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The benefits of a multilateral agreement

Taxing GHG emissions in agriculture: The benefit of a multilateral agreement

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Abstract

Reducing greenhouse gas emissions from agriculture is important in order to reach global and regional climate targets. However, the efficiency of unilateral climate policies aimed at reducing emissions might be hampered by emission leakage. One way to eliminate leakage is to implement a global emission tax. This does, however, open up questions of fairness and food security in poorer countries, where emission intensities are often higher. In this article we study the effects of different climate policies on GHG emission reduction in agriculture by simulating five policy scenarios using the CAPRI model; one scenario with an EU emission tax in agriculture, one with an EU emission tax and a border carbon adjustment (BCA), one with a global emission tax, one with an emission tax scaled by GDP per capita, and one with a global tax at 1/10 of the tax level in the other scenarios. For the global scenarios we also compute the effects on food consumption change and nutrient intake. We find that a global tax of 120 EUR per ton CO2-eq could reduce global agricultural emissions by 19%, but also jeopardizes food security in some parts of the world. A global tax at 1/10 of that rate achieves 3.2% emissions reduction but also raises concern for food security. In contrast, the unilateral EU tax of 120 EUR per ton CO2-eq, accompanied with a BCA, reduces global agricultural emissions by only 0.15%.

Key policy insights:

• A unilateral emission tax in the EU causes significant emission leakage. This result depends strongly on differences in emission intensities between regions.

• A “watered down” global emission tax achieves a considerably larger global emission reduction than an EU tax accompanied with a border carbon adjustment, while putting less strain on regional food security than a global tax at full carbon price level.

• Tax rebates for poorer countries reduce the effectiveness of the global tax because producers with higher emission intensities tend to get lower tax rates, and so other ways of taking equity into account should be sought when designing climate policies in the agricultural sector.

Keywords: climate change mitigation, agricultural emissions, economic assessment, economic models, carbon leakage, food security

Introduction

Most countries in the world have agreed to limit the global warming to “well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels” (UNFCCC 2015). Limiting global warming to less than 1.5°C rather than 2.0°C is likely to have substantial benefits, e.g. lower frequency of agricultural droughts (IPCC, 2021; Masson-Delmotte et al., 2019). However, the 2021 Emissions Gap Report (UNEP, 2021) finds that current Nationally Determined Contributions are vastly insufficient to reach even the 2.0°C target. At the current level of ambition, global temperatures would rise by 2.7°C in 2100. The GAP report also points out that agriculture can contribute by reducing emissions of methane, helping to reduce warming in the short run.

Agriculture contributes to about 16% of the total anthropogenic greenhouse gas (GHG) emissions (excluding energy use in agriculture and emissions caused by land use and land use change) (Ritchie and Roser, 2020). In a recent communication, the European Commission presents a vision of how to make Europe climate-neutral in 2050, in order to contribute to limiting global warming to 1.5°C

(European Commission, 2018). In this vision, the importance of reducing non-CO_2 from agriculture is emphasized. Thus, the agricultural sector also faces the pressure to contribute to reducing GHG emissions in the EU. However the potential of emission leakage is of concern.

Focusing climate policies on emissions from the EU is too narrow a perspective. *Unilateral* mitigation measures may have unintended consequences if international trade is not taken into account. Consider, for instance, a production tax on agricultural emissions in one region, such as the EU. The production tax may reduce emissions within the EU. At the same time, it may reduce production of food in the EU, which leads to higher prices, larger imports and lower exports. Thus, the increased imports would cause an increase in production and emissions outside of the EU. Furthermore, the reduced exports from the EU may be replaced by increased domestic production in the importing region, increasing emissions outside of the EU too. Finally, both the increased imports and reduced exports may change trade flows among third parties, therefore re-allocating production and emissions among world regions. As GHG emissions are global pollutants, such carbon leakage undermines the effectiveness of unilateral environmental measures.

Various accompanying measures, e.g. border carbon adjustment and output based rebating that alleviate the negative side effects of *unilateral* mitigation policy have been analysed (Böhringer, Fischer, & Rosendahl, 2014; Fischer & Fox, 2012, Nordin et al., 2019). The studies show that such accompanying measures can be effective to alleviate the leakage problems under some circumstances, while under other, a significant leakage remains, reducing the efficiency of the unilateral measures (Marcu et al., 2013). This paper compares a carbon tax in agriculture from the unilateral and multilateral perspectives, in order to quantify what the possible gains are from aspiring a multilateral agreement in agriculture. Furthermore, we investigate how the effects of the global tax changes if it is modified in various ways: if the tax rate depends on GDP/capita, or if the global agreement is weak and achieves only a fraction of the level of ambition of the unilateral measure. An obstacle for the introduction of a tax on agricultural commodities is that it might induce a food shortage in poor regions. Therefore, we examine how the global taxes would affect food consumption globally.

The quantitative analyses are carried out with the simulation model CAPRI. This study updates, documents and publishes the CAPRI model estimates of GHG emission coefficients for global regions outside the EU, useful for computing impacts on carbon leakage in agriculture.

The rest of this paper is outlined as follows: In section 2, we introduce and motivate the various scenarios for carbon taxation. Section 3 introduces the CAPRI simulation model, focusing on the trade components that are most relevant for this study. Section 4 describes how we estimated the global GHG emission intensities used in the simulation and the resulting tax rates used in the various scenarios. Section 5 presents the results for GHG emissions, agricultural production, and consumption. In section 6 we summarize our results, and draw some conclusions. We also discuss the mechanisms at play and the implications for policy makers.

