capturing endogenous changes in the composition of inputs that may take place in simulation (Pérez Domínguez et al. 2012). This means production technology outside the EU+ is assumed not to be affected by policy changes in the EU. To calculate total emissions in each scenario, the emissions coefficients are multiplied by production level.

EI for non-EU regions are estimated to follow the overall agricultural emissions reported in FAOSTAT GHG inventories as closely as possible over time. The estimation, carried out for each non-EU region and emission category individually, is based on time series data of regional GHG inventories and production of agricultural commodities. Data on production quantities come from the CAPRI database, and the GHG inventories come from FAOSTAT (FAO 2010–2018). In most cases the data cover the period 1990–2009, while in some cases fewer years are available. In many cases, we have many commodities compared to the number of years of GHG inventory and production data, and thus the degrees of freedom might end up being small or even negative. In order to improve the robustness of the estimates, we include prior distributions for the emission intensities in a Bayesian estimation framework (*e.g*. Koop 2003, p. 15). To capture the possible change in emission intensities over time, the estimations also contain a trend component.

Bayesian prior distributions for the EI are derived from various sources, such as the expert estimates in Leip et al. (2010). Additionally, we construct priors for many commodities and emission categories with data on activity levels and production levels from the 2014 version of the AGLINK-COSIMO model (OECD 2015). Emissions per activity are computed following the Tier 1 methodology in the IPCC Guidelines (IPCC 1997; IPCC 2006), and then converted to emissions per product. Also, average EU emission coefficients computed in the CAPRI model are used as priors when the previous sources are not available.

[v]The GWP conversion factor used is 28 for methane and 265 for nitrous oxide, from the latest IPCC report (AR5) with a 100-year time-horizon, without inclusion of climate–carbon feedbacks (IPCC 2014).

Decomposition of Emission Changes

Emissions leakage is influenced by changes in the level of production, but also by its reallocation to regions with different emission intensities. When production is reallocated to regions with higher emission intensities, the total emissions will increase for a given level of production and *vice versa*. In order to disentangle the impacts of production changes and changes in average EIs, we made an additional computation of emission changes: First, we set all the EIs equal to the global average in the reference scenario for all countries, and thereafter we calculated the emissions using the production changes in the policy scenario. This computation captures *only* the effect of changing global production levels. Those calculated changes (*i.e.*, changes due to changed production levels) were subtracted from the global changes in GHG emissions computed using regionally specific emission factors, giving the emissions changes caused by reallocation of production to regions with different EIs as a residual.

Baseline for Agriculture and Policy in the EU

The CAPRI baseline projects agricultural production and emissions to the year 2030 under a business-as-usual scenario. Trends for factors exogenous to the model such as population growth and consumer preferences are set based on external projections. The development of agriculture in the EU is based on the Agricultural Outlook published by the European Commission. The CAP is assumed to be fully implemented up to 2021 and then unchanged.

Within the CAP, the largest part is Pillar I measures, which mainly involve support and some market intervention schemes. Pillar II covers support to certain agricultural production, environmental measures, and rural development. Within Pillar I, most support (75%) consists of direct payments to farmers on a per-hectare basis for all qualifying agricultural land. The largest proportion of these payments is the Basic Payment Scheme (or the Single Area Payment Scheme in some regions), with support allocated to all agricultural land with entitlements. This support is considered to be decoupled from production, and member states are obliged to harmonize per-hectare rates across regions (European Union 2013). The greening payment is another large part, and it comes with associated constraints on crop diversification, grassland maintenance, and keeping ecological focus areas. A smaller part of Pillar I is dedicated to payments to young farmers and smaller farms, and areas with natural constraints. In addition, there is crop-specific coupled support for cotton in some countries, and complementary National Direct Payments in some countries.

VCS, the focus of the present study, permits MS to use up to 13%[vi] of the Pillar I payments for coupled support to sectors undergoing economic, social, or environmental difficulties in maintaining/increasing production (European Commission 2017b). The measure is used by most MS and mainly targets cattle[vii] and other ruminants[viii] (European Commission 2019). In total,

[vi]*The exact maximum depends on the circumstances (European Commission 2017b).*

[vii]*VCS to cattle is applied in: Belgium, Bulgaria, Czechia, Estonia, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Finland, Sweden and in the UK (Scotland).*

[viii]*VCS to the sheep and goat sector is applied in: Belgium, Bulgaria, Czechia, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Hungary, Malta, The Netherlands, Austria, Poland, Portugal, Romania, Slovakia, Finland and in the UK (Scotland).*

we modeled 278 different VCS measures across the EU member states. Thirteen percent of the total budget might be considered a minor share of the budget, but it has a potentially strong impact on emissions: Most VCS, about 43% of the total in our data set, is linked to the production of beef and veal, and another 12% to sheep and goat production. These sectors together cause large emissions of the GHG methane and N_2O, either directly or via fertilizer used for producing fodder. The dairy sector also receives much VCS, about 20% of total VCS payments, but in dairy it generally constitutes a smaller proportion of the revenues than in beef production.[ix] Among the crop sectors, the production of protein receives notable amounts (8.5% of the total) of VCS in many member states, followed by fruit and vegetables (at 5%), but these sectors are less interesting from a GHG emissions perspective.

