Economic Impacts on Agriculture of a Low Carbon Economy by 2030: An Analysis with the Aglink-Cosimo model

Hans Jensen, Thomas Fellmann, Ignacio Pérez Domínguez,
Pierre Charlebois, and George Philippidis

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Abstract

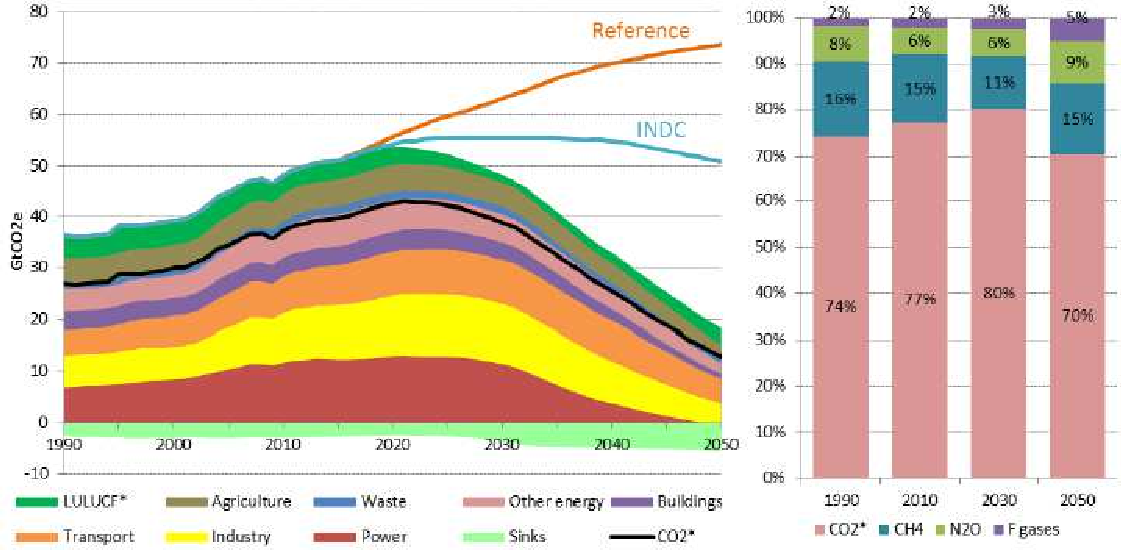
Limiting climate change below a 2°C temperature rise this century will require substantial reductions of greenhouse gas (GHG) emissions and the transition to a climate-friendly, low carbon economy, which may also impact the agricultural sector. Aglink-Cosimo, one of the main partial equilibrium agro-economic models used to prepare medium-term agricultural market outlooks, was enabled to transmit and measure the impact of a less carbon intensive economy on agricultural markets. Applying a carbon tax, we first use the MAGNET general equilibrium model and the GTAP database version 9 to quantify the macroeconomic variables which are inherent in moving to a global low carbon economy but exogenous to Aglink-Cosimo. We then employ Aglink-Cosimo to assess the impacts on agricultural markets, analysing scenarios with a global carbon tax on non-CO_2 emissions (progressively increasing to 110 US$/t CO_2eq by 2030 in developed and developing countries) without and with a dietary shift away from bovine meat consumption.

Simulation results of the carbon tax scenario show a reduction in global non-CO_2 GHG emissions from agriculture by 5.4% in 2030 compared to the baseline. Only 0.1% of the global reduction is caused by indirect macroeconomic effects (i.e. changes in GDP and prices for energy, fertiliser and pesticides), but at country level the macroeconomic effects can cause up to a quarter of the agricultural emissions reduction. In the scenario with an additional consumer preference shift away from bovine meat, a further 4.1% emission reduction is reached compared to the pure carbon tax scenario. These emissions reductions are rather low compared to other model projections, but the related impacts on agricultural production are considerable, especially at country level. Our results indicate the importance of (i) capturing future GHG policies when projecting agricultural markets over a medium-term time horizon; (ii) emission intensities across agricultural products (i.e. kg CO_2eq/kg commodity) at country level; and (iii) more sophisticated and differentiated policy approaches for the agricultural sector, specifically taking into account technology change and transfer, to reduce emission intensities especially in developing countries. The results also highlight the need to further develop the Aglink-Cosimo model to include the adoption of new technologies and to account for CO_2 emissions and removals related to land use changes, to get a broader picture of the possible contribution (and resulting impacts) of agriculture to a global low carbon economy.

1 Introduction

The UNFCCC COP21 in December 2015 resulted in the Paris Agreement, with parties agreeing to take action to limit global temperature rise this century to well below 2°C above pre-industrial levels (UNFCCC 2015). Limiting climate change below the 2°C will require substantial reductions of greenhouse gas (GHG) emissions and the transition to a climate-friendly, low carbon economy. The European Commission's report "Global Energy and Climate Outlook, Road from Paris" (Kitous et. al. 2016) provides an initial estimate of potential emission reductions by sectors in the global economy that are required to reach the 2°C target. This is done by comparing a reference scenario (business as usual) to a 2°C scenario for the world (Figure 1). Here it is estimated that the GHG emissions mitigation already required by 2030 could be achieved by the power sector contributing 39% of mitigations, followed by other energy (19%), industry (18%), agriculture (10%), buildings (6%), transport and waste (4% each), excluding emissions and sinks of the sector “Land Use, Land Use Change and Forestry” (LULUCF). More precisely, global GHG emissions of the sector “agriculture” (i.e. only accounting the agricultural non-CO_2 emissions methane and nitrous oxide) are estimated to rise to 6.283 $GtCO_2eq$ under the reference scenario compared to the 2°C scenario where agriculture emissions decline to 4.996 $GtCO_2eq$ in 2030. This represents a 20% reduction in global agriculture emissions compared to the reference scenario in 2030 (Kitous and Keramidas 2016b)[1].