Scenarios

The purpose of the study is to compare, from economic and environmental perspectives, the outcomes if the EU would choose to go ahead with unilateral mitigation measures or rather aspire various global agreements. We compute the following main scenarios:

- REF: Reference scenario.
- EUTAX: As REF, plus an emission tax levied on agricultural production in all EU countries.
- EUTAXBCA: As EUTAX plus a border carbon adjustment (BCA) for imports to the EU.
- GLOBTAX: As REF plus a global emission tax levied on agricultural outputs.
- GLOBTAXPROP: As GLOBTAX, but the tax level is scaled by GDP per capita.
- GLOBTAXLOW: As GLOBTAX, but the tax level is only 10% of the level in GLOBTAX.

The *reference* scenario implies a full implementation and then continuation of the current common agricultural policy (CAP 2014-2020) until 2030. The EUTAX scenario extends the reference scenario with a carbon tax in all EU countries of 120 EUR/ton CO_2-eq. The tax rate is based on the Swedish carbon dioxide emission tax on fossil fuels, which amounts to 1,150 SEK/ton. In the simulations, the tax is inflated by 1.9% per year (standard inflation rate in CAPRI) from 2018 to 2030, resulting in about 150 euro/ton in nominal terms. The tax is implemented as a fixed amount per kg of product, computed by multiplying each commodity's emission intensity by the tax rate. The tax per ton of product is defined before the simulation and kept constant in simulation. This way of modelling the tax implies that the producers cannot avoid the tax by changing their production technology to one with a lower emission intensity, but only by changing their production mix towards products with a smaller carbon footprint. This implementation on the one hand makes the tax less efficient than it would be if linked to the production technology. On the other hand, it is simple enough to implement even in countries with less developed administrative control structures. The tax might be viewed as an approximation of costly mitigation measures that would shift the agricultural supply functions upwards, leading to less production of emission intense commodities.

The EUTAX scenario is expected to reduce EU production and induce emission leakage when EU exports decrease and imports increase. EUTAXBCA extends the EUTAX scenario with a new tariff, a Border Carbon Adjustment (BCA) on imports to the EU. The purpose of the BCA is to reduce emission leakage and enhance the mitigating effect of the carbon tax. The same tax level, 120 EUR/ton CO_2-eq, applies to imported commodities as to commodities produced in the EU. As in the case with the production tax, the import tariff is implemented as a fixed amount per kg of product, and is computed by multiplying the tax rate by each commodity's emission intensity in the exporting region.

The GLOBTAX scenario extends the reference scenario by implementing a tax on agricultural GHG emissions globally. The tax rate per ton of emissions used in the EUTAX scenario applied is levied to agricultural production in all regions of the world depending on the regional GHG emission intensity.

The GLOBTAXPROP scenario extends the GLOBTAX scenario, making it more equitable by scaling the tax by GDP per capita in each region in relation to the average in Western Europe. A tax affecting poorer regions to a lesser extent could be a more realistic approach for reaching a global agreement. Hence, it is relevant to explore the different outcome of the GLOBTAXPROP scenario in comparison to the GLOBTAX scenario. Since Western Europe is a relatively affluent region, this scenario reduces the global average tax level.

In the GLOBTAXLOW scenario, a global tax is implemented in the same way as in the GLOBTAX scenario, however at a tenth of the tax rate (12 EUR/ton CO_2-eq) everywhere. This scenario represents the world reaching a watered-down global mitigation commitment for agriculture.

The CAPRI model

The CAPRI model is a Euro-centric simulation model of agricultural supply, demand and trade, developed and used in many applied studies since 1999. It has been frequently used to study the interactions between agriculture, trade and greenhouse gas emissions (e.g. Gren et al. 2021, Jansson et al. 2020, Himics et al. 2018, Gómez-Barbero et al. 2020). CAPRI contains two models that are interlinked. One model is a European agricultural supply model. The other model is a global market model of supply, demand and trade in agricultural commodities.

The supply model is based on the assumption that farmers try to maximize their profits under the restrictions set by land availability, technical conditions for crops and animal husbandry, and the various policy instruments that exist in the sector. The farmers do so by selecting the levels of 43 production activities, producing or using 48 inputs or outputs. For crop production, the technical conditions imply that the crop's uptake of nitrogen, phosphorous and potassium has to be met by fertilization and suitable crop rotations. Similarly for animal husbandry, the animals' requirements of protein, energy and other nutrients must be met by feeding. Some feeding stuffs can be purchased on the market, while others, like grazing, silage, and hay must be locally produced. The common agricultural policy is well represented in the form of farm payments, greening requirements and selected agri-environmental measures. Also national subsidies in e.g. Northern Sweden, Finland and Norway are included. The supply model covers regions in all EU countries and some Balkan countries, Turkey, the United Kingdom and Norway. CAPRI contains about 260 such production regions in Europe, roughly corresponding to the NUTS2-nomenclature. All other countries in the world are represented in the market model.

The market model simulates global production, consumption and trade with agricultural products, and computes the prices that steer production in the supply models. All countries in the world are represented in the market model, either as individual countries or as part of some regional aggregate. In total, there are eighty regions with their own consumption, production and processing sectors. Those eighty regions form 45 trade blocs. For instance, the EU countries form two such blocs, called "EU west" and "EU east". The model computes trade flows between all pairs of trade blocs, and provides mechanisms for simulating trade instruments such as tariffs and trade quotas. Between regions or countries within the same trade bloc, in contrast, only net trade is simulated. That means that the difference between the sum of supply and the sum of demand of all regions within the trade bloc must match the net trade of the trade bloc itself, but without further details of how the individual regions trade within the bloc. Production in the market model is represented in a simpler way than in the supply model, in particular representing the use of tradable inputs such as bulk feeding stuffs with cross-price elasticities instead of technical constraints.

CAPRI is comparative static. That means that it starts with an economic equilibrium, and computes how changes to restrictions, policies or other model parameters disrupt that equilibrium. The initial equilibrium is assumed to represent a point of time in the future, in our case 2030, and it is created by a calibration of the model to a so called "baseline". The baseline is created based on historical data series and econometric forecasts in the annual Agricultural Outlook of the European Commission. The calibration means that selected parameters of the model, governing how agents such as consumers and producers behave, are adjusted so that the baseline is in equilibrium, i.e. the prices are such that the agents choose to produce and demand precisely the amounts found in the baseline.