Simulated Scenarios

Two policy scenarios were considered:

- A reference scenario, abbreviated "Ref."
- A policy scenario, abbreviated "No VCS."

In the reference scenario, the current CAP was assumed to continue until 2030, thus including VCS as described above.

The policy scenario was identical to the reference scenario, except that VCS for ruminants was removed. In the CAPRI model, these subsidies are implemented as a direct subsidy per head, with budgetary ceilings as reported by EU countries. The budget that was released when VCS was removed was allocated to the other farm payments (the Basic Payment Scheme) in each MS, so that the total budget for farm payments in each MS remained unchanged in the reference and policy scenarios. The redistribution of support in the policy scenario resulted in an average increase in per-hectare payments for agricultural land of 6.5% in the EU, while support linked to beef cattle decreased by 69% per head, support for dairy cows by 41% per head and for sheep and goats by 36% per head. The remaining coupled support consisted of payments that are not part of VCS: national payments such as Nordic Aid and environmental and rural development support. The impact of a policy change in 2030 was derived by comparing the two scenarios.

Sensitivity Analyses

The CAPRI model results depend on a large number of parameters, some of which are more uncertain than others. In order to analyze how the results obtained in this paper depend on uncertain parameters, a set of sensitivity analyses were carried out. We selected four types of parameters that were assumed to be most critical to emissions leakage, and varied those in three levels: "low" (lo), "high" (hi) and "most likely" (ML). ML is the value used for the main results in this study. The groups of parameters subjected to the sensitivity analyses are as follows:

[ix] *In the CAPRI baseline, about 4% of the revenues of beef and ruminants in the EU are VCS, whereas only 0.8% of the revenues in dairy are VCS. Regionally and locally the shares can be much larger, since some regions like Germany apply no VCS at all.*

- The elasticities of supply (SupElas) of ruminants in the EU are influenced by the slope of the marginal cost function.[x] Higher slope means lower supply elasticity and *vice versa*. The slope was varied +/− 50% to create the lo and hi scenario variants.
- The elasticities of demand (DemElas) for meat and dairy products. We recalibrated the demand systems for all countries so that the own-price demand elasticities would be as close as possible to +/− 50% of the standard value, while observing relevant regularity conditions for demand systems.
- Substitution elasticities (CES) between imports and domestic products and between different import sources were also set to +/− 50% of the standard values. The standard values differ per product, ranging from 2 to 10.
- GHG emission factors (EF) per commodity outside of the EU. Emissions leakage depends more on the relationship between EF in the EU to those outside the EU than on the absolute level. Therefore, we chose to vary only the factors outside of the EU. Since, in general, N_2O factors are considered less certain than emissions of CH_4, which in turn are less certain than CO_2, we chose to apply the uncertainty ranges indicated in a recent IPCC report (Blanco et al. 2014, p 363) to construct the hi and lo scenarios. These ranges were +/− 60% for N_2O and +/− 20% for CH_4.

We do not know the covariance of the uncertain parameters across regions and products. In order to avoid running a very large number of simulation experiments, we chose to vary the parameters for all products and regions in concert by setting all parameters of the same type to lo/ML/hi simultaneously. For instance, we set the demand elasticities of products in all countries simultaneously to hi, ML or lo, giving just 3 demand settings instead of thousands, and similar for the other parameters in the sensitivity analysis. We thus obtain $3 \times 3 \times 3 \times 3 = 81$ result sets; this should span the extremes of the result space.

Results

Global Changes in Emissions of GHG from Agriculture

When VCS for ruminants was removed, emissions in the EU, but also outside the EU, were affected. Figure 1 shows differences in agricultural GHG emissions in thousand ton (kt) CO_2-eq. between the policy scenario and the reference scenario (*i.e.*, the simulated impacts of removing VCS) for 2030. The asterisks (*) in the top panel show the results with standard (ML) parameter settings. With the policy change, the GHG emissions in the EU decreased by 2,354 kt. However, there was an emissions leakage effect, as emissions in the rest of the world increased by 1,738 kt. This resulted in a net decrease on a global basis of 616 kt, or approximately 26% of the emissions decrease in the EU.

