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Nationally determined contributions and scenarios of agricultural emission reductions at country level

Lærke Jensbye (lgj@ifro.ku.dk). Department of Food and Resource Economics, University of Copenhagen

Francesco Clora (fc@ifro.ku.dk). Department of Food and Resource Economics, University of Copenhagen

Wusheng Yu (wusheng@ifro.ku.dk). Department of Food and Resource Economics, University of Copenhagen

1. Introduction

The global food system is being challenged by the need to adapt to climate change and to reduce greenhouse gas (GHG) emissions embodied in agricultural production, particularly in emission-intensive livestock production. However, the willingness of national governments to reduce agricultural emissions has been constrained by other concerns such as food security, poverty reduction, adaptation needs, and agricultural development (Drieux et al., 2021). Thus, few countries have formally communicated specific ambitions in reducing agricultural emissions and it is likely that mitigation efforts will differ across countries (OECD, 2019).

While the current literature has pointed out the need and the potential to reduce GHG emissions from the agricultural sector, studies formulating emission reduction scenarios according to countries' actual commitments and official communications, are lacking in the literature. This is partly due to the lack of such commitments in the first place. Currently, only a handful of countries have specified concrete goals, making formulating GHG reduction scenarios a difficult task. It is therefore common practice to target a global emissions level to reach temperature targets, and from that conduct a distribution across countries, based on different sets of assumption (Richards et al., 2018; Frank et al., 2019). Nevertheless, agriculture still has a vital role in limiting impacts of climate change. For instance, more than 80% of the adaptation measures mentioned in NDCs are concerned with food production and nutrition security (UNFCCC, 2021). Several countries have also specified targets for reforestation or limiting deforestation (Climate Change Laws of the World database, n.d.) which will limit the expansion of extensive agricultural production in some regions. The agricultural sector will therefore undoubtedly change in the coming decades, especially in light of climate change. Consequently, it is important to design and construct more realistic agricultural emission reduction scenarios to explore the likely impacts of such scenarios.

The first objective of this paper is therefore to conduct a cluster analysis on countries' likelihood of implementing mitigation policies at various ambition levels. The second objective is to quantify the effects of implementing these mitigation policy scenarios, using a recursive-dynamic computable general equilibrium (CGE) model, focusing on the resulting shifts in production patterns.

2. Clustering analysis

2.1 Methods

Clustering analysis methodology

To obtain a measure of countries' likelihood of introducing ambitious climate targets for their agricultural sector, we compare and rank countries based on several dimensions with clustering analysis. Taking inspiration in dimension choices based on studies conducted by Vyas et al (2022) and Hönle et al (2019). This analysis looks at 75 countries, which generate 90% of the global agricultural emissions (FAO, n.d.a). Countries are selected based on the share of global agricultural emissions, including the largest emitters. In addition, all EU member states are included as separate entities, as cross-country comparison of EU climate ambition are often lacking from global studies given their combined submissions to climate agreements (Hönle et al., 2019; Wiese et al., 2021).[1]

The cluster analysis is performed with respect to the following dimensions: (1) overall economic characteristics and characteristics related to the agricultural sector; (2) the number of already implemented climate change legislations concerning the agricultural sector; (3) the frequency of mitigation and adaptation action statements within agriculture in submissions to international climate agreements; (4) the current growth rates of emissions related to the agricultural sector, and forest carbon stock changes; (5) the submission record of countries in relation to international climate agreements.[2]

We conduct the clustering analysis using the k-means algorithm for dimensions consisting only of numerical variables. This algorithm minimizes the within group sum of squares of the clusters, utilizing Euclidean distance measures (Hartigan and Wong, 1979). The k-prototypes algorithm is used for handling mixed data (Huang, 1997, 1998), which in addition to Euclidean distance also include a dissimilarity score measuring overlap across categorical variables, leading to a single combined measure of commonality used in clustering (Szepannek, 2018). The resulting outcome is for each dimension a set of clusters consisting of several countries. These sets are compared, and subsequently given a rank and a numerical score for each dimension. Across dimensions, the numerical score is combined resulting in each country having a single value of relative likelihood of setting ambitious targets.