Estimation of GHG emission intensities

The estimations of GHG emission intensities (EIs) and the associated accounting framework of CAPRI have been continuously developed in several studies by several researchers, e.g. Domínguez et al. (2016) and also further extended with new data and revised methods for this present study. We therefore see fit to provide an overview of the present methods in the supplementary material (Appendix 1), as well the results of the estimations (electronic supplement). Figure 1 summarizes aggregated results for key commodities and regions.

CAPRI contains emissions of N_2O (Nitrous oxide) and CH_4 (methane) from agricultural sources, and also a selection of additional non-agricultural emissions. The emissions of N_2O and CH_4 are aggregated to agricultural CO_2 equivalents (CO2-eq) using global warming potential factors for 100 years' time horizon of 298 and 25 respectively.

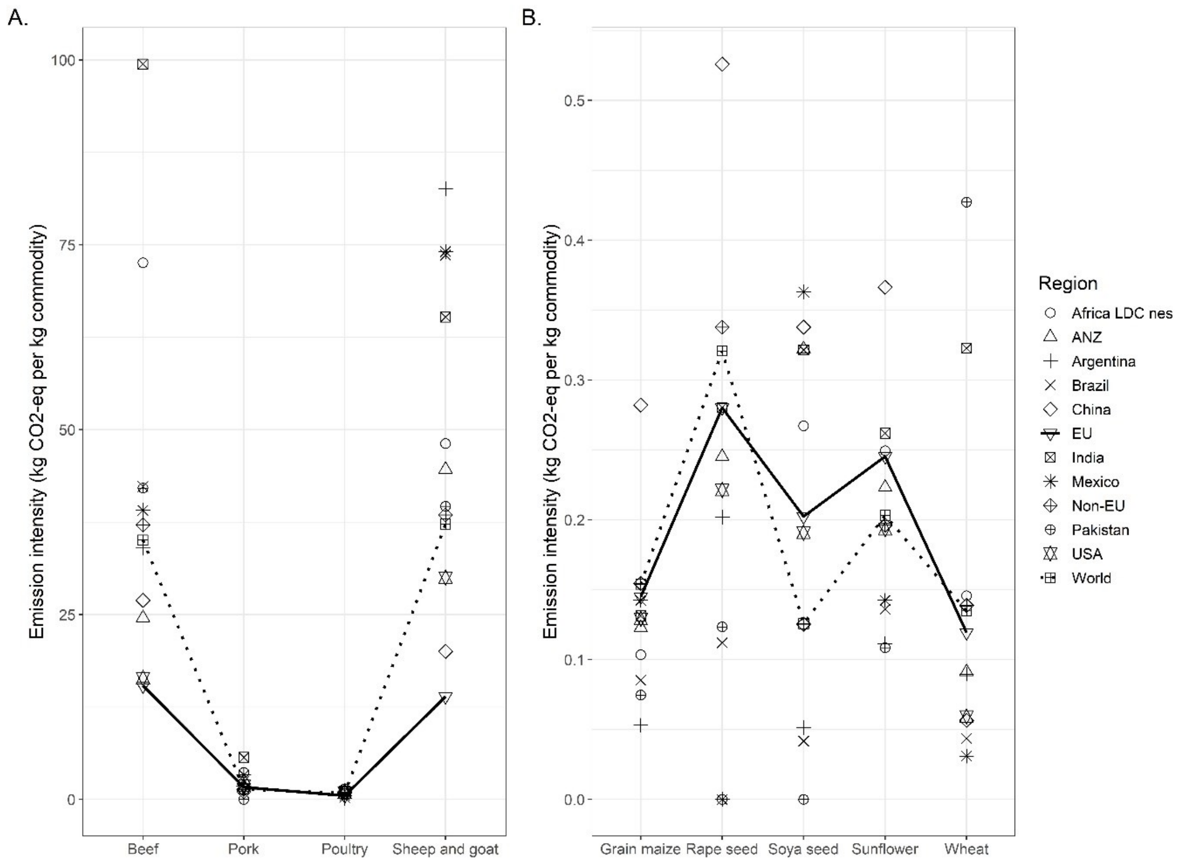

Figure 1. Emission intensity estimates for selected commodities and regions of the world in 2030. Left panel: for animal products. Right panel: for crop products.

Beef meat is most important, as it is widely traded and its production causes high emissions. In our estimates, the EU has low emissions associated with beef production by international standards (15 kg/kg), in particular compared to India (99 kg/kg) and least developed African countries (Africa LDC nes) (73 kg/kg). Brazil, Mexico and Pakistan all have EIs around 40 kg/kg. China and Australia and New Zealand (ANZ) have slightly higher EIs than the EU at about 25 kg/kg. USA, finally, has a EI very similar to that of the EU. The global average (formed using the production quantities of the baseline) is 35 kg/kg.

Sheep and goat meat has similarly high EIs as beef, whereas the pork EI is only about 5-10% of that of beef. The poultry meat EI is even lower, averaging 1 kg/kg globally. Among crops, rice stands out as high-emitting due to its association with methane from rice paddies. The EIs estimated by us average 1.5 kg/kg globally, but with considerable regional variations.

Among the animal feed products, soy is of particular interest since it is produced in large quantities and widely used as animal feed. Our estimates give an average EI of 0.13 globally, which is similar to wheat (0.13) but less than rape seed (0.32). The estimates for Brazil and Argentina stand out, with low values of about 0.05 for both countries. This result is due to low application rates of synthetic fertilizers in the AgLink data, leading to low emissions of N_2O associated with fertilizer turnover, in combination with low reported GHG emissions of N_2O from crop residues.