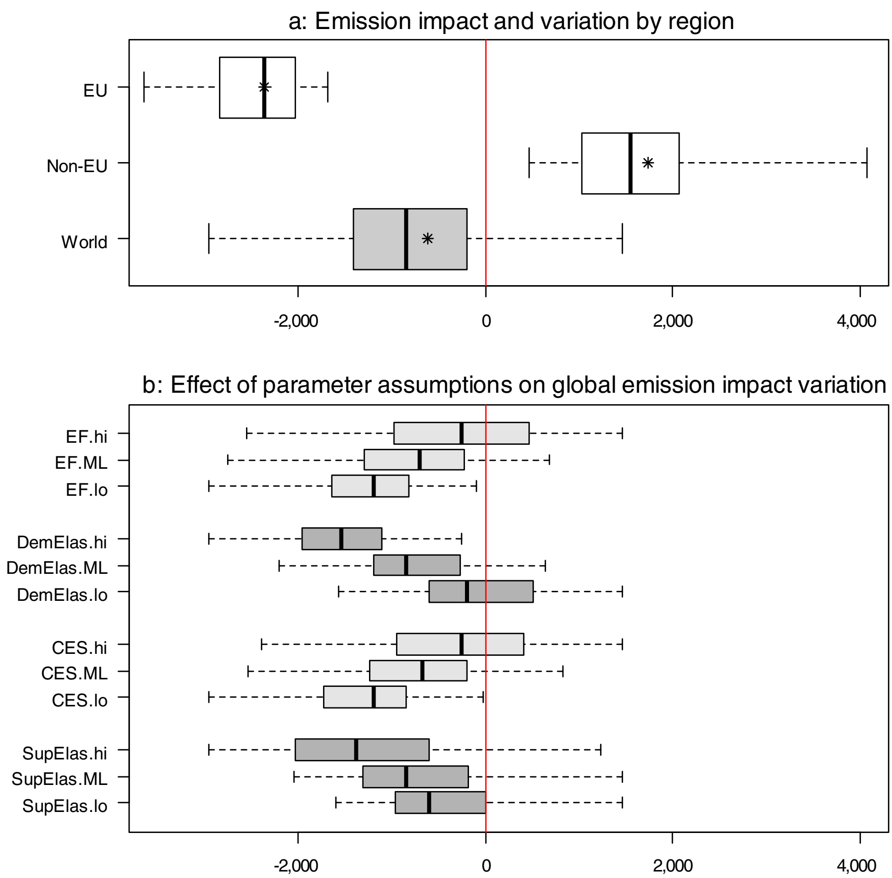
The boxes in figure 1 indicate sensitivity with respect to the four groups of parameters: supply elasticities (SupElas), demand elasticities (DemElas), import substitution elasticities (CES), and emission factors of non-EU regions (EF). The sensitivity analyses in Panel A show that the emissions in the major regions analyzed (EU, non-EU, World) depend strongly on parameters of the model, so that our results on global emissions change could be larger or

[x] *CAPRI contains quadratic cost functions in the tradition of Positive Mathematical Programming (PMP). In the sensitivity analyses, we varied the coefficient of the quadratic term.*

smaller, with the extreme outcomes for the "World" region ranging from −2,956 kt to +1,465 kt. There are more outcomes in the lower range than in the higher range, as indicated by the median line being to the left of the asterisk.

The results seem about equally sensitive to variations in the four parameters, yet the disaggregation in Panel B allows some general conclusions. Each box in Panel B shows the variation of global emissions (*i.e.* the shaded box in Panel A) if each group of parameters in turn is fixed at one of the three levels: If the emission factors of the Non-EU regions are at EF.lo (20–60% lower than standard), or demand elasticities are at DemElas.hi (50% higher than standard), or the import substitution parameters are at CES.lo (50% less than

Figure 1 Impacts on agricultural GHG emissions, with sensitivity analyses (difference to reference scenario kt CO_2-eq. per year). **Panel A**: Impacts on emissions in the EU, outside of the EU, and in total for the World (vertical axis). The main scenario outcomes, when all parameters set to "most likely" (ML), are indicated with asterisks (*). Each box with whiskers shows the variation in outcomes in 81 sensitivity experiments. The central box covers the two central quartiles, the whiskers indicate extreme values, and the heavy vertical lines in boxes indicate median results. **Panel B**: Each box with whiskers shows the variation of global emissions (the box "World" in panel A) when one group of parameters is fixed at a particular level, indicated at the vertical axis. "EF" = Emission intensities, "DemElas" = Demand elasticities, "CES" = Armington substitution elasticities, "SupElas" = Supply elasticities. "hi", "ML" and "lo" denote each of the three levels (high, most likely, and low) of the parameters that were analyzed in the sensitivity experiments. Each box thus summarizes the result of 27 sensitivity experiments, with box and whiskers defined as in A. [Color figure can be viewed at wileyonlinelibrary.com]



standard), the global emissions change is negative, regardless of how the other parameters are set within the ranges analyzed. The bottom three boxes, showing dependence on supply elasticities within the EU, illustrate how these parameters merely scale the total results, and thus are of importance to the absolute size of the impact, but not to the qualitative results.

