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Does the current trade liberalization agenda contribute to greenhouse gas emission mitigation in agriculture?

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ABSTRACT

This paper contributes to the literature on the trade liberalization – climate change nexus by investigating the impact of the current free trade agenda of the European Union (EU) on the effectiveness of a possible greenhouse gas (GHG) reduction policy for its agricultural sector. For the analysis we implement scenarios with a carbon tax on non-CO_2 emissions and trade liberalization both individually and combined in CAPRI, a global partial equilibrium model for agriculture. Scenario results indicate that the simulated trade liberalization by itself has only modest effects on agricultural GHG emissions by 2030. Pricing agricultural non-CO_2 emissions in the EU triggers the adoption of mitigation technologies, which contributes to emission reductions. Emission leakage, however, partially offsets the EU emission savings as production increases in less emission-efficient regions in the world. The combination of agricultural trade liberalization and carbon pricing increases emission leakage and, therefore, further undermines global mitigation gains. Our results hinge on the key assumptions that future trade agreements between non-EU countries are not considered and that the climate actions are limited to the EU only. Despite these limitations we conclude that, from a global GHG mitigation perspective, trade agreements should address emission leakage, for instance by being conditional on participating nations adopting measures directed towards GHG mitigation.

1. Introduction

The Paris Agreement on Climate Change legally entered into force on 4 November 2016. Specific modalities and procedures still have to be negotiated, but in general the Paris Agreement requires all Parties to take on ambitious efforts to mitigate greenhouse gas (GHG) emissions and combat climate change through “nationally determined contributions” (NDCs). Enhanced international efforts to mitigate GHG emissions coincide with an increase in the number and scale of regional trade agreements. As the Doha Round of WTO negotiations stalls, large economies try to boost their economic growth by engaging in regional trade agreements with their main partners. Examples of such behavior include the Trans-Pacific Partnership (TPP) and the Transatlantic Trade and Investment Partnership (TTIP) negotiations, each covering a large share of global trade in goods and services. The EU follows a similar strategy and is increasingly engaged in regional trade negotiations (e.g. with Canada, USA or the Mercosur countries).

The parallel development of trade liberalization and GHG reduction policies raises the question on their interplay. Whether a continuous liberalization of the agri-food markets contributes positively or negatively to emission mitigation efforts is a complex empirical question. The theoretical framework of environmental effects of trade-liberalization (Grossman and Krueger, 1991) breaks down trade liberalization impacts on GHG emissions to the following three components: (1) the scale effect, i.e. liberalized trade boosts production and consumption, ceteris paribus increasing global GHG emissions; (2) the composition effect, i.e. facilitating trade also changes the composition of the goods produced and consumed, hence the net effect on global emissions depends on the emission intensity of the industries that gain from trade liberalization; and (3) the technique effect, i.e. liberalizing trade increases technological development and technology transfer, unequivocally leading to a reduction in global emissions by promoting more emission-efficient technologies. Whether the net environmental impact

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of these three effects is positive or negative requires a quantitative analysis that weights the individual effects. Existing empirical evidence is controversial regarding the relative weight of each of the effects. Overall results move between two extremes: (i) trade liberalization and globalization leads to environmental degradation, especially in developing countries, and (ii) more liberalized trade leads to increased economic growth with positive spill-over effects on the environment (Copeland and Taylor, 2004; Wiedmann et al., 2007; Peters and Hertwich, 2008; Huang et al., 2011; Peters et al., 2011). In any case, the mixed existing empirical evidence on the net aggregated effect of trade on global emissions hints towards the case specificity of impacts.

Against this background, this paper contributes to the debate by providing a detailed analysis on how trade liberalization agreements may affect global GHG mitigation efforts for a specific sector (agriculture) and a specific country-group (the EU) with a highly developed economic and policy environment. Accordingly, the main research question we pose is: How does trade liberalization impact the effectiveness of GHG policies in the EU agricultural sector? Addressing this question, we also discuss if, and to what extent, trade liberalization shifts EU emissions to trade partners and other third countries or vice versa, and what the net impact on global emissions is. More specifically, we investigate this issue focusing on the impact of the agricultural provisions of the regional Free Trade Agreements (FTA) currently under negotiation between the EU and 3rd parties (Boulanger et al., 2016), and a (still hypothetical) policy aiming at reducing (non-CO_2) GHG emissions in EU agriculture enforced by means of a carbon tax[1] (Pérez Domínguez et al., 2016).

The choice of the agricultural sector as the focus of our interest is motivated by its importance in non-CO_2 (methane and nitrous oxide) GHG emissions, and by its important role in global food security. As key results we present production and GHG emission effects in the EU and globally, quantifying also emission leakage of trade liberalization when implemented in isolation or combined with climate policy. More specifically, we compare three scenarios against a business as usual reference for 2030. First we show how trade liberalization alone affects production and emissions, second we show how production and emissions are affected by a unilateral carbon tax for non-CO_2 emissions of EU agriculture, and last we show how the combination of the two adds up.

2. Methodology

For the analysis, we use the CAPRI (Common Agricultural Policy Regional Impact Analysis) modelling system (Britz and Witzke, 2014). CAPRI is a large-scale, comparative static, partial equilibrium model focusing on agriculture and the primary processing sectors. CAPRI links a set of mathematical programming models of the EU regional agricultural supply to a global market model for agricultural commodities. The regional supply models follow a Positive Mathematical Programming (PMP) approach for simulating the profit maximizing behavior of representative farms for all EU regions. The regional supply models are linked with a sequential calibration approach to a global multi-commodity model of the agricultural markets. International trade in the market model is implemented following the Armington assumption (Armington, 1969), i.e. imported goods are differentiated by place of origin, and consumer preferences for import demand are calibrated to a benchmark dataset (Britz and Witzke, 2014).

The standard market module in CAPRI also includes explicit Tariff Rate Quota (TRQ) functions. In this paper, however, the TRQ functions are converted into ad-valorem equivalent (AVE) tariff rates in order to simplify the scenario assumption. Representing the TRQs with their AVE equivalent tariff rates enables us to simply cut them by a given percentage, without going into assumptions on possible quota expansions or changes in in-quota or out-of-quota tariff rates. The drawback of the AVE representation of TRQs is that it might magnify trade liberalization impacts, as reaching the quota threshold does not anymore imply an immediate increase in tariff rates in the model (Himics and Britz, 2016).

With regard to GHG accounting, CAPRI endogenously calculates EU agricultural GHG emissions for nitrous oxide and methane based on the inputs and outputs of production activities. Following the IPCC guidelines (IPCC, 2006), a Tier 2 approach is used for the calculation of activity-based emission factors, but where the respective information is missing a Tier 1 approach is applied (e.g. rice cultivation). Several specific technological (i.e. technical and management-based) GHG mitigation options for EU agriculture are considered, focusing on technological options that are already available or will likely be available at the simulation year 2030. Some of them are already used in EU agriculture (e.g. precision farming) but there is ample room for expansion to a much larger number of farms or production activities. The 14 mitigation technological options listed in Table 1 have been specifically considered for this paper and can be applied by EU farmers (for a detailed description of each technology see Pérez Domínguez et al. (2016).