The production side emission accounting becomes cumbersome when we combine an emission tax in production with a border carbon adjustment. The EIs used for computing the production tax do not include emissions embodied in animal feed purchased at the market, since those inputs are already taxed upon production. For the BCA, however, we want to tax all agricultural emissions embodied in the product at the border, i.e. including animal feed used overseas. To this end, we use a set of EIs that has been modified to take feed use into account. The computation of these modified EIs is similar to the estimation of the production side coefficients discussed above.

Sensitivity analyses

The estimated emission intensities have a strong influence on the results of studies such as this. Therefore, the robustness of the estimates is of great interest, and further work on deriving statistics such as standard deviations is needed. In order to investigate the sensitivity of our results to changes in EIs, we repeated all the simulation experiments with alternative sets of estimates, where we have shrunk the EIs towards the global average in two steps. The shrinkage, rather than expanding the dispersion, can be motivated both from a statistical and from an economical point of view. From a statistical point of view, shrinkage is known to be capable of reducing the mean squared error of predictions, at the cost of introducing a bias in the estimation (e.g. Robbins, 1964). From an economic point of view, it can be argued that the emission intensities of firms competing on international markets is different from the regional average firm: their products are better substitutes, and they are likely (Melitz, 2003) to be the most productive firms in each region. Hence, the EIs applied to marginal changes, e.g. on exports to the EU, should be different from the national average, and likely more similar across regions. In order to investigate the impact of a smaller variation in international EIs, we repeated all simulations twice, where each EI was shrunk towards the world average. In the first variant, the ratio of regional to world average EI was reduced to the square root and in the second variant to the cubic root. More formally, we computed a factor z_r for each region *r* that determines the shrunk EI_r^* as a function $EF_r^* = EF_r z_r$ by requiring that the ratio of regional to global EI shrinks as the exponential function $\frac{EI_r^*}{EI_{glob}} = \left(\frac{EI_r}{EI_{glob}}\right)^e$ for $e = \frac{1}{2}$ and $e = \frac{1}{3}$. The factor z_r was computed for the reference scenario and applied in the computation of tax rates and emission results in the two sensitivity experiments relating to emission intensities. Changing the EI this way also changes (reduces) the global volume of emissions in the reference scenario. Therefore, an additional reference scenario was computed for each sensitivity experiment, and in the results section we present the impact compared to the relevant reference scenario for each sensitivity experiment (Shrinkw1 and Shrinkw1 in fig. 2 and 3).

Another important parameter is the substitution elasticity of the consumer. In CAPRI, consumers treat domestic and imported goods as imperfect substitutes, and the substitution elasticity steers the extent to which domestic products are replaced with imported substitutes when prices change. This has an immediate impact on emissions leakage. In the reference scenario they are set to values that vary by commodity from 2 up to 6 with the lower values for animal products and higher for crop products based elasticities from the literature reported in Ahmad, Schreiber and Montgomery (2020, p. 16) and on established CAPRI parameters. Appendix 2 lists all the substitution elasticity values used in this study. The substitution elasticities are important for the results, yet uncertain. Bajzik et al. (2020) carry out a meta-analysis that is not product specific and suggest using values from 2.5 to 5.1, broadly supporting the values we use. In our sensitivity analyses, we ran additional simulations where all CES parameters were 50% lower and 50% higher than in the standard setting (Hices and Loces in fig. 2 and 3).

Results

GHG emissions and leakage

Unilateral agreements

The first scenario, EUTAX, induces a reduction in regional agricultural emissions in the EU of 20 million metric ton CO_2-eq annually (5.5% of EU agricultural emissions, top light grey bar in Figure 2). However, global emissions decrease by only 4.8 million metric ton CO_2-eq (0.074% of global agricultural emissions, bottom light grey bar in Figure 2). Hence, most of the mitigation in the EU (76%) is offset by increased emissions outside the EU (NONEU in Figure 2).

In the EUTAXBCA scenario regional agricultural emissions in the EU decrease by 16 million metric ton CO_2-eq (4.3% of EU agricultural emissions, top dark bar in Figure 2), while global emissions decrease by 9.9 million metric ton CO_2-eq (0.15% of global agricultural emissions, bottom dark bar in Figure 2). This means that 36% of the emissions mitigation in the EU is offset by increased emissions outside the EU.