Figure 1: World GHG emissions in the 2°C scenarios by sector (left) and by GHG (right)



** In these graphs LULUCF CO_2 sinks are singled out and not included in the LULUCF and CO_2 categories.*

Source: Kitous et al. (2016)

Other model simulations identify similar reduction targets for agricultural non-CO_2 emissions necessary to meet the Paris Agreement. For example, applying the three integrated assessment models IMAGE, GCAM and MESSAGE, Wollenberg et al. (2016) calculated the need of global agricultural non-CO_2 emissions mitigation in the range of 11%-18% by 2030 compared to baseline emissions (representing a reduction of 0.92-1.37 $GtCO_2eq$ per year). The estimations in Kitous et al. (2016) and Wollenberg et al. (2016) are only two examples showing that the agricultural sector will be impacted both directly and indirectly by a low carbon economy. On the one hand, agriculture has to contribute to emission reductions if the global climate change goals want to be met (Reisinger et al. 2013, Gernaat et al. 2015; Kitous et al. 2016), which will have a direct impact on agricultural production. On the other hand, the agricultural sector will also be indirectly affected as agricultural intermediate prices respond to the new economic environment. Given this foreseeable challenges, there is a need to adjust existing and develop new tools that enable the detailed analysis of the economic impacts on agricultural markets of a low carbon economy.

A variety of agricultural economic models are already equipped and employed for the analysis of climate change mitigation on the agricultural sector (see, for example, the model

[1] The estimated world GHG mitigations in 2030 (reference – 2 °C scenario) amounts to roughly 14600 of which agricultural non-CO_2 GHG mitigations are estimated to around 1300 $MtCO_2eq$, representing a 20% (1300/6283) reduction in GHG emissions from agriculture.

intercomparison in van Meijl 2017). However, the Aglink-Cosimo model (OECD-FAO, 2015), as one of the main partial equilibrium agro-economic models used to prepare medium-term agricultural market outlooks, as for example annually published by the OECD-FAO (2017) and the European Commission (2017), was not yet prepared with all necessary features to account for agricultural emissions and respective mitigation efforts. Given that the outlooks produced with the Aglink-Cosimo model shape the benchmark/reference for many other agricultural economic models, it is specifically important that Aglink-Cosimo is able to transmit and measure the impact of a less carbon intensive economy on agricultural markets. Moreover, Aglink-Cosimo has important features that make it particularly suitable to analyse impacts on the agricultural sector of policies related to the movement to a low carbon economy. For example, the model has a global coverage of the main agricultural commodities produced, consumed and traded, a detailed representation of domestic and trade-related agricultural policies, and accounts for substitution effects between agricultural commodities through explicit price transmission equations.

In this paper we briefly outline the model adjustments that were necessary to enable Aglink-Cosimo for non-CO_2 emission accounting and to reflect the impacts of a low carbon economy, and then we present an application of the updated model. As Aglink-Cosimo is a partial equilibrium model, the scenario analysis of a low carbon economy on the agricultural sector requires first capturing the macro-economic impacts in a Computable General Equilibrium (CGE) model and transmitting these changes to the Aglink-Cosimo model. In a second step we then analyse agriculture's possible contribution to reductions in GHG emissions by implementing scenarios with a global GHG emission tax without and with a dietary shift away from bovine meat consumption.

2 The Aglink-Cosimo model

The Aglink-Cosimo model is a recursive-dynamic, partial equilibrium, multi-commodity market model of world agriculture. The model was developed by the OECD[2] and FAO secretariats, with the double purpose of preparing medium-term (usually about 10 years) agricultural market outlooks, and to provide an economic simulation model for policy simulations. The model calculates endogenously the development of annual supply, demand and prices for the main agricultural commodities produced, consumed and traded worldwide. In the present version it covers 82 individual countries and regions, 93 commodities and 40 world market clearing markets prices. The Aglink-Cosimo country and regional modules are developed and maintained by the OECD and FAO Secretariats together with country experts and national administrations. In a joint publication, the OECD and FAO provide annually an outlook for the development of agricultural markets and prices. A large amount of expert knowledge is applied at various stages of the outlook process and Aglink-Cosimo is used to facilitate the consistent integration of this information. Moreover, the outlook is built on the basis of specific assumptions on the development of exogenous macro-economic indicators (like GDP growth, exchange rates, population growth, crude oil prices), which at the moment of preparing the projections seem plausible given the global environment (Araujo-Enciso et. al. 2015; OECD-FAO 2015).For this paper and the model developments necessary with respect to GHG emission accounting, the latest Aglink-Cosimo model version, released with the OECD-FAO (2017) agricultural market outlook, was used. This latest version had already been extended to 2030 and also has a complete land allocation system introduced for the 14 Aglink countries, taking into account double cropping systems where the respective data is available, i.e. Brazil (Charlebois et al. 2017), China, and double cropping of soybeans in the

[2] The results of any analysis based on the use of the Aglink-Cosimo model by parties outside the OECD/FAO are outside the responsibility of the OECD and FAO Secretariats. Conclusions derived by third-party users of Aglink-Cosimo should not be attributed to the OECD, FAO or their member governments.

USA (OECD-FAO 2017). Taking this initial model version and its underlying database, four additional updates were required to model the impact of a low carbon economy on the agricultural sector: (1) enhanced land allocation, (2) diminishing food demand elasticities with growing income, (3) increase in factor productivity and long run yield elasticities, and (4) estimation of emission intensities. These four model improvements are briefly outlined below.