The underlying assumptions on implementation costs, cost savings, mitigation potential of the modelled technological mitigation options are mainly taken from the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) database (GAINS, 2013, 2015; Höglund-Isaksson et al., 2013, 2016), and information collected within the AnimalChange project (Mottet et al., 2015). The level of production activities and the use of mitigation technologies are constrained by various factors, including land availability, fertilization requirements of the cropping systems versus organic nutrient availability, feed requirements in terms of dry matter, net energy, protein, and fiber for each animal. Moreover, production activities and decision making are also influenced by agricultural and environmental policy restrictions. A detailed description of the general calculation of agricultural emission inventories in CAPRI is given in Pérez Domínguez (2006), Leip et al. (2010) and Pérez Domínguez et al. (2012), and detailed description of the modelling approach related to the technological GHG mitigation options is presented in Van Doorslaer et al. (2015), Pérez Domínguez et al. (2016) and Fellmann et al. (2018).

Two additional issues are worth mentioning. First, the calculation of emissions is not homogenous between the EU and the rest of the world. While the emissions of EU agriculture are calculated directly based on the IPCC guidelines on a per activity basis in the CAPRI supply model, GHG emissions for the rest of the world are estimated on a commodity basis (i.e. per kg of product) in the market model of CAPRI. Second, and linked to the different calculation approach, in previous analyses non-EU emission intensities were purely based on historic emission and production data from FAOSTAT. This did not allow the integration of technical trends, e.g. improved emission efficiency over time. As the projection year for our analysis is 2030, neglecting trends in emission intensities in non-EU countries could lead to an overestimation of emission leakage (Barreiro-Hurle et al., 2016). GHG emission intensity improvements in the rest of the world could be a result of climate or non-climate related developments. Improvements could, for example, come of developed countries allocating climate funding to the adoption of GHG mitigation technology or as a consequence of GHG mitigation policies being implemented and subsidized in non-EU regions. Additionally, emission mitigation may also spread irrespectively of climate change concerns, for example if fertilizer efficiency improves or if anaerobic digestion plants are installed for purely economic reasons. Global emission trends could also imply a deterioration of efficiency over time due to composition effects.[2] To incorporate the possibility of emission intensity changes over time, trend functions are estimated for the emission intensities in the rest of the world using IPCC Tier 1 coefficients as prior information within a robust Bayesian estimation framework, combining data on

[1] A carbon tax refers to a tax attributed to a unit of emissions expressed in CO_2 equivalents.

[2] Assume, for example, that production of beef in one country is represented by a single value, but in reality production takes place both in dairy systems in one part of the country and with dedicated beef breeds in another. If the relative weights of those systems in overall beef production would change, the average emission intensity of “beef” would change too.

Table 1
Technological GHG mitigation options available for adoption by EU farmers.

Sector	Technological mitigation options
Livestock	Anaerobic digestion at farm scale, Low nitrogen feed, Linseed as feed additive, Nitrate as feed additive, Vaccination against methanogenic bacteria in the rumen, and specific breeding programs to increase (i) milk yields of dairy cows and (ii) ruminant feed efficiency
Crops	Precision farming, Variable Rate Technology, Better timing of fertilization, Nitrification inhibitors, Rice measures, Fallowing histosols (organic soils), Increasing legume share on temporary grassland

production quantities and emission inventories from FAOSTAT (for more information on the approach see Jansson et al., 2010, 2014; Pérez Domínguez et al., 2016).

3. Scenario assumptions

Three policy scenarios are compared to a business as usual scenario (Reference): (i) a scenario that assumes an ambitious EU trade agenda to be fulfilled by 2030 (FTA scenario), (ii) a scenario for EU agriculture where a carbon tax of 50 EUR/t CO_2 equivalents is applied to non-CO_2 (i.e. methane and nitrous oxide) emissions of EU agricultural activities (EU Carbon Tax scenario), and (iii) a combination of the two. With the three scenarios we aim to disentangle the economic and environmental effects of trade liberalization and emission reduction policies, and shed some light on their interaction (Combined scenario). The simulation year for all scenarios is 2030 and in all scenarios farmers can voluntarily adopt technological mitigation options. The uptake of the mitigation technologies is driven by the model's profit maximization framework, and therefore farmers will only adopt the technologies if this improves farmers' competitiveness by reducing production costs. That may happen, for example, after the introduction of a carbon tax, which links the GHG emissions involved in the production of commodities to production costs.

3.1. Reference scenario 2030

The reference scenario assumes status quo policy as based on the information available mid-2016 (e.g., abolishing the EU milk and sugar quotas) and only considers agricultural, environmental and trade policies that are already ratified. The reference scenario is calibrated to the European Commission’s outlook for agricultural markets and income (European Commission, 2015), which itself is based on the OECD-FAO (2015) agricultural market outlook and gives medium-term projections up to the year 2025 in a consistent framework, using also external sources for the assumptions on macroeconomic developments (like GDP growth, exchange rates, world oil prices, and population growth). As the projection year for our analysis is 2030, we extrapolated and supplemented the European Commission’s projections with other information to arrive at the CAPRI reference scenario for the year 2030. A detailed description and discussion of the CAPRI calibration process is given in Himics et al. (2014).

3.2. FTA scenario

As the WTO negotiations seem to be stalled, the EU is actively seeking to engage in regional (bilateral) FTAs with the aim to boost economic growth. The EU's current trade agenda is filled with ongoing trade negotiations with its main trade partners and with countries in key geopolitical positions. In this paper we focus on those trade deals that are already under negotiation or likely to be negotiated in the mid-term (Boulanger et al., 2016). More precisely we take into account (i) two recently concluded but not yet adapted FTAs with Canada and Vietnam; (ii) major ongoing trade negotiations with the USA, the Mercosur countries, Japan, Thailand, the Philippines and Indonesia; (iii) two FTAs with Australia and New-Zealand, which are likely to be initiated in the short-term.

The varying roles agricultural policy plays in the different countries as well as food security and food safety issues related to foreign food commodities often make agriculture a stumbling block of trade negotiations. Although tariffs on traded goods generally have been decreasing in the last decade, tariffs and other border protection instruments on agri-food commodities are still relatively high. As concluded tariff schemes are not yet available for most of the FTAs considered, we apply a simplified and rather ambitious assumption on tariff reduction: full elimination of tariffs for most (non-sensitive) agricultural commodities and a 50% (partial) tariff cut for the rest of the products. The selection of sensitive products follows the approach of Boulanger et al. (2016), and it is based on expert judgment supplemented by a selection algorithm focusing on foregone tariff revenues.[3]

The agricultural sector is specifically subject to a multitude of sanitary and food safety regulations that often act as non-tariff barriers (NTMs) to trade. Although those NTMs are significant, we did not include the potential reduction of NTMs in our analysis, lacking an adequate database at the global scale with a detailed coverage of agri-food trade. In addition, Armington trade models, such as CAPRI, are not able to simulate emerging trade flows (those that currently are not observed but which are likely to become significant after trade liberalization). Both the lack of NTMs and the zero trade flow issue related to the Armington trade specification imply a possible underestimation of the trade liberalization impacts (Philippidis et al., 2013, 2014). On the other hand, the EU's trade agenda is modelled to be fulfilled in isolation, i.e. further trade agreements excluding the EU are not considered. This assumption probably leads to an overestimation of the efficiency of EU trade liberalization, as countervailing regional FTAs, or a future WTO agreement would likely lower the EU gains from this liberalized trade agenda.