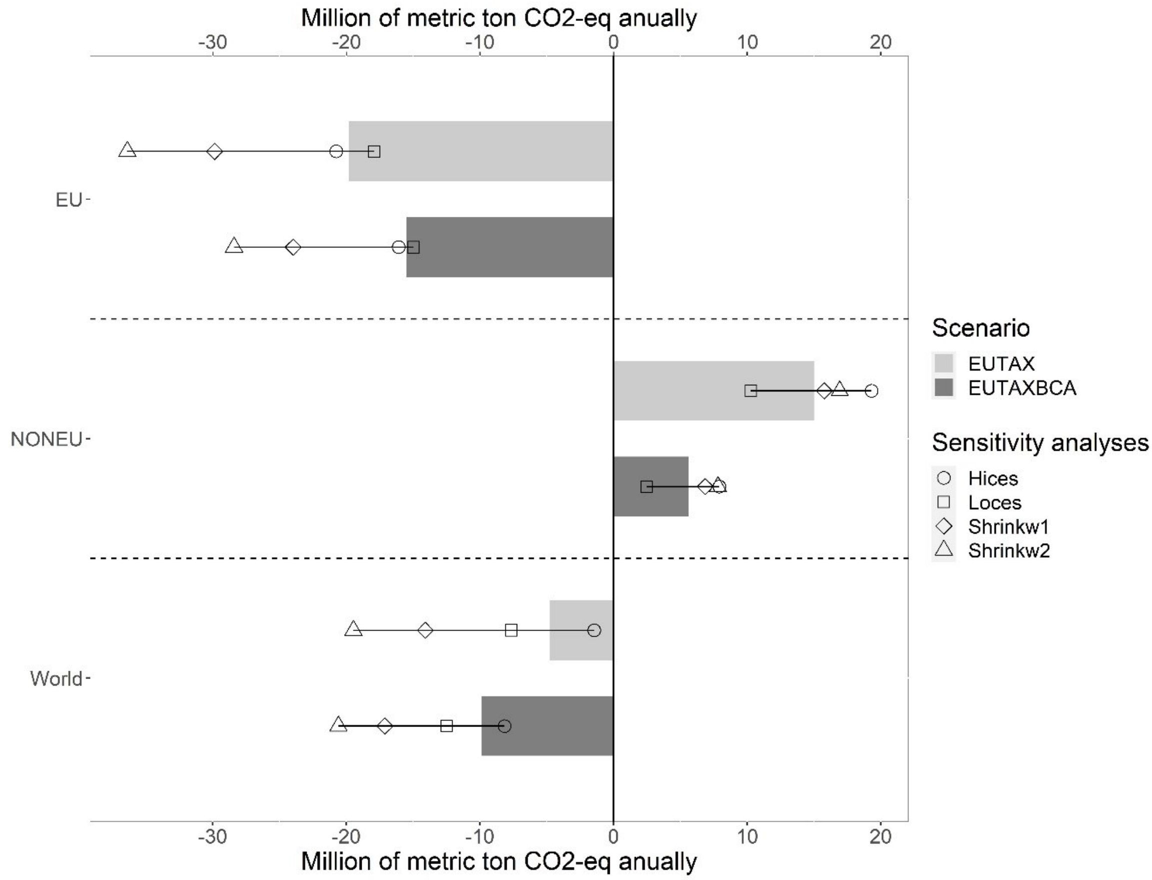

Figure 2. Mitigation in the EU and leakage to Non-EU countries in the unilateral scenarios. Million tons CO2-eq annually, difference to reference scenario. Lines at the end of the bars indicate the range of outcomes in the sensitivity analyses.

In the EUTAX scenario, changes in regional emissions are driven by a few animal products: beef, pork, sheep and goat meat (SGMT) and milk. Beef production accounts for the largest share of the reduced emissions in the EU, 47% (9.2 million tons). However, on a global scale the decrease in emissions from beef production is only 0.99 million tons. This can largely be attributed to considerable differences in emission intensity for EU and non-EU production, since only 36% of the reduced production in EU is replaced by non-EU production. Cereal production is also a large contributor to reduced emissions in the EU in the EUTAX scenario, due to the large quantities produced, 18% of the total reduction (3.6 million tons). Of the reduced EU production 20% is replaced by non-EU production. However, non-EU production is slightly less emission intensive, and cereal production therefore contributes to the largest share of the reduced emissions globally, 64%

(3.0 million tons). SGMT production is a smaller industry, and despite large emission intensity it contributes to just 4.1% (0.81 million tons) of the reduced emissions in the EU. About 53% of the reduced EU SGMT production is replaced by increased non-EU production. However, due to significantly larger emission intensities in non-EU production, the EU tax leads to a 0.64 million ton increase in global emissions from SGMT production.

In the EUTAXBCA scenario the changes in emissions largely follows the same pattern as in the EUTAX scenario. Generally, the BCA prevents that reduced EU production is replaced by imports, and hence, emission leakage is smaller than in the EUTAX scenario. This is apparent concerning beef production, where only 20% of the reduced EU production is replaced by non-EU production. Emissions from beef production in the EU are reduced by 7.8 million tons in the EUTAXBCA scenario. However, due to the larger emission intensities in non-EU production, the global emissions from beef production only shrink by 2.9 million tons. The BCA is particularly effective in the SGMT and dairy markets, where global emissions decrease *more* than EU emissions. This is because the BCA reduces EU demand for imports, and if non-EU producers cannot easily replace exports to the EU with increased exports to other markets, they reduce production and emissions. This effect causes global emissions from SGMT production to decrease by 2.7 million tons, while EU emissions from SGMT production decrease by just 0.052 million tons.

Multilateral agreements

In the GLOBTAX scenario, global agricultural emissions decrease by 1,200 million metric ton CO_2-eq (19% of global agricultural emissions), i.e. 120 times as much as in the EUTAXBCA scenario. Since the tax is global, no emission leakage arises. A large share (26%) of the emission reduction takes place in LDC-countries despite their much smaller share (5.5%) in total agricultural production (tons primary production in the CAPRI database), because their EIs are generally higher than those of non-LDC countries (lower panel in, figure 3).