First, a complete land allocation system was imposed for the 68 Cosimo countries specified in the model, where initially 'pasture land' and 'other crop land'[3] was exogenous. The full land allocation is especially important in the context of emissions related to land use and land use change (LULUC). A full matrix of crop land supply elasticities was estimated for the Cosimo countries, specifically including pasture and other crop land, which, for example, now also allows taking into account ruminant production returns on the land allocation. Even though CO_2 emissions related to land use changes are not yet considered in the emission accounting in the model, capturing changes in total land use already gives an indication on the effect of policy changes on the respective emission developments.

Secondly, when doing medium to long-term projections, constant food demand elasticities are a clear limitation, especially when analysing markets in developing countries. Therefore, adjustments in the model were applied to the income, own and cross food demand elasticities in developing countries, which were transformed from scalar to a vector so that with increasing wealth over time, own- and cross-price food demand elasticities are reduced (basically reflecting that developing countries close the income gap to developed economies and move along the Engel curve).

Thirdly, another important issue to consider in medium to long-term analysis is 'productivity', which usually increases over time, reflecting an increase in factor productivity. Therefore, a long-term crop yield response to movements in agricultural commodity prices and input costs as well as to the share of labour was also introduced into the model. The adjustment includes (i) the introduction of long term elasticities responding to historical long term crop prices and cost signals, (ii) changes in the share of labour in the total cost index were revised according to the change in real GDP per capita, and (iii) the introduction of an input demand system, reflecting that the move to a low carbon economy will likely affect the prices of fertilisers, chemicals and energy, which in turn could lead to changes in the input mix.[4]

Finally, modelling agriculture's contribution to GHG emissions reduction targets involves (i) estimating emission intensities per agricultural activity for Aglink-Cosimo countries/regions and (ii) imposing the possible use of a carbon tax in the model. So far, the model only accounts for the agricultural non-CO_2 emissions methane and nitrous oxide[5], which are calculated endogenously following the IPCC (2006) guidelines at the tier 1 level using FAOSTAT data for the emission factors (Tubiello et al. 2014a,b, FAOSTAT 2018). The GHG emissions are linked to the hectare of land and the head of livestock, respectively, as these inventories are explicitly represented in the Aglink-Cosimo model. The quantity of GHG emissions per country/region is calculated by the multiplication of the activity data by the Tier 1 emission factors. In order to perform different policy scenarios, the non-CO_2 emission inventories in Aglink-Cosimo are aggregated in CO_2 equivalents. The calculation of emission factors is based on historic emissions and production data, but to allow for the integration of

[3] ´Other crop land´ is an aggregate of the land used by all other crops not specifically included in Aglink-Cosimo (e.g. perennials and vegetables).
[4] The first two adjustments were taken over from developments by Thompson et al. (2017).
[5] Following the UNFCCC reporting, agricultural methane and nitrous oxide emissions are attributed to the sector 'agriculture', whereas emissions and removals of carbon dioxide (CO_2) from land use, land use change and forestry (LULUCF) are separately accounted for in the sector LULUCF. CO_2 emissions related to energy consumption at the farm and the processing of agricultural inputs are attributed to other sectors.

technical trends and hence emission efficiency improvements in the emission factors, trend functions have been estimated. The trend functions for emission intensities are estimated within a robust Bayesian estimation framework that combines data from FAOSTAT on production quantities and emission inventories. The approach is further outlined in Jansson et al. (2010) and Pérez Domínguez et al. (2012, 2016). Regarding carbon taxes, the taxes on emissions are introduced in the individual area and livestock number equations, which allows to analyse the tax effects in terms of emission reductions and production impacts at country level. The carbon tax is introduced per tonne of carbon-equivalent emitted by each production activity in a certain region, so that emission intensity across activities is taken into account.

3 Scenario background and setting

For this paper we want to assess the impact of a low carbon economy on the agricultural sector. Moreover, we want to analyse agriculture's possible contribution to reductions in GHG emissions by implementing scenarios with a global carbon tax without and with a dietary shift away from bovine meat consumption.

In the present Aglink-Cosimo model roughly 65% of GHG emissions stem from bovine meat and dairy production. In the past, GHG intensities from these livestock commodities have been reduced due to the evolution from less to more intensive productions systems, resulting in increases in commodity output per animal and per unit land that are larger than the corresponding increases in emissions per animal or per unit land area (Tubiello et al. 2014a). Following this past trend, increasing agricultural yields, by moving towards more intensive livestock production systems and the possibility of retiring land from agricultural production, creating potential carbon sinks, is one possible mitigation strategy, which could be combined with changes in consumer's preferences towards a diet containing less bovine meat (Lamb et. al 2016). One way to accomplish this strategy and to enforce agriculture's contribution to GHG emission mitigation is to introduce a carbon tax per tonne of GHG emissions measured in CO_2eq. This in effect puts a larger tax on commodities with higher GHG intensities, which typically would be ruminant meat and milk from less intensive livestock productions systems, as they emit more emissions per kg meat and milk than more intensive production systems. The resulting commodity price increase gives an incentive to consumers to change their consumption habits to less emission intensive products (e.g. eating less cattle meat).

Against this background we first run a business as usual scenario (baseline), and then two scenarios with a carbon tax, in the latter two also specifically accounting for the macroeconomic effects inherent in moving to a global low carbon economy. In the scenario "tax + macro shocks" (ScenTM) we introduce in 2020 a homogenous carbon tax of 10 US$/t CO_2eq increasing to 110 US$/t CO_2eq by 2030 in all developed and developing countries (but excluding least developed countries). With this we can highlight the impact a carbon tax would have on agricultural production and consumer diets. The second scenario "tax + macro shocks + preference shift" (ScenTMP) combines the carbon tax scenario with an additional consumer preferences shift away from cattle meat (following the modelling approach of Santini et al. 2017). As a simplified assumption we aim to double the reduction in bovine meat consumption achieved by the emission tax. With this second scenario we want to get an indication on the potential and impact of a more directed dietary shift and how this may further contribute to achieve a low carbon economy.