3.3. EU carbon tax scenario

With respect to GHG emission mitigation obligations, the EU agricultural sector is currently included under the Effort Sharing Decision (ESD) within the “2020 Climate and Energy Package” of the EU (European Council, 2009). In this ESD, the EU member states have GHG emission mitigation targets that are specific to individual countries but not to individual sectors. Up to now no explicit policy measures have been implemented to directly force the agriculture sector to reduce GHG emissions. This holds even though there are a number of measures targeting agriculture with objectives that also have climate benefits, such as the EU's Nitrates directive. However, recent scenario analyses indicate that reductions in agricultural emissions will be important to achieve global climate goals of limiting warming to 1.5 or 2 degrees Celsius above pre-industrial levels (Gernaat et al., 2015; Wollenberg et al., 2016). In this context the Paris Agreement puts the agricultural sector back on the agenda of emission mitigation. In this paper we investigate the possible impacts of a carbon tax to be put in place for agricultural non-CO_2 emissions at EU level. We therefore put a tax of 50 EUR/t CO_2 equivalents on methane and nitrous oxide emissions on EU agricultural activities.

3.4. Combined scenario

To measure possible interaction effects between trade and climate policies, we also construct a scenario combining the two policy options: 50 EUR/t CO_2 equivalents tax on agricultural non-CO_2 emissions in the EU

[3] The selection of sensitive products has been carried out based on trade statistics at the tariff line level (HS6). The FTA scenario results in 98.5% of the tariff lines fully liberalized while the remaining 1.5% are subject to the reduced tariff cuts.

while at the same time taking into account a successful EU bilateral trade agenda. In section 5 the robustness of the Combined scenario is tested by varying the carbon tax level and the ambition of the EU's trade agenda.

4. Scenario results

In the following we concentrate on some key results with respect to EU production and related GHG emissions, and then quantify the impacts of the scenarios on global emissions. All scenario results are compared relative to the reference scenario in 2030.

A successful completion of the EU's trade agenda alone affects the EU's agricultural non-CO_2 GHG emissions only modestly, as in the FTA scenario emissions from agriculture are reduced by −1.6% in the EU. The imposed carbon tax on EU agricultural non-CO_2 emissions achieves a much larger reduction of −9.5%, while a combination of the two policies further decreases agricultural emissions by an additional percentage point to −10.7%.

The positive environmental impacts in the FTA scenario are mostly due to a reallocation effect of domestic agricultural supply from the EU to more competitive non-EU producers, i.e. the substitution of own domestic production with imports. Utilized agricultural area (UAA) in the EU is reduced significantly by almost 0.7 million ha, mainly due to a 6% decrease in cereals production. In parallel, set aside area and fallow land increases by almost 11%, thus further reducing arable land. The decrease in UAA and cereals production is accompanied by a 2% decrease in total nitrogen fertilizer application, which is a major source of agricultural nitrous oxide emissions. The EU beef meat herd, a main contributor of methane emissions from agriculture, is also decreasing by 2.4%, leading to a decrease in beef production of 1.6% (see Fig. 1). While EU poultry meat production is also decreasing by 2.6%, pork meat production slightly increases by 0.5%. The impact of these production developments on EU GHG emissions are, however, minor as the emission intensity of pork and poultry is rather low compared to beef production activities.

The negative supply effects of introducing a carbon tax on non-CO_2 emissions from EU agriculture are also focused on the same sectors. However, as livestock production is more emission-intensive than crop production, the livestock sector is considerably more affected in the EU Carbon Tax scenario and the crop sector is less negatively affected than in the FTA scenario. Nonetheless, UAA is decreasing by 0.2 million ha in the EU Carbon tax scenario, and set aside and fallow land increases by almost 25%. Cereals production decreases by 2.3% compared to the reference scenario. Adjustments in livestock production are dominated by a reduction in ruminant herd sizes, with a −5.5% decrease in the number of animals linked to beef production and a −2.8% decrease in herd sizes of sheep and goat fattening, resulting the in meat supply decreases of 3% and 2.7%, respectively.

In a nutshell, in isolation both liberalizing trade and imposing a carbon tax reduces GHG emissions in the EU. However, while trade liberalization affects more EU crop production and related emissions, the carbon tax on EU agricultural non-CO_2 emissions impacts more on the livestock sector. The decrease in GHG emissions in the Combined scenario is basically achieved by an accumulation of the supply effects observed in the EU Carbon Tax and FTA scenarios. Accordingly, the impacts in the crop sector are generally more driven by the FTA and changes in the livestock sector more by the EU Carbon Tax. As a result, UAA declines by almost 1.6 million ha, cereals production decreases by 8% and set aside and fallow land increase by more than 32%. The EU beef cattle herd drops by almost 9%, leading to a decrease in beef production of 5%, whereas animal numbers and production of sheep and goat meat decline by 4.5%.

Fig. 2 shows how each of the modelled technological GHG mitigation options contribute to the EU emission reduction in the three policy scenarios. The reference scenario is not indicated because the mitigation technologies are projected not to be widely implemented in the absence of a policy incentive, as in most cases adoption is not profitable for the farmers. This holds also in the FTA scenario, where only the measure 'fallowing of histosols' (i.e. organic soils taken out of production) is applied beyond the reference scenario level and contributes with about 17% to the total EU emission reduction in the FTA scenario. The remaining 83% of the emission reduction is due to decreased production levels. However, the positive uptake of the fallowing of histosols measure is a mere side effect of the above mentioned general increase of set aside and fallow land. It is therefore triggered by the loss of competiveness in the crop sector in the FTA scenario, and not by decreasing marginal costs as a result of adopting the measure. The picture changes in the EU Carbon Tax scenario, where the technological mitigation options contribute to 42% of the total emission reduction. Introducing the carbon tax triggers an adjustment in the marginal cost of production of agricultural activities, linking those to the emissions. Mitigation technologies improve emission efficiency and therefore reduce marginal costs in the presence of a carbon tax. In this case the marginal cost of adopting a measure is lower than the expected reduction in marginal cost and, therefore, farmers' adopt the measure. Among the available voluntary measures, anaerobic digestion and fallowing of histosols are the technologies that contribute most to the total mitigation in the EU Carbon Tax scenario (about 15% and 14%, respectively), followed by nitrogen as feed additive (4.4%), vaccination against methanogenic bacteria in the rumen (4%) and linseed as feed additive (2.7%). In the Combined scenario, technological mitigation options contribute to 38% of the total EU emission reduction. The share is lower than in the EU Carbon Tax scenario,