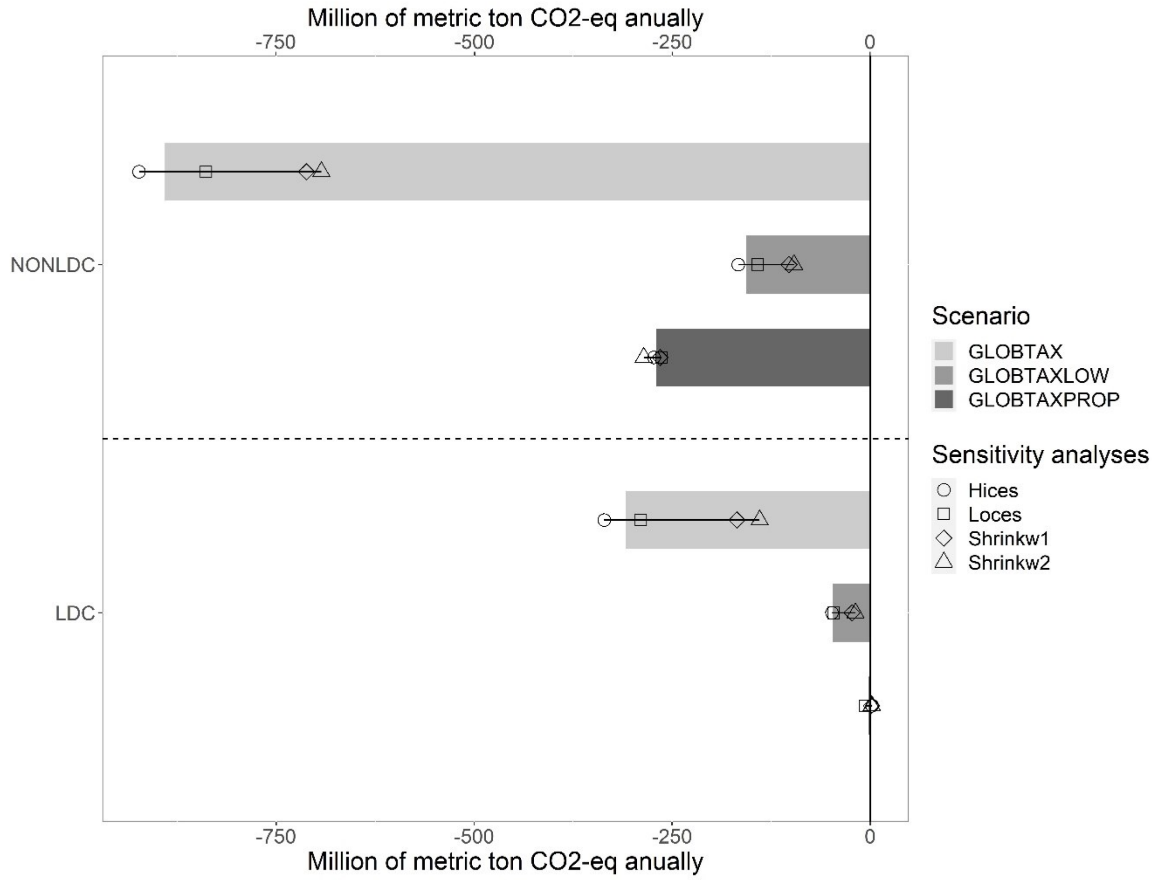

Figure 3. Mitigation in LDC and Non-LDC countries in the global scenarios. Million tons CO2-eq annually, difference to reference scenario. Lines at the end of the bars indicate the range of outcomes in the sensitivity analyses.

In the GLOBTAXPROP scenario, global emissions decrease by 270 million metric ton CO_2-eq (4.2% of global agricultural emissions). Many poorer countries have higher EIs, and the tax therefore tends to become lower where emissions are higher and vice versa, explaining that global abatement is smaller than in the GLOBTAX scenario. The dark bars in Figure 3 shows the abatements in non-LDC and LDC countries. Since the tax rate in this scenario is proportional to prosperity, most abatement takes place in non-LDC countries. In the LDC countries, there is almost no abatement at all, since the tax is entirely offset by higher world market prices that result from a lower global supply.

In the GLOBTAXLOW scenario, global emissions decrease by 200 million metric ton CO_2-eq (3.2%). While the tax rate in the GLOBTAXLOW scenario is only 10% of the GLOBTAX tax rate, the emission reduction is 17%. This indicates that the marginal abatement effect of a global uniform emission tax decreases with increasing tax rates.

Food security - calorie consumption

In this section, we focus on the scenarios with global taxes, since the scenarios with unilateral measures in the EU have a limited impact on global food security.

In the GLOBTAX scenario, global calorie consumption decreases by 0.50%. Among individual commodities, the consumption of sheep and goat meat (-24%) and beef meat (-17%) decrease most strongly. The reduction in calorie intake caused by the lower consumption of those commodities is offset by increased consumption of products subject to lower taxes such as pig meat, poultry meat, cereals, vegetables, and potatoes.

Looking at the regional impacts, one might expect a more severe impact on calorie consumption in poorer countries due to the negative correlation between prosperity and emission intensity in ruminant production. However, the results don't allow any such general conclusions. Figure 4 plots the relative change in energy intake by consumers against regional prosperity (GDP per capita and year 2030), for all regions in the model. Even though the largest negative impacts on energy intake are found among the poorer regions on left hand side of the plot, there are also many poor regions for which energy intake increases. In those cases, the shift away from ruminant meat to other products is sufficiently large to compensate for the loss in energy intake. This is possible because the consumers (in the model) do not deliberately demand "energy", but try to satisfy their preferences for different products based on prices and their available budget, and because the diet is dominated by crop products rather than ruminant meat. Reducing meat consumption by say 10% and instead increasing cereals consumption by 10%, from a point where cereals consumption already is much higher than meat consumption in absolute terms, can result in an increase in energy intake and be economically feasible, albeit less attractive to the consumer than the pre-tax situation.