Quantifying expectations from clustering to emissions trajectory

The sets obtained from the cluster analysis are used to generate agricultural emissions trajectories for the included 75 countries. Countries not included in the clustering analysis are assumed to follow their historical emissions trend. The countries deemed most likely to introduce agriculture-specific emission reduction targets are assumed to set such targets (relative to their stated economy-wide goal) in the same proportion as the countries that have currently set targets for the agricultural sector.[3] The countries with decreasing likelihood of reducing agricultural emissions will be assumed to have lower targets for their agricultural

[1] Considering EU countries as individual entities (and not EU as a whole) in the clustering analysis also allows for more granularity when designing the scenarios to be simulated with the CGE model.

[2] An overview of the data sources for the separate dimensions is included in Table 2.

[3] Denmark currently has a 70% economy-wide target (Danish Ministry of Climate, Energy and Utilities, 2020), and has recently communicated a 65% reduction target ambition in its agricultural sector by 2030 (Danish Ministry of finance, 2021). Therefore, the weight on the economy-wide target would be 65/70. The same weight is applied to other "high-ambition" countries. For example, Germany has a 55% economy-wide target, which according to our calculation would result in a reduction in its agricultural sector emissions by 51%= 55%*65/70.

sector relative to their economy-wide goals, than the countries who have already made commitments. Lastly, a large group of nations that are deemed least likely to set ambitious targets will be assumed to set no significant boundaries for their agricultural emissions and will therefore be expected to follow their historical emissions trend.

2.2 Results

Global agricultural emissions, aggregated from the country-specific agricultural emission trajectories calculated above, are shown in Figure 1 ("Clustering Trajectory v1"). Figure 1 also reports global agricultural emissions if countries were to impose their economy-wide target on their agricultural sectors ("NDC homogeneous" trajectory). The two shaded areas in Figure 1 represent the range within which agricultural emissions should be constrained to limit the temperature increase to 2 degrees compared to pre-industrial levels by 2100, and an expected range of emission if no mitigation actions were to be implemented, as estimated by Wollenberg et al. (2016).