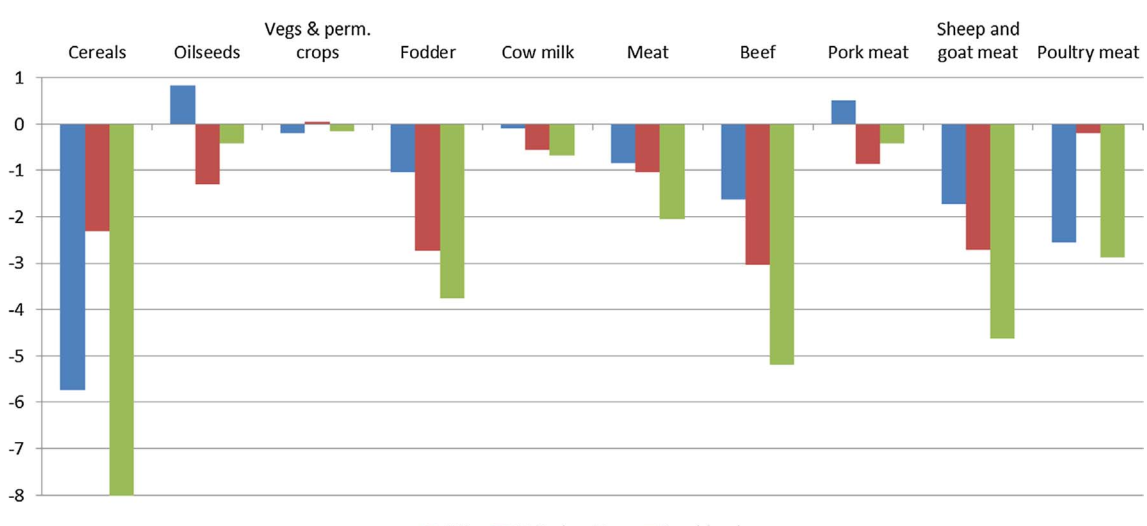

Fig. 1. Percentage change in EU agricultural supply compared to the reference scenario by 2030.

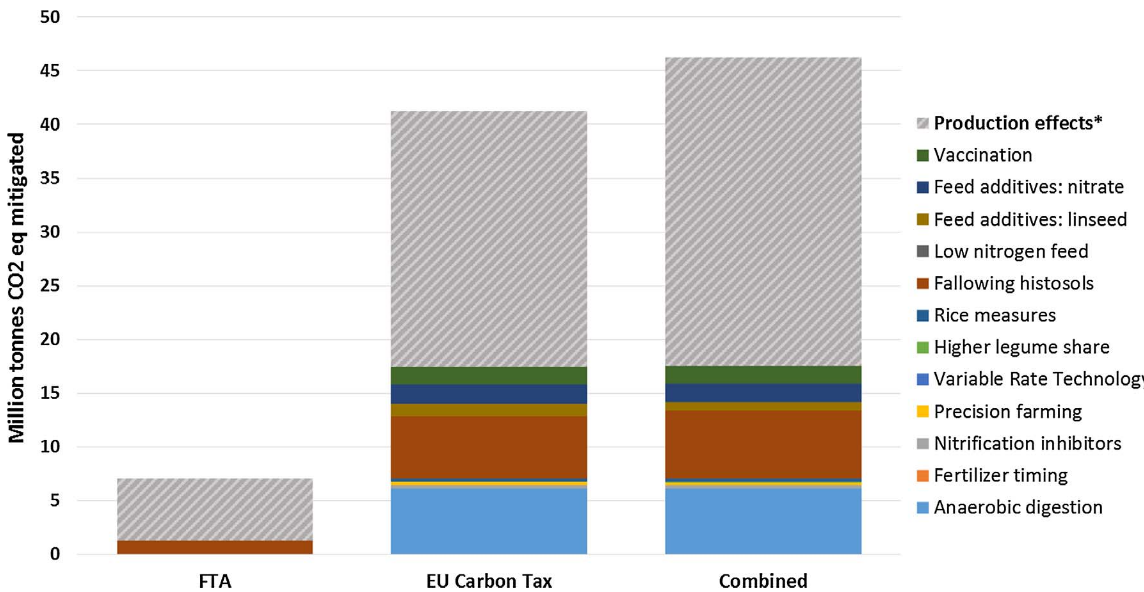

Fig. 2. Contribution of the technological mitigation options to total EU emission reduction by 2030. (*The mitigation effects linked to genetic improvement measures cannot be analyzed in isolation and are included in the mitigation achieved by changes in production).

but this is due to the higher total reduction in the Combined scenario, i.e. the absolute contribution per mitigation technology is quite similar in both scenarios, with the biggest changes compared to the EU Carbon Tax scenario being a further increase of almost 0.6 million tons CO_2 equivalents mitigated by the fallowing of histosols and 0.4 million tons less by the use of linseed as feed additive.

When investigating the interplay of trade and climate policies it is of major importance to assess net emission changes globally. The unilateral trade and climate reduction commitments of the EU in the simulated scenarios could in theory lead to positive or negative changes in global agricultural emissions, because production is shifted to more cost-efficient regions but these regions might be less efficient from a GHG emission perspective. Fig. 3 shows that emission leakage indeed happens in our scenarios, as many non-EU countries increase their agricultural production to compensate for supply changes in the EU. The biggest increase in emissions is shown for Australia and New Zealand, where especially the cattle and sheep herds are increasing significantly in the EU Carbon Tax and Combined scenarios.

As shown in Fig. 4, emission leakage is quite substantial in all three scenarios. In relative terms, emission leakage is highest in the FTA scenario, where the increase of emissions in the rest of the world more than offsets the reduction in the EU, leading to a situation where the FTA actually results in a net increase in total global emissions of almost 3.6 million tons CO_2 equivalents (which translates into a net increase in global agricultural emissions of about 0.1%). Emission leakage is relatively less in the EU Carbon Tax scenario, where 21% of the EU mitigation effort is leaked to non-EU countries, resulting in a net decrease in global agricultural emissions of 0.5%. Finally, emission leakage is again relatively higher in the Combined scenario (50%), resulting in a net decrease in total global agricultural emissions of 0.3%.