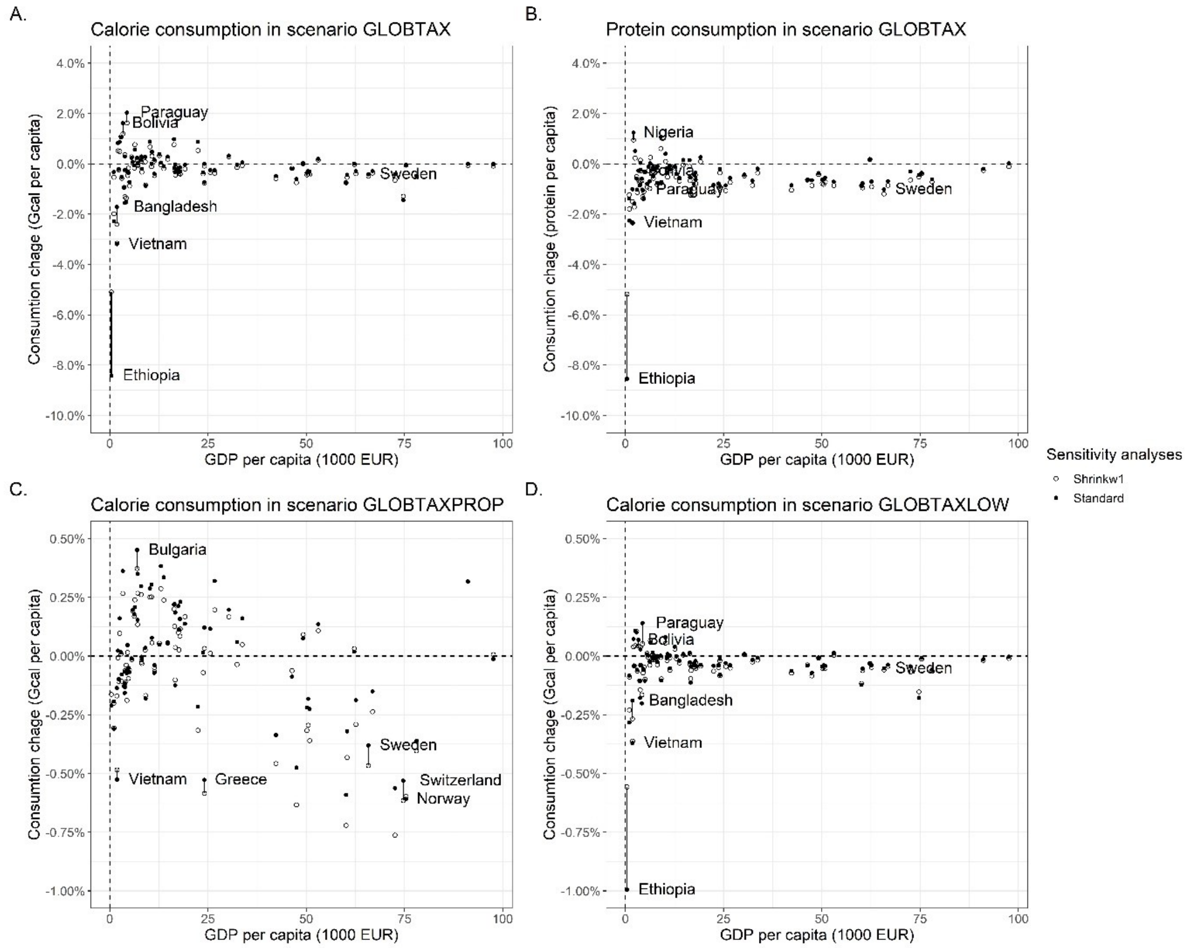

Figure 4. Change (%) in calorie consumption vs regional prosperity (consumer expenditure in euros/capita/year). Each dot represents the results for one region in the standard scenario, each ring the sensitivity experiment “Shrinkw1”. Panels A, B: impacts on energy and protein consumption in GLOBTAX scenario. Panels C, D: impacts on calorie consumption in GLOBTAXPROP and GLOBTAXLOW scenarios.

Ethiopia, Vietnam, and Bangladesh are examples of large poor countries where calorie consumption decreases severely, by 8.42%, 3.19%, and 1.71% respectively. In contrast, the tax increases calorie consumption in e.g. Nigeria, Bolivia, and Paraguay, by 0.83%, 1.61%, and 2.03% respectively in the GLOBTAX scenario.

In the GLOBTAXPROP scenario, global calorie consumption decreases by 0.079%. Thus, the effect on global consumption is smaller than in the GLOBTAX scenario. The composition of consumption changes, away from beef and sheep and goat meat towards more pork, poultry, cereal, and vegetable consumption. The impact on the poorest countries of the world is smaller than with the GLOBTAX scenario, whereas the impact on richer countries is larger (figure 4c). The country that experiences the largest decrease is *Norway (*-0.61%). Other wealthy countries are also among the most affected, e.g. *Japan* (-0.56%) and *Switzerland* (-0.53%). None of the poorer nations severely affected in the GLOBTAX scenario experiences a similar effect on calorie consumption in the GLOBTAXPROP scenario. This can probably partly be attributed to the fact that the GLOBTAXPROP scenario does not induce a change in consumed commodities to the same extent as the GLOBTAX scenario.

In the GLOBTAXLOW scenario, global calorie consumption only decreases by 0.069%. The regional impacts are similarly distributed as in the GLOBTAX scenario, but smaller. Ethiopia and Vietnam are the countries most severely affected, with decreases of 1.0% and 0.37% respectively.

Summary, conclusions and discussion

Summary

The purpose of this study was to quantify the potential gains of a multilateral agreement on greenhouse gas mitigation in agriculture versus an ambitious unilateral policy. To this end, we used model simulations to compare the impacts of a unilateral carbon tax in the EU against three versions of a global multilateral tax arrangement. The tax rate was based on the Swedish CO_2 tax on fossil fuels of about 120 euro/ton CO_2. The tax was implemented as a fixed amount per ton of product sold, based on the average emissions associated with production in the region of origin.

Our results indicate that the unilateral policy in the EU is associated with considerable carbon leakage: 76% of the emission reduction within the EU is off-set by increased emissions outside of the EU (EUTAX scenario). If the EU tax is combined with a carbon tax on imports (scenario EUTAXBCA), the rate of leakage is reduced to 36%, and the global mitigation effect of the tax doubles.

When a tax of 120 EUR/CO_2-eq is applied to all regions of the world (GLOBTAX), the global agricultural GHG emissions are reduced by 19%, or about 1.2 Gt CO_2-eq per year, significantly contributing to a sustainable food system in terms of climate impact. The global carbon tax has by definition no leakage. The global tax shifts production away from ruminant meat towards pig meat, poultry meat and crop products. Although consumption patterns change the global intake of energy and protein is relatively stable.

