Modelling the potential to abate greenhouse gases from agriculture using detailed abatement technologies in a CGE model

If the current emission reduction targets submitted under the Paris agreement are to be fulfilled, the temperature goal of the agreement is expected not to be met (Chan et al., 2022; IPCC, 2022). To avoid the most extreme climatic impacts, emissions from the agricultural sector must also be reduced (Crippa et al., 2021). However, the need to reduce emissions in the agricultural sector is challenged by the need to increase production to supply food for a growing population, and by the multilateral focus on adaptation to the already occurring and future climatic changes (Godde et al., 2021; UNFCCC, 2021). These concerns have resulted in a limited number of countries setting explicit reduction targets for their agricultural sector (Hönle et al., 2019; OECD, 2022). Uneven commitments and ambition levels in reducing agricultural emissions, along with the differences in marginal abatement costs across countries, complicate the analysis of the expected future agricultural production patterns. For instance, the technical reduction potentials may be higher in countries falling behind the current best practices and technologies; however, these countries often do not have the highest decarbonization ambitions. The absence of effective international technology transfer further limits these countries' ability to exploit their lower marginal abatement costs (De Cara & Jayet, 2011; OECD, 1998). This implies agricultural sector emission reductions on both global and regional scales are unlikely to be reached in an economically efficient manner. Many studies using CGE models bypass these complications by using simple carbon pricing mechanisms to target declared or desirable emission reduction scenarios, thus unable to capture the differential costs and potentials of abatement technologies across countries. In this paper, we incorporate both the potential production shift from differences in emission reduction ambitions and the influence of differential technological reduction potentials, to obtain a more realistic understanding of the resulting production changes.

Objectives

We quantify the distributional consequences of climate change mitigation targets imposed on the agricultural sector at country level, taking into consideration the available abatement technologies that are likely to be adopted by individual countries when facing rising carbon prices. Available technologies and the costs of adopting them are often represented by the so-called Marginal Abatement Cost curves (MACCs). Thus, the methodological contribution of this paper is to incorporate existing MACC estimates into the CGE model used for this analysis, and through model simulations to illustrate how the inclusion of the MACCs generate better estimates of the costs of de-carbonizing the agriculture sector.

Modeling approach

We propose an approach to introduce into a CGE model endogenous emission intensity reduction that mimics estimated MACCs, which captures costs and abatement potentials of currently available technologies. Matrixes including the price, emission abatement and availability of technologies linked to all emission flows are set up outside of the CGE model, based on the US EPA MACC estimates for 2030 (US EPA, 2019). Using these data, we insert a set of equations into the CGE model, specifying the endogenous adoption of different technologies by comparing the costs of the technologies and the levels of the carbon prices.

This way, the implementation of each technology is determined based on the net cost of its inclusion, which has been found to be the main decision-making factor for livestock producers (Hristov et al., 2013). We reveal the implications of using this new approach on the estimated costs of de-carbonizing the agriculture sector and production scales and patterns through a set of model simulations, as detailed below.

Scenarios

We consider an agricultural emission reduction scenario developed by Jensbye, Clora and Yu (2022) where reduction targets are differential across countries, reflecting countries' commitments to the Paris agreement and their national circumstances. This scenario is first simulated using simple carbon price instruments (scenario 1), as customarily done in the CGE literature. In an alternative scenario (scenario 2), we use the modified CGE model that incorporates the MACCs to solve for a different set of national carbon prices that achieve the same emission reduction targets at country level. Recognizing the fact that in the absence of carbon prices in the agricultural sector, emission intensities have improved autonomously, a second set of scenarios further imposes emission intensity improvements that track observed historical development.

In total, we simulate four different scenarios, which are differentiated by the inclusion/exclusion of the reductions due to the endogenous adoption of new emission-abating technologies and historical emission intensity development.

Model and baseline:

The scenario simulations will be implemented in an extended recursive dynamic version of the GTAP v7 model (Corong et al., 2017). This extension, among other features, includes non-CO_2 emission (Chepeliev, 2020a) and allows implementation of multiple carbon prices in each economy for different parts of the economy, allowing for the simultaneous solution of emission reduction targets set for different sectors (Clora, Yu, Baudry, et al., 2021; Clora, Yu, & Corong, 2021).

The model is calibrated on the GTAP Power v10 (Chepeliev, 2020b) and the GTAP non-CO2 v10 (Chepeliev, 2020a) databases, aggregated to reflect the focus on the livestock sector. The databases, of which the base year is 2014, are updated in annual steps to recreate a baseline towards 2030. In our baseline, we target macroeconomic drivers following SSP2 drivers (Fricko et al., 2017), i.e. real GDP (Dellink et al., 2017), population and labor force projections (Kc & Lutz, 2017). Economy-wide GHG emissions in each country follow a trajectory consistent with their NDC pledges (UNFCCC, n.d.).

Expected Results

The analysis of results will focus on the costs of decarbonizing the agricultural sector, shifts in the patterns of production and international trade, and on other core economic impacts due to reaching the targets set in each scenario. The results of this study will also shed light on alternative modeling approaches of emission reducing technologies in a CGE model.

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