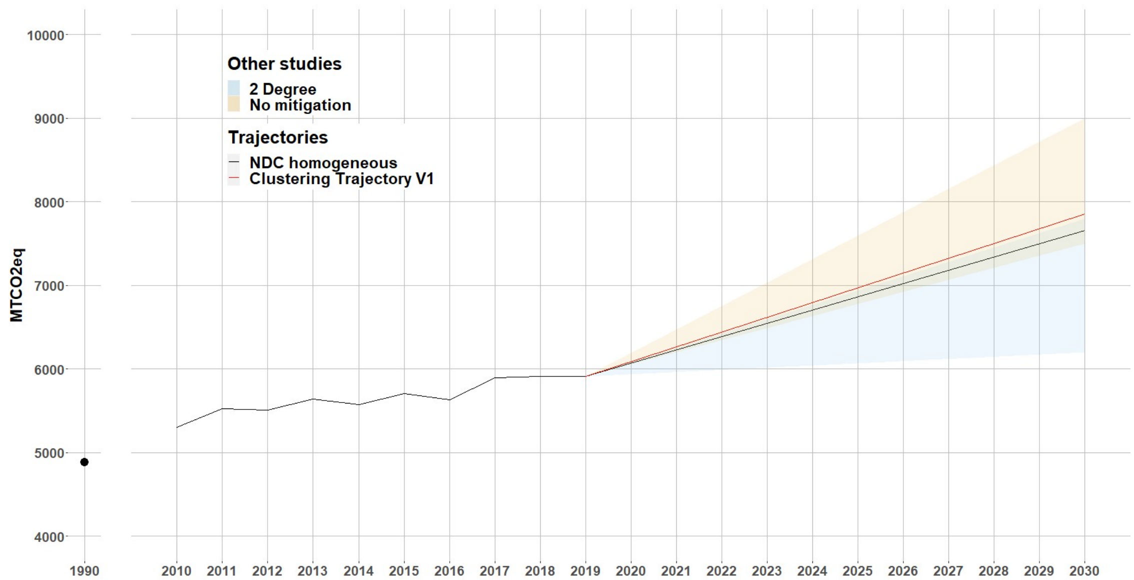

Figure 1 Preliminary global emission trajectory derived from clustering

3. CGE Analysis

3.1 Model

A modified version of the recursive dynamic GTAP-E model will be used to carry out the analysis, as designed in Clora et al. (2021). The model is an extension of the GTAP-E-RD model, which was used by Corong & Strutt (2020), which combined the standard GTAP-E model (Burniaux and Truong, 2002; McDougall and Golub, 2007), with the recursive dynamic GTAP-RD model (Aguiar et al., 2019). Of interest to this paper, the model developed by Clora et al. (2021) includes the GTAP v10 non-CO_2 emissions database (Chepeliev, 2020a), as most agricultural emissions are non-CO_2. It also adds two sector- and country/region-specific GHG emission trading systems, to the economy-wide GHG emission trading system present in GTAP-E. This addition is relevant for this paper, as it allows to implement differential emissions targets across agricultural and non-agricultural sectors.

The model is calibrated on the GTAP-Power v10 dataset (Chepeliev, 2020b) and on the GTAP v10 non-CO2 dataset (Chepeliev, 2020a). The sectoral aggregation will reflect this analysis' focus on the livestock sectors, which have different emission intensities. The regional aggregation is centered around the largest agricultural producers, whereas the analysis of the results has a larger focus placed on the European markets. The two datasets, of which the base year is 2014, are updated towards 2030 in annualized steps. The baseline used for the analysis will be based on SSP2 (Shared Socioeconomic Pathways middle of the road scenario) projections of macroeconomic developments such as population, GDP , labor force growth , developed and adopted in Clora et al. (2021).

3.2 Scenario design

Based on the trajectories developed from the clustering analysis, two sets of scenarios will be simulated against the baseline. In the first set, all sectors (including agriculture) will be subject to the same economy-wide carbon tax to achieve the NDC goals. In the second set, we adopt the sector-specific targets for the agricultural sector while allowing the rest of the economy to observe the national targets. This is implemented by differential carbon prices across agricultural and non-agricultural sectors.

While carbon price is generally considered as the main policy instrument to realizing emission reductions, technological solutions that result in emission intensity reduction should also be considered. Thus, we consider three emission intensity trajectories for each set of scenarios: *historical trends*, *accelerated advancement*, and *catching up*. The emission intensity trajectories will be based on emission intensity data from the most recent decade where such data exist (FAO, n.d.b). The "historical trend" will be calculated as the average annual growth rate of emission intensity of each country over the past ten years, while "accelerated advancement" is assumed to be twice the size of the historical trend. Lastly, in the case of "catching up", a convergence of emission intensities are assumed whereby countries currently with higher emission intensities will experience larger reductions. In effect, we study six sets of scenarios in our analysis, as summarized in the table below.

Table 1: Scenarios

	Part of Economy-wide target	Separated reductions for the agricultural sector
Historical trend	A1	B1
Accelerated advancement	A2	B2
Catch-up	A3	B3

3.3 Expected results

When analyzing the results of the scenarios, the focus of the analysis will be placed on the changes in production and trade patterns arising from the differential emission reduction targets across countries. Furthermore, simulation results will reveal the implications of treating agricultural emissions separately by applying sector-specific carbon prices. Lastly, the impact of the varying technological advancement assumptions will be analyzed, to ascertain the differences in outcomes due to these assumptions, and how large a role differences within this assumption impacts the following results.

4. Conclusion

To be added

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Table 2: Variables for clustering

Cluster dimensions	variables	Sources
Country characteristics	Food security index GDP (Gross Domestic Product) per capita Agricultural emissions share	(Economist impact, 2021) (World Bank, 2021) (FAO, n.d.c)
Word mentioning	NDC (NECP for EU nations) word mentioning's per page mitigation, adaptation, forestry, and livestock focused.	(UNFCCC, n.d.) (European commission, n.d.)
Legislation	Agricultural mitigation laws and LULUCF mitigation laws introduced after 2010	(Climate Change Laws of the World database, n.d.)
Current growth rates	Growth rates in agricultural emissions Growth rates in forest carbon stock	(FAO, n.d.c)
Submission	Submission records of NDC, NECP, LTS and BR/BUR documents. Specifics related to their targets: Inclusion of agricultural sector, emission sources N_2O and CH_4, specific sectoral targets and lastly statement of net zero goals	(UNFCCC, n.d.) (European commission, n.d.)

Notes: NDC: Nationally determined contribution; NECP: National energy and climate plan; LTS: long-term strategies. BR/BUR: Biennial reports/Biennial update reports