The global carbon tax of 120 EUR/CO_2-eq has dramatic impacts on e.g. beef meat production in some regions where the emission intensities are high. Furthermore, the consumer prices rise and reduce the intake of energy and protein in some poorer countries where food security is already a problem. Therefore, we also simulated two scenarios where the global tax is either differentiated across world regions in proportion to prosperity, or where the global tax rate is only one tenth of that in GLOBTAX. Differentiating the tax with respect to prosperity (GLOBTAXPROP) does indeed alleviate the problems in poorer regions but also reduces the effect of the tax on emissions, which only decline by 270 Mt CO_2-eq (4.2%), or 1/4 of the reduction in the GLOBTAX scenario. Poorer regions tend to have less productive agriculture and therefore higher emission intensities per unit of output, whereas the opposite tends to hold true for the wealthier parts of the world. The differentiated tax then tends to become higher where emissions are low and lower where they are high.

In GLOBTAXLOW, the tax rate in the global agreement is reduced to 12 EUR/CO_2-eq, or one tenth of the level in GLOBTAX. This represents a watered-down global agreement. The results still show a considerable global reduction of emissions of 200 Mt annually (3.2%), but with less dramatic changes in production and consumption patterns in poorer regions of the world. Furthermore, the reduction in global emissions per euro of tax rate is larger than in the GLOBTAX scenario, indicating that the marginal effect of the global tax is higher at the lower tax level but declines when the tax rate is higher.

Conclusions

Our analysis supports the struggle to reach a global agreement on agricultural greenhouse gas mitigation that treats all emissions equally, regardless of origin. Even a modest global commitment would bring considerable mitigation, plucking the lowest hanging fruit. A tax rebate for the poorer countries, as modelled here with a tax rate proportional to consumer expenditure per capita, significantly reduces the mitigation effect.

From the EU perspective, as for all countries that have relatively low emission intensities, the global deal has the additional appeal of boosting competitiveness. A carbon tax designed this way internalizes the public costs for emissions from the agricultural sector, creating a comparative advantage for countries that are more efficient in terms of emissions per unit. The global tax would reduce global supply and raise consumer prices of many products. In regions with low tax rates, the negative impact of the tax on producer prices is smaller than the positive impact of the higher consumer prices. These regions will expand their production despite the shrinking global market. In countries where emissions per ton are higher, the converse happens.

A global, multilateral agreement, might meet resistance from countries that are bound to lose international competitiveness. Indeed, it may lead to negative social consequences if large numbers of farmers are driven out of business. However, the tax also has a revenue side. This money could be re-funded to compensate poorer countries, support investments that make production more efficient in terms of GHG emissions, or support restructuring of production to direct resources into less polluting sectors. The large variation in emission intensities across regions suggests that a considerable potential for efficiency gains exist.

Discussion

The leakage rate that we find in the agricultural sector in the unilateral tax scenarios is larger than leakage of CO_2 emissions found in fossil fuel related sectors. Böhringer, Balistreri, and Rutherford (2012), summarizing results of twelve different models, find an average leakage rate of 24% in the simulation of unilateral abatement by EU+EFTA (sensitivity run). Our high leakage is primarily driven by ruminant meat products, which have very different EIs in different countries (Figure 1). As indicated by our sensitivity analyses, leakage also depends strongly on elasticities. We don't know enough about the parameters of the various models used in Böhringer, Balistreri and Rutherford (2012) to explain why our leakage rates are larger.

Frank et al. (2019) also apply the CAPRI model to study the impacts of global carbon taxes and find about twice as high mitigation impacts as our results at a similar carbon tax level. The main explanation for the difference is that they tax emissions directly instead of applying the tax per commodity, and allow for technological changes in the production of each product, so that the farms can reduce emissions in response to the tax by adopting specific mitigation technologies. Examples of such technologies are anaerobic digestion, precision farming and fertilization, targeted breeding efforts, and the impact of endogenous feed mix changes. We opted for the simpler implementation because sales of products is something that is already subject to measurements and taxation, making an actual implementation relatively simple in administrative terms, whereas the step to a global farm level emission accounting system seems challenging at this point. The difference in outcome between our results and theirs broadly indicate the potential efficiency gains in mitigation that can be reached if the abatement measures can be set up as to provide producers with incentives for technical change.

The results for leakage in the unilateral scenarios (EUTAX, EUTAXBCA) are particularly sensitive to model parameters. If the substitution elasticities are higher than in the standard results, the leakage can approach 100%, but it might also be closer to 50% if CES elasticities are lower, or if the marginal emission intensities are more homogeneous across the world than our standard estimates (e.g. sensitivity scenario Shrinkw2 in figure 2). Moreover, the effect of the BCA on leakage is good in the standard results. However, with more homogeneous emission intensities (shrinkw2), there is almost no difference in global mitigation impact between EUTAX and EUTAXBCA.

The CES parameters play less of a role with a global taxation. However, the spread of the emission intensities (sensitivity analyses Shrinkw1 and Shrinkw2) directly impacts on the level of taxation and mitigation in LDC (figure 3, lower panel). Less spread of the EIs means that less mitigation takes place in LDC countries, with lesser implications on food security.

Even in the GLOBTAX scenario, global levels of protein and energy consumption (and production) remain stable. A key explanation is that producing high-emission animal products requires more land and other inputs than producing plant-based human food such as vegetables, cereals and pulses (Erb et al. 2016). A small reduction in animal production releases much land for crop production. Therefore, carbon tax impacts on food security can be further mitigated if human diets for some reason change more strongly from meat consumption towards plant-based foods, which could be produced on some of the land that is freed-up when meat production is reduced while also releasing land for other uses. Frank et al. (2019) study the impacts of dietary preference shifts and find that it could lead to large additional greenhouse gas mitigations when combined with low or moderate carbon tax levels, whereas the additional benefit of dietary shifts are smaller at high carbon prices.

Even though the carbon tax does not provoke a food security problem at the global level, the local impacts can be large when production shifts between countries, and at the level of household types the impacts are likely to be larger still. Therefore, food security is not as much a technical as an economic problem – there is enough protein and calories available globally. How shall the poorest households of the world that rely on farming for their income be able to afford nutritious food? This highlights the need to use the tax revenues wisely. International re-distribution of tax revenues should be part of the deal.

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