Most of the relatively lower emission leakage in the EU Carbon Tax scenario can be attributed to the above mentioned higher share of mitigation technologies (42%) in EU emission mitigation. A higher rate of adoption of mitigation technologies improves the carbon efficiency of EU agricultural production, and therefore decreases the negative supply effect of the carbon tax. In parallel, EU import demand becomes relatively smaller, which decreases the leakage effect, under the assumption that the EU's trading partners are less emission efficient. Accordingly, as the share of mitigation technologies in EU mitigation is lower in the Combined (38%) and especially the FTA (17%) scenario, emission leakage is relatively higher in these two scenarios. As mentioned above, the rate of technology adoption in the EU Carbon Tax and Combined scenarios is triggered by the carbon tax, as for the adopting farmers the marginal cost of applying the technologies is lower than the marginal cost of paying the tax or reducing production levels. The absolute level of the contribution of the mitigation technologies is basically the same in the two scenarios with the carbon tax in place, i.e. the FTA in the Combined scenario does not trigger more technology adoption in the EU. Instead, the FTA results in a drop of EU producer prices, leading to additional EU production decreases which are substituted by more competitive imports from third countries, but as these countries have higher emission factors (i.e. higher emissions per kg produced), the net effect in EU emission mitigation is further diminished by emission leakage. In the scenario without trade liberalization, in addition to the effect of technology uptake, tariffs allow EU agriculture to continue being more competitive due to higher domestic prices.

With respect to the sectoral economic welfare effects (i.e. only considering economic welfare linked to agricultural outputs, and not to other sectors or environmental externalities), our scenarios show that trade liberalization and the introduction of a carbon tax drive the results to different directions: the former puts a downward price pressure on EU agriculture, whereas the latter leads to the opposite effect and EU agricultural prices increase. The trade liberalization agenda of the EU leads to increasing consumer surplus in the FTA scenario (+12.3 billion Euros), as further opening up to international competition decreases EU food prices (Table 2). The impact on agricultural income in the EU is negative (−9.6 billion Euros) due to shrinking agricultural supply and lower producer prices. Conversely, the introduction of the carbon tax on non-CO_2 emissions generates a decrease in consumer surplus of about 5.4 billion Euros due to food price increases. The corresponding increase in producer prices would lead to increasing agricultural income in terms of gross value added before taxes (+6 billion Euros). In the Combined scenario, the downward price pressure of the trade liberalization dominates, resulting mostly in decreasing agri-food prices and consequently in larger consumer surplus, with a parallel (albeit lower) decrease in agricultural income.

Following a supply side implementation of the carbon tax, we account for the carbon tax directly under EU agricultural income. Assuming that farmers have to pay the full burden of the newly introduced carbon tax, EU agricultural income would decrease significantly in both scenarios involving a carbon tax, with a higher decrease in the Combined scenario (−13.6 billion Euros in the EU Carbon Tax scenario and −23.9 billion Euros in the Combined scenario). Avoiding the estimation of transaction costs related to monitoring agricultural emissions and collecting the tax from farmers, the carbon tax is added as a lump sum transfer to government revenues. Our partial equilibrium framework is not suitable for modelling possible options for redistributing this tax revenue back to economic agents. At least part of

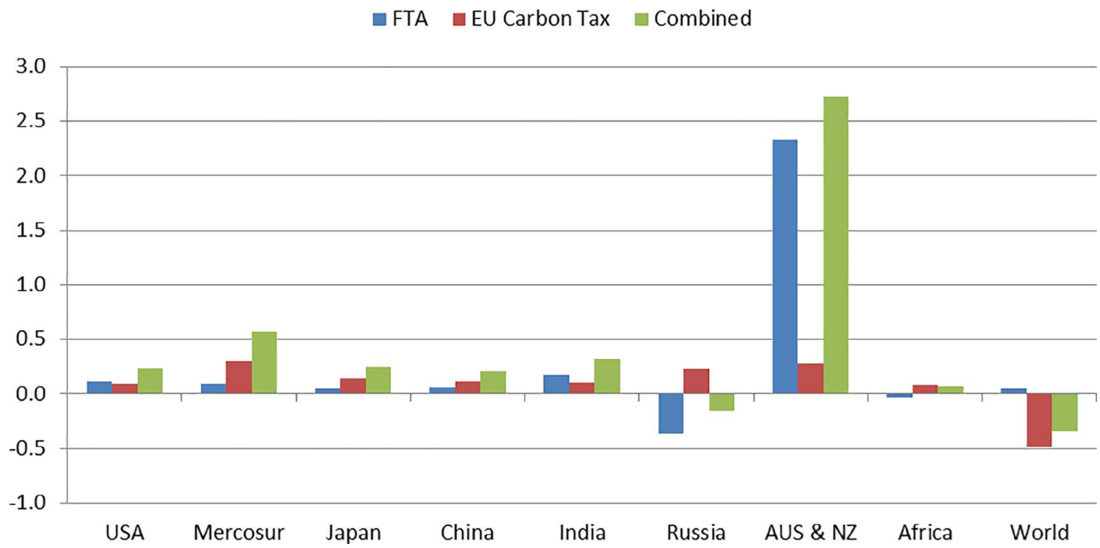

Fig. 3. Global change in agricultural non-CO_2 emissions by 2030 (%-change compared to reference scenario).

the tax revenue, however, could eventually be redistributed to farmers, e.g. by supporting the adoption of mitigation technologies, in order to further incentivize emission-efficient farming practices.

The profit of the processing industry is mostly affected by primary agricultural commodity prices: it either benefits from lower prices in the FTA scenario or is worse off due to increasing prices in the other scenarios. Tariff revenues increase in all scenarios mainly due to increased volumes of trade, taking into account that tariff cuts for sensitive products (whose trade contributes the most to total tariff revenues) are only partial. Tax payer costs of agricultural subsidies, that cover the costs of the Common Agricultural Policy, do not change significantly in any of the scenarios, which is partly due to the limited impacts on total agricultural supply in the EU, but also indicates that a significant part of the subsidies are decoupled from production.

5. Sensitivity analysis

Tariff reductions in the FTA and Combined scenarios have been implemented in a simplified manner, using a full tariff elimination assumption on non-sensitive goods and a 50% tariff cut on sensitive ones. There is, however, a large uncertainty around the magnitude of the tariff cuts. For FTAs still under negotiation the final tariff schedules might lead to a less or more ambitious trade opening for the EU than those implemented in our scenarios. Similarly, the magnitude of a potential EU-wide carbon tax for agriculture is uncertain, as such a tax is currently not considered in the EU political discussions. Acknowledging the potentially significant impacts that the above uncertainties can have on simulated results, we provide a sensitivity analysis on the Combined scenario with alternative assumptions on trade liberalization and on the level of the carbon tax. By combining more and less ambitious trade liberalization assumptions with a higher and lower rate for the carbon tax, a total of four alternative scenarios are compared to the Combined scenario described in the previous sections (Table 3).

The results of the sensitivity analysis confirm the main drivers of EU emission changes. The reduction in EU non-CO_2 emissions is driven mainly by the introduction of a carbon tax on agriculture. Correspondingly, none of the lower carbon tax scenarios reaches a comparable level in emission savings to the Combined scenario. Even in the case of a more ambitious trade agenda, emission savings in EU agriculture hardly reach 25 million tons of CO_2 equivalents. In contrast, doubling the carbon tax relative to the Combined scenario increases emission savings by more than 50%. Combining the higher carbon tax with a more ambitious trade agenda provides relatively small additional benefits in terms of emission savings, with only about 6 million tons of CO_2 equivalents difference between MA_HT and LA_HT. The application of some technological mitigation options increases with an increasing carbon tax, but the larger part of the emission savings is attributed to the production effect (Annex Fig. A1).