Given that the Aglink-Cosimo is a partial equilibrium model, the total impact of a low carbon economy cannot be directly evaluated. The majority of emission reductions will have to be made by other sectors of the economy (Kitous et al. 2016), and imposing a carbon tax on the global economy will induce macroeconomic effects (e.g. changes in prices for crude oil, fertilisers and pesticides as well as changes in real GDP) that in turn will impact on the agricultural sector. As the macroeconomic variables are exogenous in the Aglink-Cosimo model, the macroeconomic impact of a low carbon economy has to be first captured and quantified in a Computable General Equilibrium (CGE) model and then transmitted to the Aglink-Cosimo model. Therefore a set of carbon tax scenarios was run using the Modular Applied GeNeral Equilibrium Tool (MAGNET) model and the GTAP database version 9 with base year 2011. MAGNET is a multi-regional, multi-sectoral, applied general equilibrium model based on neo-classical microeconomic theory (Woltjer et al. 2014). Two versions of the MAGNET model were used. The first one, a standard MAGNET model built using the dynamic steering system to compile a GHG emissions model and associated databases. Adjustments were then made to this initial model so that the primary agricultural sector was excluded from carbon taxes in a second model version, i.e. the carbon tax was removed from equations modelling primary agricultural taxes within the model. The same baseline scenario was run on both model versions projecting the GTAP database over four time periods (2011 – 2017, 2017 – 2020, 2020 – 2025, and 2025 – 2030). Carbon tax scenarios were then imposed as counterfactual simulations in the years 2020, 2025 and 2030 in both models, where the respective nominal Aglink-Cosimo carbon taxes of 10, 60 and 110 US$/t$CO_2$eq were deflated to real 2011 US$. The resulting percentage changes in the price of energy (aggregated price change of crude oil, gas, coal) as well as changes in the price of mineral fertilisers and pesticides (chemical price change) were transmitted to the Aglink-Cosimo model. Since we cannot directly impose a carbon tax on crude oil and pesticides in the Aglink-Cosimo model, we took the energy/pesticide price changes from the general MAGNET model where carbon taxes were imposed on all sectors. Conversely, for fertilisers, we directly imposed a carbon tax in the Aglink-Cosimo model, wherefore we took the price change from the MAGNET model version excluding primary agricultural carbon taxes.

4 Scenario results and discussion

Baseline

Baseline results show an increase in agricultural non-CO_2 GHG emissions from 4.8 GtCO_2eq. in 2016 to 5.4 GtCO_2eq by 2030 (Figure 2, left panel). This is in line with the projected FAOSTAT estimate of 5.8 Gt CO_2eq in 2030 (FAOSTAT 2018)[6] but well below other model (MAGNET, IMAGE) baseline projections of agricultural GHG emission (Frank et. al. 2018).

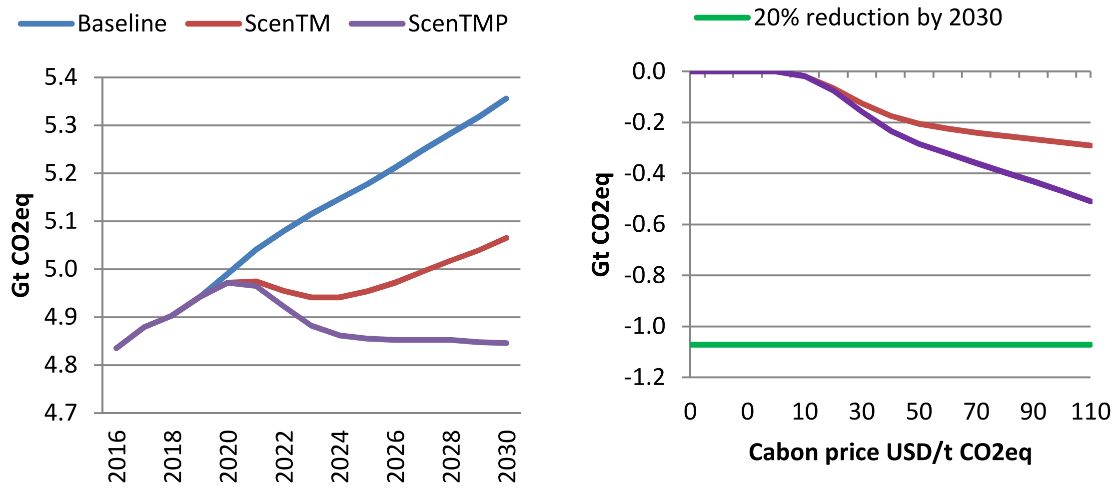
The projected increase in agricultural GHG emissions in the baseline is driven by increased demand for agricultural commodities by a growing population. However, due to yield gains per hectare land and head of livestock, the per capita emissions are declining over time. Not surprisingly, commodities with the highest GHG intensities (kg CO_2eq/kg commodity) are cattle and sheep meat followed by chicken and pig meat, whereas the lowest emission intensities are found in cereals (Tubiello et al. 2014a). This of course points the finger at animal husbandry as the main possible source of agricultural GHG mitigations. The Aglink-Cosimo baseline projects that roughly 80% of agricultural GHG emission stem from animal husbandry, with enteric fermentation accounting for 50% of agriculture emissions. This falls in line with FAO estimates (FAOSTAT 2018), which find that roughly 70% of agricultural GHG emissions stem from livestock.