Studying the main results in more detail, we find that about 90% of the emissions reduction in the EU derived from production of beef, with an absolute decrease in emissions of 2,088 kt CO_2-eq (Table 1). This was a result of less production, as production in relative terms decreased by 1.1% (see Table 2). As can be seen in Table 1, milk was the largest source of emissions in the EU, but the change in emissions for milk—where VCS is less important—was much smaller than for beef. Emissions from pork and poultry increase

Table 1 Emission Impacts in Major Regions of the World Attributable to Changes in Production of Various Commodities (kt CO_2 eq. per year)

	EU		Non-EU		World	
	Ref	**No VCS**	**Ref**	**No VCS**	**Ref**	**No VCS**
Cereals	35,763	8	261,089	–22	296,853	–14
Oilseeds	8,377	12	58,685	–24	67,062	–13
Other arable field crops	1,312	2	14,784	–2	16,096	–1
Vegetables and Permanent crops	3,312	–1	42,922	0	46,234	–1
All other crops	1,286	1	4,694	0	5,979	1
Beef	129,281	–2,088	2,742,253	1,606	2,871,535	–482
Pork meat	45,295	69	178,796	0	224,091	68
Sheep and goat meat	19,864	–75	652,177	195	672,041	120
Poultry meat	7,612	12	97,375	5	104,986	17
Raw milk	175,299	–305	1,008,638	–8	1,183,938	–313
Eggs	2,751	2	30,310	–1	33,060	1
Secondary products	5,066	9	966,617	–10	971,683	–1

Note: For each region EU, Non-EU and World, the two columns indicate in turn (Ref) the amount of emissions attributable to the commodity groups indicated in the table rows in the reference scenario, and (No VCS) the impact of the policy scenario expressed as difference to reference scenario.

Table 2 Impact of Removal of Voluntary Coupled Support (VCS) for Ruminants on the Beef Market in the European Union

		No VCS	
	Ref	**Difference to Ref**	**% change to Ref**
Production (kt)	7,900	–89	–1.1%
Consumption (kt)	7,955	–50	–0.6%
Import (kt)	781	17	2.2%
Export (kt)	726	–22	–3.1%
Producer price (€ per tonne)	4,367	105	2.4%
Consumer price (€ per tonne)	9,146	105	1.1%

Note: The column Ref shows the situation in the reference scenario. Production, consumption, import and export quantities are given in thousands of tonnes (kt), whereas prices are given in EUR per tonne. The impact in No VCS is given both as difference and as percentage change to Ref.

due to consumers replacing some of the more expensive beef with relatively less expensive pork or poultry. Since emission intensities for poultry and pork are significantly lower than for beef, the emission increase associated with pork and poultry production was small. For crop products, emissions barely changed. The slight increases in emissions associated with arable crops were caused by a larger crop area combined with lower average yields. Feed demand went down and exports increased, leading to the small net increases in emissions in the EU shown in Table 1.

Different products have different sensitivities to emissions leakage. For beef, much of the reduction in the EU was canceled out by increased emissions outside the EU. For sheep and goat meat, there was even an increase in emissions globally, despite the 75kt CO_2-eq. reduction in the EU in the policy scenario. In contrast, the reduction in emissions from milk production in the EU was accompanied by an additional small emissions reduction outside of the EU, caused mostly by a reallocation of production among world regions. For crops, increased exports from the EU replaced production abroad, leading to reduced emissions there and a small net reduction associated with crops globally.

Beef markets merit extra attention, because beef meat was the largest contributor to the change in GHG emissions following the removal of VCS. Table 2 shows changes in the EU beef market. In the policy scenario, beef production in the EU decreased, leading to higher producer and consumer prices for beef meat in the EU. The higher prices dampened the negative impact on production. Production decreased by 89kt, while consumption was rather inelastic and decreased by only 50kt. The balance between decreased production and consumption of beef was maintained by a reduction in exports (−22kt) from the EU, and by increased imports to the EU (+17 kt). This caused production changes in countries outside the EU, driving the results on emissions leakage.

Table 3 shows impacts on production in and trade with the non-EU regions of CAPRI that are most strongly affected. Imports of beef to the EU increased most from the US, while exports from the EU decreased, in particular for

Table 3 Impacts on Production and Trade of Removing Voluntary Coupled Support (VCS) for Ruminants in the European Union (EU) for Selected non-EU Countries and Regions with Large Impacts

Country or region	Ref(kt)			No VCS(difference to Ref, kt)		
	Production	Import	Export	Production	Import	Export
USA	11,627	29	0	5	7	0
Brazil	10,818	75	5	8	1	−1
Russia	1,784	0	46	6	0	−8
Mediterranean[a]	1,028	1	44	2	0	−8
Kazakhstan	449	0	13	1	0	−2
Western Balkans[b]	196	7	25	01	1	−1

[a]*Tunisia, Algeria, Egypt, and Israel.*
[b]*Albania, Macedonia, Serbia, Montenegro, Bosnia and Herzegovina, and Kosovo.*
Note: The reference scenario (Ref) values are in thousand tonnes (kt). For No VCS, the values are differences to Ref (kt).