In the Combined scenario we observed that both trade liberalization and the introduction of a carbon tax contribute to increasing non-CO_2 agricultural

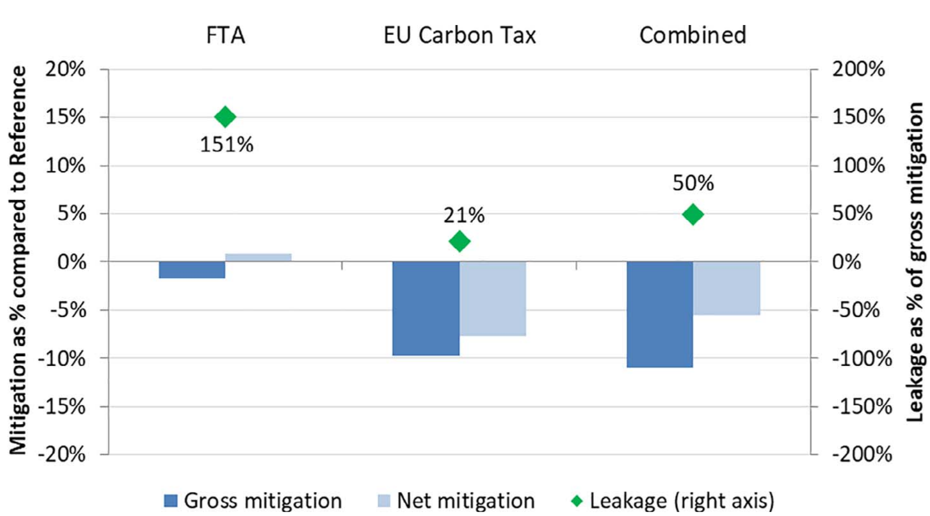

Fig. 4. EU emission mitigation and leakage as percentage of gross mitigation by 2030.

Table 2
Decomposition of welfare effects in the EU agricultural sector, 2030.

		FTA	EU Carbon Tax	Combined
		Absolute (Billion EUR) and percentage difference to the reference scenario		
a.	Consumer surplus	12.3 (0.06%)	−5.4 (−0.03%)	7.8 (0.04%)
b.	Agricultural income	−9.6 (−4.53%)	−13.6 (−6.44%)	−23.9 (−11.26%
	− excluding Carbon tax	−9.6 (−4.53%)	6.0 (2.82%)	−4.6 (−2.15%)
c.	Profit of processing industry	0.7 (1.75%)	−1.5 (−3.85%)	−0.8 (−2.03%)
d.	Tariff revenues and TRQ rents	0.8 (12.9%)	0.3 (4.04%)	1.3 (19.93%)
e.	Tax payers' cost of agricultural subsidies	−0.1 (−0.13%)	−0.1 (−0.14%)	−0.2 (−0.34%)
f.	Government revenue from Carbon tax	n.a.	19.6 (n.a.)	19.3 (n.a.)
	Total welfare change (a + b + c + d − e + f)[a]	4.3 (0.02%)	−0.7 (0%)	3.8 (0.02%)

[a] Total welfare effects linked to the EU agricultural sector, calculated as the sum of consumer surplus plus producer surplus (agricultural income and profits from the processing industry) plus tariff revenues minus taxpayer costs plus government revenue Carbon tax.

Table 3
Combined scenario assumptions for the sensitivity analysis.

	Trade liberalization	
	Less ambitious	More ambitious
Lower carbon tax	**LA_LT scenario** 25% tariff cut on sensitive goods, 50% tariff cut on non-sensitive goods, 25 EUR/t CO2 eq. carbon tax	**MA_LT scenario** 75% tariff cut on sensitive goods, 100% tariff cut on non-sensitive goods, 25 EUR/t CO2 eq. carbon tax
Higher carbon tax	**LA_HT scenario** 25% tariff cut on sensitive goods, 50% cut on non-sensitive goods, 100 EUR/t CO2 eq. carbon tax	**MA_HT scenario** 75% tariff cut on sensitive goods, 100% tariff cut on non-sensitive goods, 100 EUR/t CO2 eq. carbon tax

emissions in non-EU countries, due to a relatively emission-efficient EU agriculture and to shrinking EU agricultural supply. These tendencies are confirmed by the sensitivity analysis. A more ambitious liberalization combined with a higher carbon tax (MA_HT) increases emissions in third countries the most, with the FTAs being responsible for the lion share of the impacts (Annex Fig. A2). Accordingly, the driving forces for emission leakage are also confirmed by the sensitivity analysis (Annex Figs. A3 and A4). A more ambitious trade agenda would increase emission leakage at all levels of an EU carbon tax, and the lower carbon tax is not sufficient to offset the induced emission leakage to non-EU countries, with an emission leakage coefficient similar to the pure FTA scenario (123% in MA_LT vs. 151% in FTA). On the other hand, a higher carbon tax reduces EU emissions to such an extent that emission leakage under more ambitious trade liberalization only slightly increases (from 50% in Combined to 65% in MA_HT).

6. Discussion and conclusions

Our findings provide some empirical evidence on a negative (and significant) effect of trade liberalization on GHG mitigation efforts in EU agriculture. The Combined scenario shows that the current EU trade liberalization agenda would undermine the global mitigation that could be achieved with unilateral measures in the EU.[4] Would the EU accomplish its trade liberalization agenda while setting a sector specific mitigation policy for the agricultural sector this could more than double emission leakage rates (Fig. 4). However, the combined impact of the simulated trade liberalization and EU carbon tax would still result in net mitigation of global agricultural non-CO_2 emissions (Fig. 3). Contributing to the stream of literature examining the empirical measurement of the trade-liberalization – GHG emissions nexus, we conclude that trade liberalization in the agricultural sector by the EU does not lead to environmental gains. Regarding the interplay of trade and climate policy, we find that the negative impact on non-CO_2 GHG emissions of trade liberalization is smaller than the positive emission impact of climate policy. However, the relative impact varies by region and commodity, which potentially allows designing a more targeted approach to avoid the contradicting impacts of both policies.

With respect to unilateral mitigation efforts, our results on emission leakage are in line with the majority of empirical evidence in the literature (e.g. Lee et al., 2007; Herrero et al., 2016; and previous work with CAPRI in Pérez Dominguez et al., 2012, 2016; Van Doorslaer et al., 2015; Fellmann et al., 2018), although some authors find that unilateral emission reduction policies can lead primarily to a loss in competitiveness rather than to significant emission leakage effects (Matoo and Subramanian, 2013).