Over the baseline period the average global meat (beef, pork, poultry, and sheep) consumption increases from 42.6 to 43.1 kg/capita/year in 2030, with notably poultry and sheep meat consumption increasing, while pork consumption declines and beef consumption per capita remains nearly unchanged. Even though the per capita consumption of bovine meat remains stable, the increasing population means increasing total demand for bovine meat,

[6] It is to be expected that the Aglink-Cosimo projected GHG emissions are lower than the ones estimated by the FAO since the present model does not include emissions from burning savanna and crop residues.

leading to an expansion of the global livestock inventories. The expected yield increases are not enough to meet the increased demand for food and feed, leading to an expansion of the global utilised agricultural area by 28 million hectares in 2030 compared to the base year 2016.

Figure 2. Global agricultural non-CO_2 GHG emissions, 2016 – 2030



Macroeconomic impact on agriculture

As shown in Figure 2 (right panel), the introduction of a carbon price in ScenTM reduces global agricultural non-CO_2 GHG emissions by 5.4% in 2030 (-0.291 $GtCO_2$eq.). Of this reduction, the macroeconomic spill over effect from the rest of the economy of imposing an equivalent carbon tax accounts for 0.1% of the total or 2.6% of the agricultural GHG emissions reduction (-0.008 $GtCO_2$eq). The largest macroeconomic impact stems from the reductions in GDP (reducing global incomes), followed by the changes in input prices. The price of oil, fertiliser, and pesticides are expected to increase by respectively 4%, 5%, and 0.5% in 2020, rising to price increases of 32%, 36%, and 3.5%, respectively, in 2030 as the carbon tax increases. The largest impacts on real GDP by 2030 occur in India, China, and Russia, where the MAGNET model estimates reductions in GDP of 2.1%, 2.0%, and 1.7%, respectively. This relatively large impact of imposing a carbon tax is due to the fact that we have used a standard MAGNET model, where no adoption of new mitigating technologies have been modelled or structural changes in management systems have been applied. The mitigation of GHG emissions is mainly active through reductions in production quantities, directly reducing real GDP. This mimics the present version of the Aglink-Cosimo model and is at present the optimal way to link the two models.

The macroeconomic spill over effects account for 2.6% of global agricultural GHG emissions mitigation, but at the country level the contributions vary significantly. For example, in the USA, Canada, and China the macroeconomic spill over accounts for 26%, 24% and 9%, respectively, of these countries total mitigation in the agricultural sector. Other regions/countries with less intensive agricultural production (i.e. relying less on the input use of fertiliser and fuel), become relatively more competitive as they are less affected by the macroeconomic changes induced by moving to a global low carbon economy. As a consequence, the macroeconomic shocks actually lead to an increase in the agricultural emissions of countries like Brazil, Argentina, and Australia.