Table 4 Impacts on Beef Production, the Suckler Cow Herd, Methane Emissions and Total non-CO_2 Emissions After Removing Voluntary Coupled Support (VCS) for Ruminants in the European Union (EU) Including the UK, for Selected Countries with Large Impacts

	Suckler cows[a]		**Beef production**[b]		**Methane emissions**[c]		**Non-CO2 emissions**[c]	
Germany	**23**	**4.7%**	**−1**	**−0.1%**	**21**	**0.1%**	**14**	**0.0%**
Spain	−153	−7.1%	−10	−1.5%	−404	−1.9%	−563	−1.6%
France	−339	−7.1%	−35	−2.0%	−686	−1.6%	−924	−1.2%
Ireland	41	4.2%	2	0.3%	76	0.4%	104	0.4%
Italy	−16	−5.8%	−6	−0.9%	−75	−0.4%	−101	−0.3%
Portugal	−53	−9.1%	−2	−1.3%	−152	−3.0%	−213	−2.8%
United Kingdom	73	5.5%	4	0.5%	122	0.4%	156	0.3%
Poland	−14	−4.4%	−6	−1.3%	−118	−0.9%	−167	−0.5%

[a] *Thousand animals and percentage change* vs *baseline.*
[b] *Thousand tonnes and percentage change* vs *baseline.*
[c] *Thousand tonnes CO_2 eq. and percentage change* vs *baseline.*

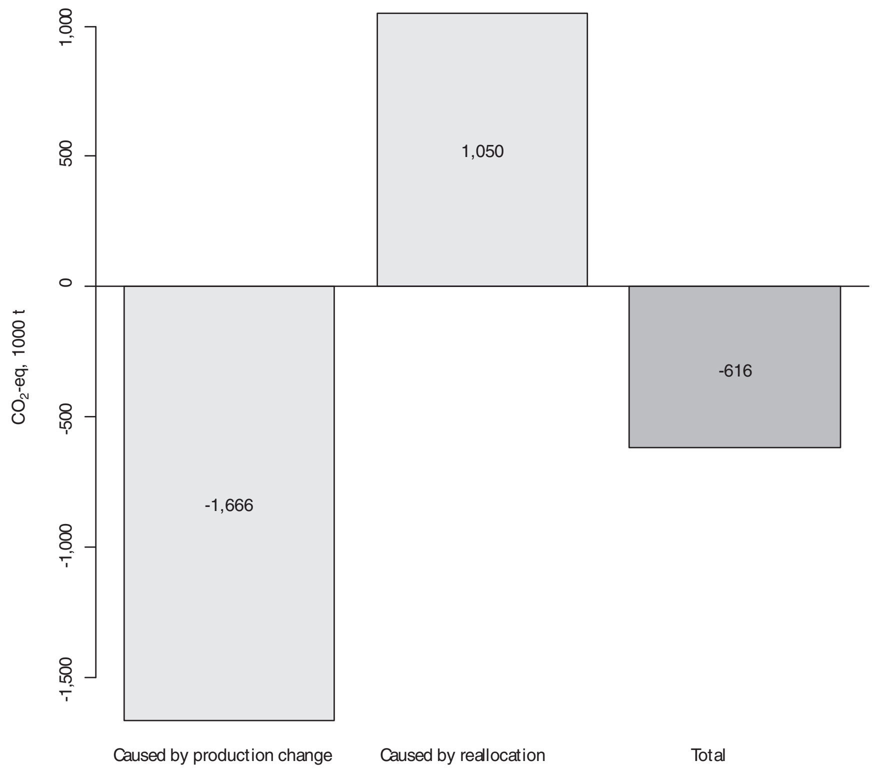
Mediterranean countries and Russia. The latter was met by a production increase in Russia. Argentina and Brazil remained the main trading partners, but their exports to the EU did not change greatly. Instead, changing world market prices affected their trade with other parts of the world, resulting in large production increases in Brazil. Other regions outside the EU also changed their production and trade relations. India's production and exports increased slightly, which had a large effect on global emissions, since Indian production is relatively emissions intensive.

Within the EU, the largest decreases in GHG emissions in absolute terms were found in France, Spain, and Poland. In contrast, in the United Kingdom, Ireland, and Germany, where ruminant production receives little or no VCS, GHG emissions increased, since in these regions ruminant herds slightly increased in response to the higher prices. Table 4 shows the changes in the suckler cow[xi] herd, beef production, methane, and total non-CO_2 GHG emissions in the EU countries with the largest absolute changes in the latter. The increase in emissions in the countries with expanding ruminant sectors might be considered a case of "intracommunity leakage" where the GHG-saving effects in the majority of countries are counteracted by emission increases in others.