Regarding the trade-liberalization – GHG emissions nexus, our simulated trade-liberalization impacts on global mitigation efforts of agricultural non-CO_2 emissions are negative. The negative net effect of the modelled FTAs on global agricultural GHG emissions is due to an increase in production in non-EU countries with relatively high emission intensities (more GHG emissions per kg produced). In the scenarios with a successful EU FTA agenda in place, production increases are, for example, especially shown for Australia and New Zealand with respect to beef and sheep meat as well as dairy production. Both countries have generally more extensive production systems than the ones in the EU, which are on the one hand very competitive on the international markets, but, on the other hand, come along with higher emissions per kg produced. Therefore Australia and New Zealand substantially contribute to the simulated emission leakage effects, with more than 5.4 and 6.3 million tons CO_2 eq. in the FTA and the Combined scenario, respectively, compared to 0.6 million tons of CO_2 eq. in the EU Carbon Tax scenario without a FTA in place. It has to be mentioned that our modelling approach is not able to decompose the total environmental impacts to scale, composition and technique effect. The modelling approach for non-EU emissions does not capture technology transfer or additional efforts in non-EU countries to increase emission efficiency. We rather focus on the scale and composition effects, as the Armington approach to trade covers the change in import demand patterns, and the partial equilibrium framework of CAPRI takes into account the supply side adjustments in agriculture and primary processing in great detail.

As outlined in the literature, the extent of emission leakage and hence the net gain of national mitigation efforts for global GHG emissions reduction depends significantly on the relative GHG efficiency (i.e. emissions per unit of output) of agriculture in the exporting countries compared to the importing country (Caro et al., 2014; Pérez Domínguez and Fellmann, 2015;

[4] Although we implement a specific carbon tax on agricultural non-CO_2 emissions, the carbon tax can also mimic the operation of a larger policy package including possible elements of efforts for improved emission efficiency (e.g., farmers' education, cost compensation for the adoption of technological GHG mitigation measures) and even compulsory GHG mitigation measures (e.g. reduction targets). Thus, the generalization of our results to a broader set of policies is to some extent possible, although the welfare implications are conditioned by the policy instrument implemented.

Scott and Barrett, 2015). Additional measures to assure that compensatory actions are taken for the specific product/origin combination most affected by trade liberalization would assure the integrity of the climate change mitigation efforts of the EU. Although we do not go into a political economy discussion on the viability of the above policy options, our finding may support combining a unilateral EU carbon tax with other policy instruments (such as border tax adjustments) in order to prevent or reduce the leakage effect. However, border tax adjustments, such as tariffs on imports based on the emission intensity of their production could be in conflict with many objectives of the EU trade agenda. Moreover, border adjustment measures are often seen as an inappropriate and non-useful measure, especially in the context of WTO rules and due to potentially negative welfare effects in particular for developing countries (Frankel, 2008; Stavins et al., 2014).

In our analysis we do not calculate with possible future regional FTAs outside the EU's trade agenda, or with a successful completion of the current WTO negotiation round. Therefore the gains from trade for the EU and for its FTA partners are probably overestimated. The impact of this assumption on simulated emission leakage effects is ambiguous, as the EU may manage to expand production (and related emissions) for commodities where it traditionally has an export position in global markets (e.g. dairy) while the opposite holds for commodities where imports may grow significantly (e.g. beef). In this context it has to be mentioned that in our analysis emissions from the transport sector are also not taken into account, which is a rapidly growing source of emissions itself with obvious linkages to increased international trade in goods. We concentrate on non-CO_2 emissions (where agriculture is an important emitter) and we do not take into account CO_2 emissions (or sinks) from the land use, land-use changes and forestry (LULUCF) sector.

It has to be highlighted that the reported emission leakage impacts crucially depend on the estimated emission coefficients for the commodities produced in non-EU countries. As EU agriculture is assumed to be relatively emission efficient globally, the substitution of domestic EU production with less emission efficient imports offsets the emission savings in the EU, leading to emission leakage that can eventually result in a net increase in global emissions. While our approach for estimating emission factors for non-EU countries takes into account the changes in emission intensities over time (based on past trends), technological mitigation options are not specifically considered in the model outside the EU. Thus, changes in emission factors outside the EU are not model-endogenous (but rather fixed) in our comparative simulations. As our scenarios with the EU carbon tax show, the application of mitigation technologies contributes to the reduction of EU emissions from agriculture and at the same time moderates the negative supply effect on EU production, hence diminishing emission leakage effects. The lack of model-endogenous mitigation technologies in non-EU countries limits the validity of the simulated effects on emission leakage, but whether the leakage effects are over- or underestimated depends on the particular mix of emission intensity changes globally. It remains for further research to calculate emission factors for commodities produced in non-EU countries under different technological development options.

Furthermore, we assume a unilateral climate action from the EU, which distorts relative carbon prices extremely in favor of non-EU countries. The resulting lower competitiveness of the EU agricultural sector on global markets probably adds to an overestimated impact on trade in our Combined scenario. Accordingly, the extent of emission leakage depends on the commitments other countries make regarding their contributions to the Paris Agreement. It remains to be seen how the global climate agreement will be put into action, but our scenario results show that multilateral commitments will be necessary not only in the light of emission leakage and global emission mitigation, but also with respect to minimizing distortions to agricultural competitiveness arising from unilateral emission mitigation obligations.

Notwithstanding the above caveats, our paper provides an unambiguous message, as it points to the importance of designing future FTAs in the framework of national determined contributions (NDCs) within the Paris Agreement, assuring that mitigation efforts are not undermined in sectors where trade is forecasted to increase the most. Depending on the relative development of the trading partners, the mitigation efforts could be partly funded by the developed party of the FTA, by both parties or by the emitting party.

Disclaimer

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

Appendix A

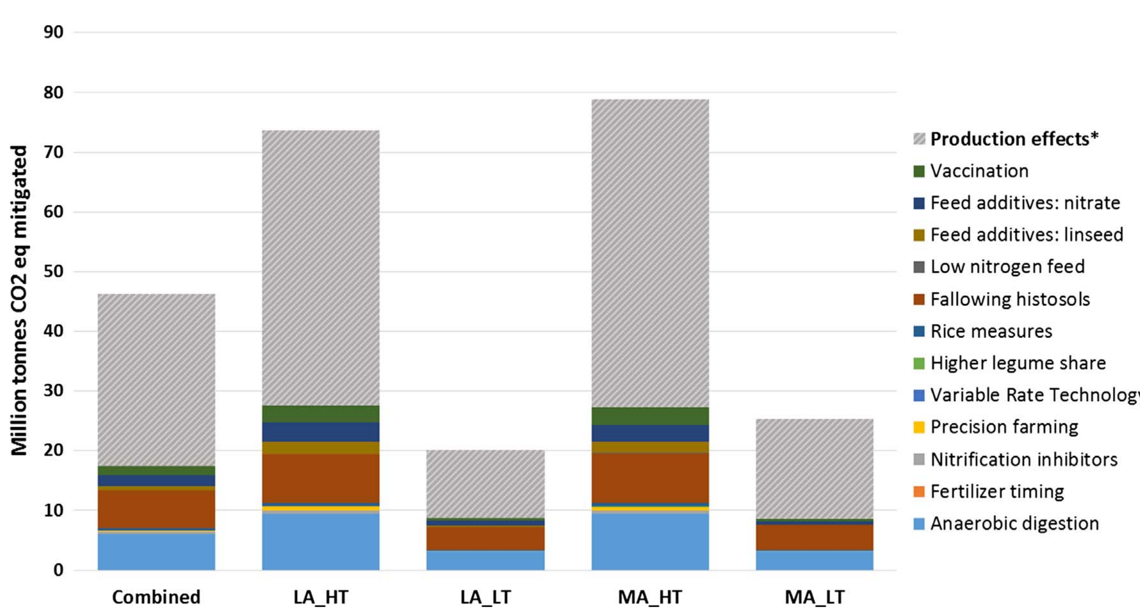

Fig. A1. Contribution of the technological mitigation options to total EU emission reduction by 2030, sensitivity analysis results.