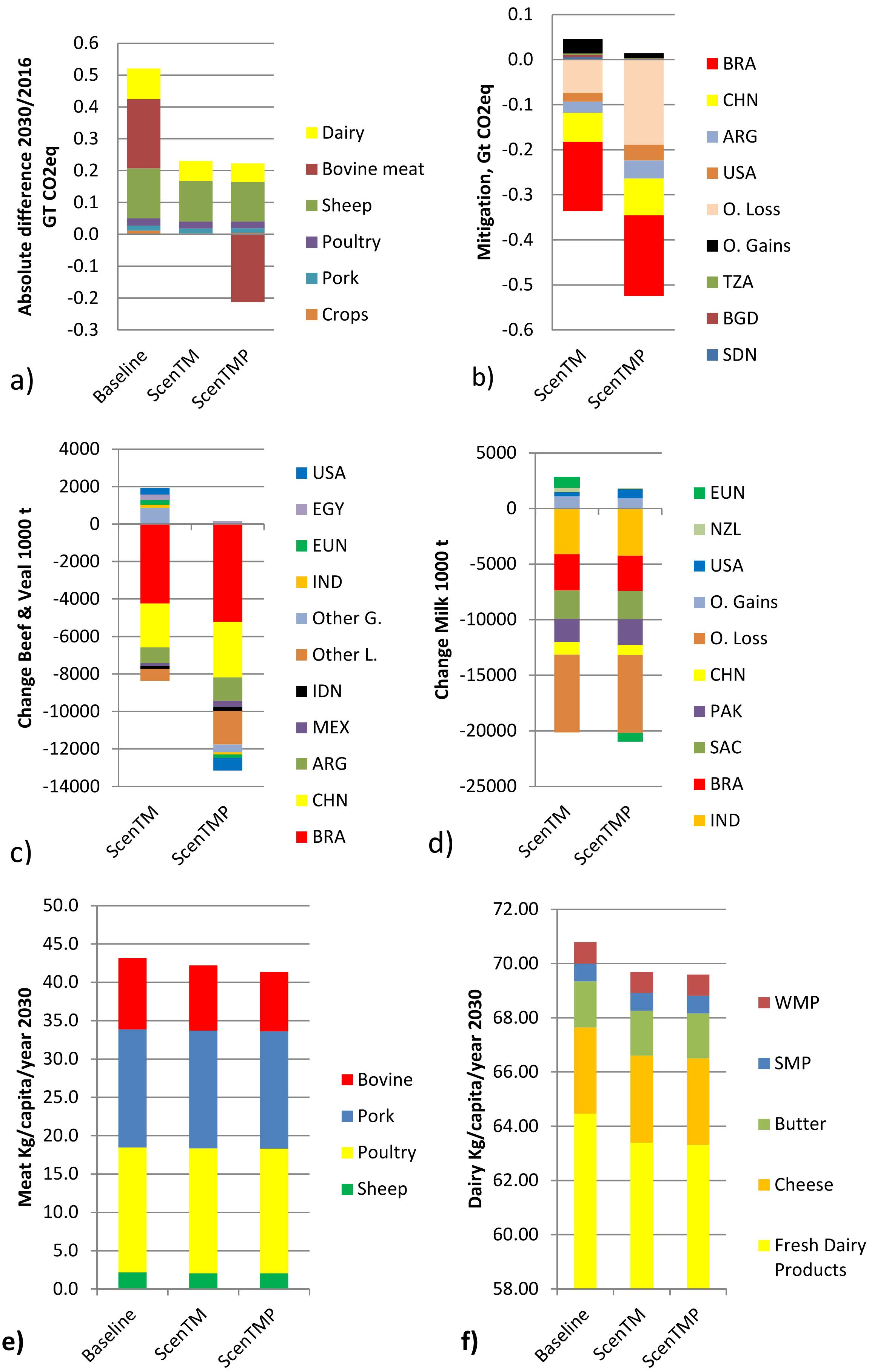
Impacts of an agricultural carbon tax

As mentioned above, the introduction of a carbon tax reduces global agricultural non-CO_2 GHG emission by 5.4% in 2030, (-0.3 $GtCO_2$eq). This is a relativity small decline in absolute values, especially compared to the 20% (1.07 $GtCO_2$eq) reduction of agricultural GHG emissions estimated by Kitous et al. (2016) and the 11-18% (0.92-1.37 $GtCO_2eq$) identified by Wollenberg et al. (2016) necessary by 2030 to achieve the goals of the 2°C scenario. Given our medium-term time horizon of implementing a carbon tax (2020 - 2030), and the phasing in of taxes over the period, a 20% reduction seems perhaps rather optimistic. When looking at other studies, typically with a longer time span, a 20% reduction is possible. Frank et al. (2018) compare the mitigation potential of imposing a homogenous carbon tax on the agricultural sector across four models, highlighting that the models already at a carbon price of 100 US$/$tCO_2eq$ show a significant potential for emission reductions of 1.6 to 2.6 $GtCO_2eq$/year by 2050, which is equivalent to a 20 – 35% reduction compared to the respective baselines. This of course is in a 20 year longer time span (2030 - 2050) than in our study and the carbon tax is in real US$, which in nominal prices would be equivalent to a tax of 200 - 250 US$ in 2050 (depending on the rate of inflation) when implemented in the Aglink-Cosimo model which uses nominal US$.

Given the relatively lower carbon tax imposed, a 5.4% reduction in GHG emissions is actually in line with other model results when taking into account the shorter time span and especially the time it takes to adopt new technologies and structural change, which holds for both agricultural production/management systems as well as consumer behaviour. In the longer run models (100 US$/$tCO_2eq$ in 2050), technical and structural changes account for 75% - 80% of agricultural emissions reduction. The remaining mitigation of 20 - 25% is achieved through a reduction in production levels (Frank et al. 2018). It has to be mentioned that in the present Aglink-Cosimo model we do have endogenous increases in agricultural yields over the projection period, but no endogenous adoption of new mitigation technologies or major structural changes. Therefore, the mitigation of GHG emissions from the agricultural sector is mainly achieved by reducing production levels, but also by the reallocation of production between countries (Figure 3). The introduction of a carbon tax should increase farmer's incentives to adopt new technologies/management systems, and consumer's incentives to change their consumption habits. In the medium-term scenario presented in this paper we are likely underestimating the adoption of new technologies and structural change within the agriculture sector, but given the time horizon to 2030 the impact this would have on reducing agricultural GHG emissions is relatively smaller than the 80% projected by other models in 2050.

Looking closer into the results, the impact of the carbon tax is, not surprisingly, most pronounced in the livestock sector (Figure 3a). Over the baseline period, agriculture emissions increase by 0.52 Gt CO_2eq, with the majority stemming from increased production of dairy products and bovine/sheep meat production. The introduction of a carbon tax mainly reduces the production of bovine meat and milk production, reducing the increase in emissions to 0.23 Gt CO_2eq (Figure 3c, 3d). The carbon tax, however, also reallocates production between countries/regions (Figure 3b). Notably, the production of both milk and bovine meat increase in the USA and EU, while India increases its beef production and New Zealand its milk production. At the other end of the scale, especially Brazil, China and Pakistan are reducing their production of milk and beef. These movements in domestic production are driven by the relative impact of the carbon tax, where: i) countries with relatively low GHG intensities (kg CO_2eq/kg commodity) become more competitive on the world market, with global exports increasing (cheese +5% and butter +7% in 2030), but ii) global consumption of bovine meat (-8%) butter (-2%) and fresh dairy products (-2%) declines as domestic consumer prices increase (Figure 3e, 3f). In the USA, for example, consumers reduce their average bovine meat consumption by 3%, consuming 2% more poultry and pork meat instead. Nonetheless, US bovine meat production increases, as exports grow by 5.8 million tonnes driven by the relatively more competitive intensive production systems in the USA.

Figure 3. Changes in agricultural non-CO_2 GHG emissions (a, b), beef & milk production (c, d), and meat & dairy consumption (e, f)



Impact of a preference shift away from bovine meat

A change in consumer diets is seen as a possibility to reduce the carbon footprint of agriculture, especially if the diet favours eating less bovine meat. Such a movement in consumer's global preferences can be expected to have a large impact in countries where per capita consumption is high (e.g. USA), and comes along with reducing domestic production, imports and possible expanding exports. In the Aglink-Cosimo baseline, 49% of the global bovine meat production is consumed in the USA, China, Brazil and the EU (Table 1). During the baseline period, per capita consumption of bovine meat is projected to decline in these countries with the exception of China, where per capita consumption of meat increase from 5.7 to 7.1 kg, which is still well below the projected consumption level of the USA (35.8 kg/per capita) by 2030.