In our computations, removing VCS to ruminants increases agricultural incomes in the EU by about €1,400 million annually.[xii] The income increase is due to two things: Firstly, the VCS funds are transferred to the basic farm payment, where it tops up income without requiring additional variable costs, *i.e.*, animals that were unprofitable without subsidies are no longer produced, while the subsidy is still obtained. Secondly, the prices of some animal products rise and thus raise farm incomes. There is reduction in consumer welfare of €868 million annually due to the higher prices. The impact on tax

[xi] *Cows rearing calves for beef production*
[xii] *In CAPRI this is computed as gross value added plus subsidies,* i.e. *the total amount available for remuneration of capital and labor.*

Figure 2 Global changes in greenhouse gas emissions in 1000 tonnes annually, decomposed into those caused by production and those caused by differences in emission intensity in producing countries



payers is negligible, €40+ million spending, since the total CAP budget is unchanged. Thus, we might expect a gain in welfare in the EU across these three groups totaling €492 million euro annually.

Decomposition of Emissions Leakage

The results show that abolishing VCS to ruminants would reduce global agricultural GHG emissions due to the reallocation of production. To gain insights into this process, we decomposed the changes in emissions. The obvious reason for increases in emissions outside the EU is increased production of beef in countries outside the EU. Another reason is that production is more or less intense in terms of GHG emissions in different locations, which means that reallocation of production has an impact on emissions. In addition, changing conditions may alter production technology, which could affect the emission intensity of a product. In our simulations, these technological changes were only modeled endogenously for EU+ countries.

The disaggregation of emissions changes for beef resulting from production volume and reallocation effects are presented in figure 2. The bar to the left shows the emissions changes that would have occurred if the average emission intensity in the world (from the reference scenario) applied to all regions, while the production changes remained the same. This emissions change can be attributed to the change in global production volume. The reduction in production would thus have reduced global emissions by 1,666 kt CO_2-eq. However, the actual emissions reduction globally was 616 kt

CO_2-eq., which is 1,050 kt less than the emissions reduction brought about by production level changes. This discrepancy is explained by the reallocation of production to locations with higher emission intensity than the EU.

Summary and Conclusions

This study used the simulation model CAPRI to analyze impacts of the current voluntary coupled support for the ruminant sectors in the EU on GHG emissions in the EU and globally. Our results show that removing VCS of ruminants in the EU may lead to an emissions reduction of −2,354kt CO_2 eq. annually, corresponding to −0.5% of total agricultural GHG emissions in the EU. However, about three-quarters of this reduction would be canceled out by emissions leakage (*i.e.*, increased emissions outside the EU).

Inelastic demand and opportunities to trade would cause a shift in production from the EU to other countries, and hence the higher emissions outside the EU. In addition to the impact on emissions caused by higher production volumes outside the EU, emissions leakage is further magnified by the emissions-intensive production methods used in countries where production might expand (*e.g.*, Brazil and India). This illustrates one of the problems with a unilateral policy and policies mainly affecting EU production volumes rather than production technologies and consumption. Emissions leakage means that in order to attain a specific global reduction in emissions, unilateral local policies would have to reduce local emissions to a much larger extent than indicated by the global reduction target.

Furthermore, the emissions leakage would vary across product categories. For example, the global emissions for goat and sheep meat would increase even though EU emissions declined. For beef meat, the global emissions reduction would be about 23% of the emissions reduction in the EU, while for milk the global emissions reduction would be even slightly larger than in the EU. This indicates that production subsidies for some products may cause more harm to climate efforts than subsidies to others depending on trade relations and relative emission intensities, but further research on specific products is required to form a solid base for policy decisions.

Our analysis also entailed a sensitivity analysis of how key results depend on selected model parameters. Demand elasticities, emission intensities, and the preferences for domestic as opposed to imported food all influence the results strongly, although our main results are stable for the bulk of the sensitivity analysis outcomes. Despite uncertainties when pushing critical parameters far, our results clearly stress the importance of keeping emissions leakage in mind when designing policies. They also show that subsidies to the emissions-intensive ruminant segment of agriculture can exacerbate climate change. Compared with other studies on EU agriculture, the leakage effect in our analysis was quite modest, which might be a particularity of the VCS instrument. For example, Fellmann et al. (2018) found that emissions leakage effects reduced the impact of more general policies to reduce EU agricultural emissions by as much as 91%, of which about 90% was attributable to cattle. Van Doorslaer et al. (2015), also using CAPRI, found that unilateral policies aimed at reducing emission intensities via improved production technologies generally led to less leakage than policies setting reduction targets achieved mainly by reduced production. They also found that for more ambitious mitigation targets the leakage is generally larger, and thus the cost of achieving a global emissions reduction target using unilateral policies would increase with the level of ambition in emissions reduction targets.