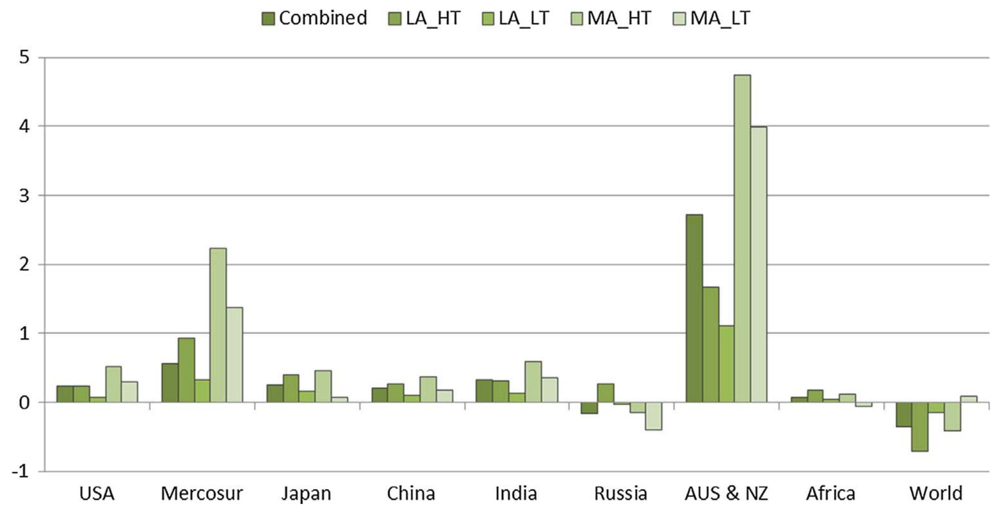

Fig. A2. Global change in agricultural non-CO_2 emissions, sensitivity analysis results by 2030 (%-change compared to reference scenario).

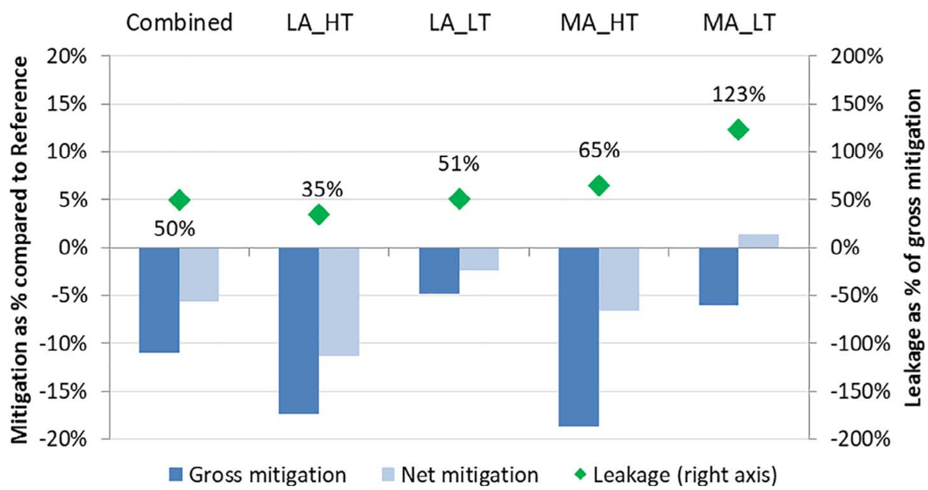

Fig. A3. EU emission mitigation and leakage as percentage of gross mitigation by 2030, sensitivity analysis results.

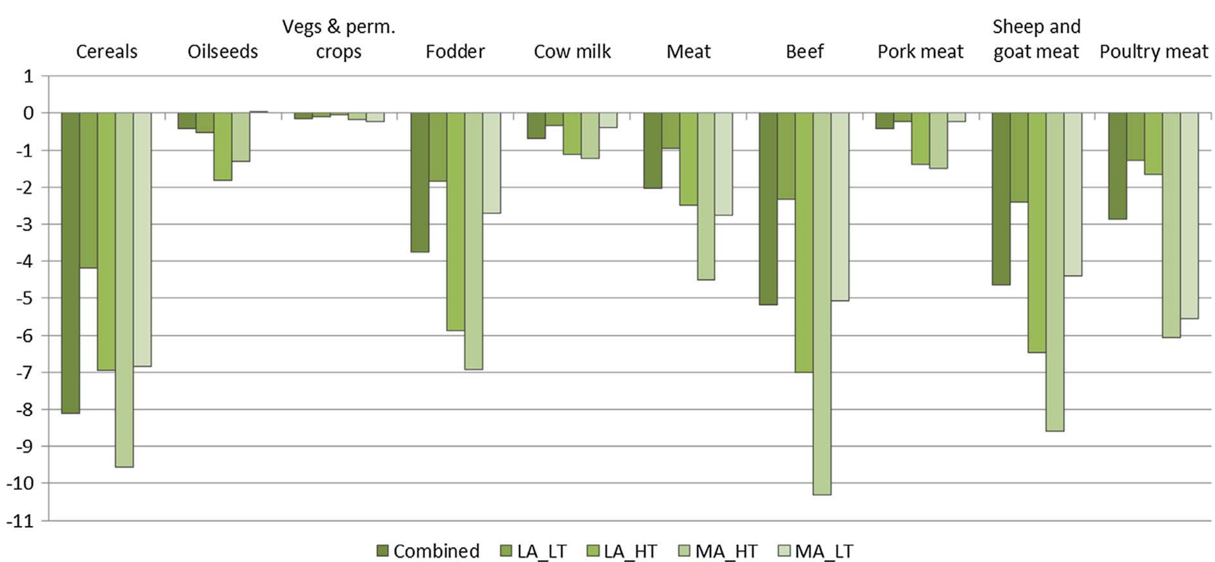

Fig. A4. Percentage change in EU agricultural supply compared to the reference scenario by 2030, sensitivity analysis results.

Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodpol.2018.01.011.

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