Table 1. Bovine meat consumption, production, imports and exports, 2030 baseline

	Consumption	Production	Exports	Imports
	Relative share in global (%)			
USA	16.2	15.6	11.3	14.9
CHN	12.7	11.4	0.3	8.7
BRA	10.9	14.3	20.4	0.4
EU	9.4	9.4	2.5	2.3
AUS	1.1	3.9	17.3	0.1
IND	1.4	4.1	15.8	0.0
VNM	2.0	0.5	0.0	9.9
Total	53.8	59.1	67.7	36.3
	Total global (1000 t)			
World	78623	78747	13167	13032

In the scenario ScenTMP we introduce both a carbon tax and an additional preference shift away from bovine meat consumption to measure the impact this would have on global GHG emissions. Initially, the carbon tax scenario ScenTM reduces global beef consumption (and hence production) from 78.6 mt to 72.2 mt. In ScenTMP we double this initial reduction of 6.4 mt in bovine meat consumption, which leads to a drop in global bovine meat production to 65.6 mt. In relative terms, global bovine meat consumption was reduced by 8% in ScenTM, which was increased to a 16% reduction by introducing the addition preference shift in ScenTMP. The net effect of this additional preference shift is a reduction in global agricultural GHG emissions by an additional 4% (0.22 Gt CO_2eq) in 2030 (Figure 1). Our results indicate that it would indeed require a profoundly large change in consumer diets away from bovine meat and possibly dairy products to deliver a substantial contribution to agricultural emissions mitigation.

Some specific has direct implications for production, and a closer look into the results shows that for the global agricultural GHG emissions development it specifically matters where (i.e. in which country/region) the production is affected. Table 2 depicts developments in bovine meat production per country/region and the respective emission intensities measured in kg CO_2eq per kg commodity in 2030. The carbon tax in ScenTM decreases global bovine meat production by 8%. Most countries/regions show production decreases, but increases in production of bovine meat are indicated for, Africa (+7), North America (+3%) and the EU (+4%). While the latter two have relatively low GHG emissions per kg meat, Africa's LDC countries are exempt from the imposed carbon tax. As a net effect, in ScenTM the average world emissions in kg CO_2eq/kg bovine meat are reduced from 29.2 to 28.8 due to a more efficient allocation of bovine meat production in the world. In ScenTMP, the simulated further reduction of the amount of bovine meat consumed leads to (additional) production decreases in all countries/regions, including Africa, North America and the EU. The average world emissions are reduced to 28.4 kg CO_2eq/kg bovine meat.

Table 2. Bovine meat production and kg CO2eq/kg bovine meat in 2030

	Baseline	ScenTM	ScenTMP		Baseline	ScenTM	ScenTMP
	1000t	*% change to baseline*			*Kg CO2eq/kg bovine meat*		
Africa	7956	7	-2	Africa	43.6	42.4	42.3
China	8939	-26	-33	China	17.7	17.3	16.2
India	3244	5	-4	India	50.8	50.9	49.3
Asia	9813	-1	-10	Asia	37.0	36.8	36.4
Brazil	11211	-38	-47	Brazil	36.9	38.8	40.9
L America	9961	-10	-20	L America	33.4	34.0	33.6
EU	7410	4	-3	EU	16.0	15.6	15.7
Europe	2804	-1	-8	Europe	53.3	53.1	51.2
N America	13768	3	-6	N America	13.2	11.4	11.1
Oceania	3641	-4	-10	Oceania	20.5	21.0	20.5
World	78747	-8	-17	World	29.2	28.8	28.4

Note: Asia: excluding China and India; Europe: excluding EU; Latin America: Middle and South America (excluding Brazil); North America: USA and Canada

Land use

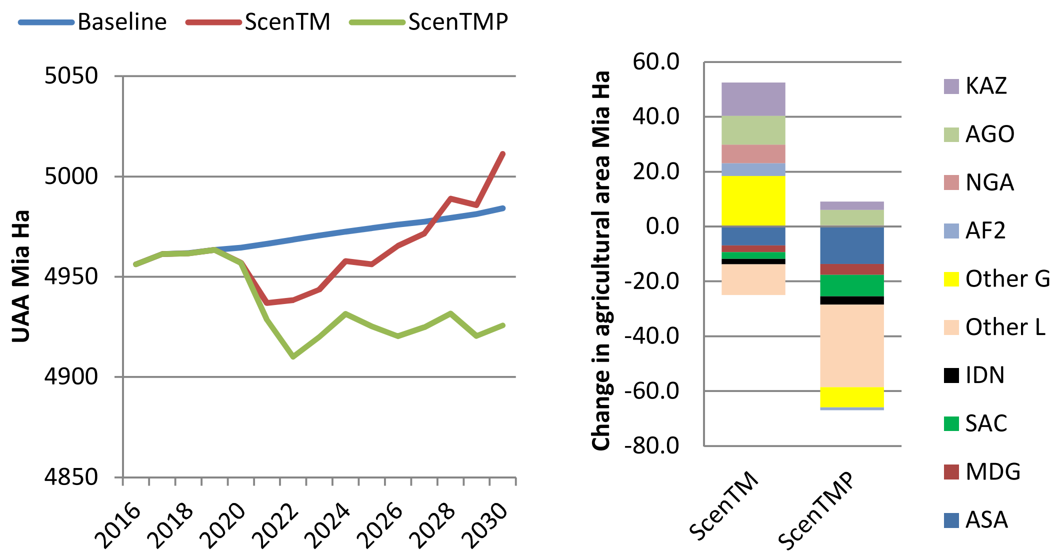
In the present model version of Aglink-Cosimo, LULCF-related CO_2 emissions and sinks form agricultural production are not accounted for. However, the model projects land use chance (LUC), which already can give an indication on the related CO_2 emissions.