A reduction in global emissions, albeit small and despite leakage effects, achieved by *not* subsidizing a polluting industry might be an efficient contribution to climate policy, since shifting coupled subsidies to decoupled subsidies may be expected to improve efficiency in the economy, and thus improve overall welfare. If the combined welfare[xiii] change for agricultural producers, consumers, and tax payers (€494+ million annually) is divided by the reduction in emissions in the EU (2,354kt annually), we find that each tonne of emission reduction is associated with a social *benefit* of €209 per tonne on average. However, the reduction in emissions achieved should also be viewed in the context of conflicting policy objectives. The stated policy objective for VCS is to maintain important and vulnerable agricultural subsectors (European Commission 2017b). The scheme can be perceived as successful in this regard, as our results clearly showed that removal of the subsidy would cause a decline in production. Whether the potential benefits of VCS for ruminants in terms of maintaining production in the EU justify the negative impact on the climate is a political question that should be a key element in evaluation of the policy.

References

Allen, Ben, and Anne Maréchal. 2017. Agriculture GHG Emissions: Determining the Potential Contribution to the Effort Sharing Regulation. In *Report prepared for Transport and Environment*. London, UK: Institute for European Environmental Policy.

Blanco, Gabriel, Reyer Gerlagh, John Barrett, et al. 2014. Drivers, Trends and Mitigation. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report*, ed. Ottmar Edenhofer, Ramón Pichs-Madruga, Youba Sokona, et al.. Cambridge, UK and New York: Cambridge University Press.

Blanco, María, Fabien Ramos, Benjamin Van Doorslaer, Pilar Martínez, Davide Fumagalli, Andrej Ceglar, and Francisco J. Fernández. 2017. Climate Change Impacts on EU Agriculture: A Regionalized Perspective Taking into Account Market-Driven Adjustments. *Agricultural Systems* 156: 52–66. https://doi.org/10.1016/j.agsy.2017.05.013.

Britz, Wolfgang, and Peter Witzke. 2014. *CAPRI Model Documentation 2014*. Edited by Wolfgang Britz and Heinz-Peter Witzke. Bonn: Institute for Food and Resource Economics, University of Bonn. Capri-model.org/docs/capri_documentation.pdf (accessed September 3, 2020).

European Commission. 2016. Carbon leakage. Last Modified August 17, 2016. http://ec.europa.eu/clima/policies/ets/allowances/leakage/index_en.htm.

——. 2017a. *The Future of Food and Farming. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2017) 713 final*. Brussels, Belgium: European Commission.

——. 2017b. Voluntary Coupled Support. Notification of the Revised Decisions Taken by Member States by 1 August 2016 ("the review"). In *Informative Note: September 2017*. European Commission.

——. 2017c. *MFF post 2020*. European Commission http://ec.europa.eu/budget/mff/index_en.cfm#RPFF (accessed February 6, 2017).

[xiii] *Producer welfare of farmers is measured in CAPRI by the increase in gross value added, while consumer welfare derives from the money metric related to the demand system in CAPRI. Welfare for non-EU regions is measured differently in some details in CAPRI such that global welfare is not reported to avoid problematic aggregations*

——. 2019. Voluntary Coupled Support. Review by the Member States of their Support Decisions Applicable as form Claim Year 2019. In *Informative Note:* September 2019.

European Environment Agency. 2015. Trends and Projections in Europe 2015. Tracking Progress Toward Europe's Climate and Energy Targets. In *EEA Report No 4/2015*. Luxembourg, UK: European Environment Agency.

European Union. 2013. Regulation (EU) no 1307/2013 of the European Parliament and of the Council of 17 December 2013 Establishing Rules for Direct Payments to Farmers under Support Schemes within the Framework of the Common Agricultural Policy and Repealing Council Regulation (EC) no 637/2008 and Council Regulation (EC) no 73/2009. *Official Journal of the European Union* L347/608.

FAO. 2010–2018. FAO.FAOSTAT. License: CC BY-NC-SA 3.0 IGO. Extracted from: http://www.fao.org/faostat/en/#data. Online database accessed over several years.

Fellmann, Thomas, Ignacio Pérez Domínguez, Peter Witzke, and Diti Oudendag. 2012. Mitigating GHG Emissions from EU Agriculture—What Difference Does the Policy Make? Paper presented at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil.

Fellmann, Thomas, Peter H. Witzke, Franz Weiss, Benjamin Van Doorslaer, Dusan Drabik, Ingo Huck, Guna Salputra, Torbjörn Jansson, and Adrian Leip. 2018. Major Challenges of Integrating Agriculture into Climate Change Mitigation Policy Frameworks. *Mitigation and Adaptation Strategies for Global Change* 23(3): 451–468.