In the baseline, the total utilised agricultural land (UAA) increases by 28 million hectares over the projection period, which is an average yearly increase of 0.04% (Figure 4). This change from forestry and other land use into cropland or grazing land and the associated GHG emissions from net forest conversion or vice-versa has not be taken into consideration in this study. Nonetheless, what can be seen from the scenario results is that imposing a carbon tax (ScenTM) actually increases global UAA by an additional 27 million hectares with pasture land expanding by 30 million hectares (i.e. 3 million ha of cropland is converted to pasture land). The main bulk of this increased pasture land is found in Africa where bovine meat production increases by 7%. Conversely, the carbon tax together with the introduction of a consumer preference shift away from bovine meat (ScenTMP) reduces producer prices in all countries, including LDCs, resulting in a decline in global UAA by 58 million hectare, with pasture land decreasing by 59 million hectare compared to the baseline by 2030.

The land use change implied with increasing UAA generally comprises CO_2 emissions, whereas removing land from agricultural production and converting it to perennial plants such as trees, grass or shrubs, is generally regarded as a positive contribution to climate change mitigation through carbon sequestration (Powlson et al. 2011). However, the net effect of the global increase/decrease in UAA on CO_2 emissions and removals is not straightforward. For example, the reduction in UAA in the ScenTMP scenario does not necessarily lead to a net decrease in global LUC-related CO_2 emissions, as soil carbon emissions and removals depend on many factors, like e.g. the management system and location (Powlson et al. 2011, Oertel et al. 2016, Thamo et al. 2017). Moreover, the decrease/increase in UAA is not universal in the scenarios, and while many countries reduce their agricultural land in the ScenTMP, the change in UAA in 2030 also comprises countries expanding their UAA, among others the African countries Angola and Nigeria. This is not surprising since the two countries are exempted from the simulated carbon tax, making their domestic agricultural production more competitive in the market, which leads to production increases that also involve increasing

UAA. How large the net contribution of the change in land use would be to global GHG emissions mitigation is difficult to quantify, given the regional distribution of land moving in and out of agricultural production. Taking pasture land out of production in the outback of Australia compared to pasture land in the EU does not imply the same reduction of GHG emissions per hectare (see e.g. the discussion and literature in Powlson et al. 2011 and Oertel et al. 2016). The Aglink-Cosimo model needs to be further updated and enabled to take LULUCF emissions into account to get a fuller picture of the (potential) contribution of agriculture, forestry and other land use to GHG mitigations.

Figure 4. Change in utilised agricultural area



Conclusions

This paper outlines the work of developing a methodology in the Aglink-Cosimo model to transmit and measure the impact of a low carbon economy on agricultural markets. Extensive improvements have been made to the model, like extending the complete land allocation system, introducing diminishing food demand elasticities with growing income, introducing increases in factor productivity and long-run yield elasticities, and estimating emission intensities per agricultural activity for Aglink-Cosimo countries/regions

We applied the updated Aglink-Cosimo model in two simulation scenarios with a carbon tax, in both specifically accounting for the macroeconomic effects inherent in moving to a global low carbon economy (captured with the MAGNET model and implemented as macroeconomic shocks into Aglink-Cosimo). An initial scenario has been undertaken where a homogenous tax on agricultural non-CO_2 emission is implemented in all developed and developing countries (least developed countries are exempted). The carbon tax starts with 10 US$ per tonne of CO_2eq in 2020, raising to 110 US$/t CO_2eq by 2030. Simulation results show that global GHG emissions from the primary agricultural sector are reduced by 5% in 2030 compared to the baseline. Only 0.1% of the reduction is caused by indirect macroeconomic effects, i.e. by price changes in energy, fertiliser, pesticides and GDP due to the carbon price. However, at country level the macroeconomic effects can cause up to a quarter of the agricultural emissions reduction. In a second scenario which combines the carbon tax scenario with an additional consumer preferences shift away from cattle meat, a further 4% reduction in agricultural non-CO_2 emissions is reached compared to the pure carbon tax scenario (i.e. -9% compared to the baseline).

Our scenario results highlight the importance of capturing future GHG policies imposed on the agricultural sector when projecting agricultural markets over a medium-term time horizon. Even though the reductions in agricultural non-CO_2 emissions achieved in our scenarios might seem to be rather low, and fall short of the emission reductions that are projected by other models to be necessary to achieve the goals of the Paris Agreement, the related impacts on agricultural production are significant, especially when looking at the impact at country level. The scenario results indicate that when no major change in technological development is assumed by 2030, agriculture could contribute to the move to a global low carbon economy mainly by the reduction in production levels, with adverse effects for food production in several countries. Especially production in some developing countries would be relatively more affected by a global agricultural carbon tax, as they are usually characterised by higher emission intensities (kg CO_2eq/kg commodity) and are less competitive on the world market. Furthermore, the results indicate that for the net mitigation of global agricultural GHG emissions it specifically matters where (i.e. in which country/region) production is affected by the simulated carbon tax and consumer preference shifts. If decreases in consumption mainly lead to production reductions in countries with relative low emissions per kg commodity (as for example in US bovine meat production), then the resulting emission reductions from dietary changes might only lead to relatively small extra mitigation compared to the baseline developments. This points towards the importance of both (a) technology change and transfer, to reduce emission intensities especially in developing countries, and (b) more sophisticated and differentiated policy approaches for the agricultural sector, specifically taking into account point (a), to achieve a significant contribution of agriculture towards the move to a global low carbon economy.

The results also highlight the need to further develop the Aglink-Cosimo model to include the adoption of new GHG emissions abatement technologies and the contribution of structural change within farming in the modelled counties. Moreover, Aglink-Cosimo should be enabled to account for CO_2 emissions and removals related to land use and land use changes, to get a broader picture of the possible contribution (and resulting impacts) of agriculture to a global low carbon economy.

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