Gerber, Pierre J., Henning Steinfeld, Benjamin Henderson, Anne Mottet, Carolyn Opio, Jeroen Dijkman, Alessandra Falcucci, and Giuseppe Tempio. 2013. *Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

Gocht, Alexander, Pavel Ciaian, Maria Bielza, Jean-Michel Terres, Norbert Röder, Mihaly Himics, and Guna Salputra. 2017. EU-Wide Economic and Environmental Impacts of CAP Greening with High Spatial and Farm-Type Detail. *Journal of Agricultural Economics* 68(3): 651–681. https://doi.org/10.1111/1477-9552.12217.

Golub, Alla, Benjamin Henderson, Thomas W. Hertel, Pierre J. Gerber, Steven K. Rose, and Brent Sohngen. 2013. Global Climate Policy Impacts on Livestock, Land Use, Livelihoods, and Food Security. *Proceedings of the National Academy of Sciences* 110 (52): 20894–20899. https://doi.org/10.1073/pnas.1108772109.

Grosjean, Godefroy, Sabine Fuss, Nicolas Koch, Benjamin L. Bodirsky, Stéphane De Cara, and William Acworth. 2016. Options to Overcome the Barriers to Pricing European Agricultural Emissions. *Climate Policy* 18(2): 151–169.

Himics, Mihaly, Thomas Fellmann, Jesús Barreiro-Hurlé, Peter Witzke, Ignacio Pérez Domínguez, Torbjörn Jansson, and Franz Weiss. 2018. Does the Current Trade Liberalization Agenda Contribute to Greenhouse Gas Emission Mitigation in Agriculture? *Food Policy* 76: 120–129. https://doi.org/10.1016/j.foodpol.2018.01.011.

IPCC. 1997. Volume 3: Greenhouse Gas Inventory Reference Manual. In *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, ed. J.T. Houghton, L.G. Meira Filho, B. Lim, K. Treanton, I. Mamaty, Y. Bonduki, D.J. Griggs, and B.A. Callander. Bracknell, UK: Intergovernmental Panel on Climate Change, Meteorological Office.

——. 2006. In *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme*, ed. H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe, 2. Hayama, Japan: IGES.

Koop, Gary. 2003. *Bayesian Econometrics*. Sussex, UK: J Wiley and Sons.

Lee, Heng-Chi, Bruce A. McCarl, Uwe A. Schneider, and Chi-Chung Chen. 2007. Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation. *Mitigation and Adaptation Strategies for Global Change* 12(4): 471–494.

Leip, Adrian, Franz Weiss, Tom Wassenaar, Ignacio Pérez Domínguez, Thomas Fellmann, Philippe H. Loudjani, Francesco Tubiello, David Grandgirard, Suvi

Monni, and Katarzyna Biala. 2010. *Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (GGELS) - Final Report*. Brussels: European Commission, Joint Research Centre.

Lesschen, Jan Peter, Martin van den Berg, Henk Westhoek, Peter Witzke, and Oene Oenema. 2011. Greenhouse Gas Emission Profiles of European Livestock Sectors. *Animal Feed Science and Technology* 166(Supplement C): 16–28. https://doi.org/10.1016/j.anifeedsci.2011.04.058.

Markusen, James R. 1975. International Externalities and Optimal Tax Structures. *Journal of International Economics* 5(1): 15–29.

IPCC. 2014. Anthropogenic and Natural Radiative Forcing. *In Climate Change 2013 – The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 659–740). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781107415324.018.

OECD. 2015. AGLINK-COSIMO Model Documentation. A Partial Equilibrium Model of World Agricultural Markets. Edited by OECD-FAO Agricultural Outlook.

Pérez Domínguez, Ignacio 2005. Greenhouse gases: Inventories, abatement costs and markets for emission permits in European agriculture: A modelling approach. *Dissertations*. Bonn University. http://nbn-resolving.de/urn:nbn:de:hbz:5N-05383

Pérez Domínguez, Ignacio, Thomas Fellmann, Peter Witzke, Torbjörn Jansson, Dite Oudendag, Alexander Gocht, and David Verhoog. 2012. Agricultural GHG Emissions in the EU: An Exploratory Economic Assessment of Mitigation Policy Options. In *JRC Scientific and Policy Reports*. Seville, Spain: European Commission.

Van Doorslaer, Benjamin, Heinz P. Witzke, Ingo Huck, Franz Weiss, Thomas Fellmann, Guna Salputra, Torbjorn Jansson, Dusan Drabik, and Adrian Leip. 2015. An Economic Assessment of GHG Mitigation Policy Options for EU Agriculture. In *Report EUR 27097 EN*. Luxembourg, UK: Joint Research Center.

Zhang, Zhong X. 2012. Competitiveness and Leakage Concerns and Border Carbon Adjustments. *International Review of Environmental and Resource Economics* 6: 225–287.