Global Context Matters: Spillovers from Denmark's Agricultural Climate Policy under Alternative Global Pathways

Introduction

Denmark is the first country in the world to implement a greenhouse gas (GHG) tax in the agricultural sector, alongside a large-scale land retirement program. Beginning in 2030, a price on GHG emissions from livestock and parts of the emissions from crop production will be introduced, complemented by measures to retire agricultural land (Danish Council on Climate Change, 2025; Danish Government, 2024a, 2024b). In a globally integrated agri-food system, however, unilateral action by a small open economy can trigger international spillovers as sectoral competitiveness is affected and production is reallocated across regions. Understanding these spillovers is therefore critical for assessing the environmental effectiveness of national climate policies in agriculture.

Existing studies using global computable general equilibrium (CGE) or partial equilibrium (PE) models to assess climate policy in agriculture typically focus on global mitigation scenarios (Frank et al., 2019; Fujimori et al., 2022; Hasegawa et al., 2018), with limited attention to production reallocations driven by unilateral policies. Other contributions examine large countries or regions such as the US, China, and the EU (Adenauer et al., 2025; Matthews, 2022; Zhang et al., 2024). Many of these studies, especially the ones focusing on the EU, analyze competitiveness effects and carbon leakage of unilateral policies, often simulating alternative policy designs against a given baseline trajectory for the policy and non-policy countries/regions. These studies report a wide range of carbon leakage rates, from -5% to over 101% (Matthews, 2022), reflecting differences in policy ambition and design, as well as modelling assumptions related to elasticities, time horizons, baseline developments, and the availability of abatement technologies. A smaller body of literature focuses on national agricultural climate policies, including studies on Denmark (Sørensen et al., 2025), Chile (Mardones and Lipski, 2020), Germany (Henseler et al., 2020), and France (Lungarska and Chakir, 2018). These analyses generally concentrate on domestic economic and environmental impacts, with limited coverage of international spillovers arising from changes in trade and production patterns.

While some of the studies simulating global climate policy evaluate their impacts under alternative socioeconomic developments, often represented by the five alternative Shared Socioeconomic Pathways (SSPs) (Fujimori et al., 2022; Hasegawa et al., 2018), within the broader literature on leakage and competitiveness, an important yet underexplored dimension concerns the sensitivity of carbon leakage to alternative global socioeconomic and climate policy trajectories. In fact, in most studies, the rest of the world is assumed to follow a business-as-usual pathway, such that leakage is evaluated in only one external context. This limits our understanding of how unilateral agricultural climate policies interact with different future developments in the global agri-food system.

To our knowledge, no study has quantified the international spillovers of planned agricultural climate policy in a small open economy such as Denmark while systematically accounting for alternative socioeconomic and global climate policy developments. This paper addresses two questions: (i) What are the international spillovers of Denmark's agricultural climate policy? (ii) How sensitive are these spillovers to alternative socioeconomic pathways and climate policy ambition elsewhere? Using an extended global CGE framework, we model 45 scenarios combining Danish policy designs with global contexts defined by SSPs and varying levels of agricultural climate change mitigation ambition in the rest of the world. The model used incorporates endogenous technology adoption, land supply responses, and evolving food preferences under calorie constraints, offering a structured assessment of how national agricultural climate policies interact with global systems.

Methods (model and data)

We perform this analysis by using the model developed in Clora et al. (2024), which extends the recursive dynamic version of the GTAP v7 model (Aguiar et al., 2019; Corong et al., 2017). Among other features, the model allows for the implementation of differentiated sectoral carbon prices by distinguishing agri-food sectors from the rest of the economy (Clora et al., 2023), incorporates mechanisms to capture changes in consumer preferences across SSPs driven by socioeconomic factors (Bouyssou et al., 2025), and models the adoption of abatement technology in the agrifood sectors (Jensbye et al., 2023). As compared to previous applications (Clora et al., 2024; Jensbye et al., 2023) which rely on a global technology catalogue (US EPA, 2019), we update Danish abatement potentials and costs using country-specific data from the Danish Council on Climate Change (2023).

The model is calibrated on the GTAP-AGROFOOD v10 database (Britz, 2022), merged with the GTAP-Power v10 database (Chepeliev, 2020). Key elasticities are adjusted using data from recent literature (Akin-Olçum et al., 2022; Ivanic et al., 2023; Tabeau et al., 2017). The dataset is aggregated to represent key agrifood commodities, and major producing and consuming countries. The dataset is updated in one-year steps towards 2050.

Three Danish agricultural climate policy scenarios are simulated, reflecting a gradual implementation of the agreed regulation (Danish Council on Climate Change, 2025; Danish Government, 2024b). In the first scenario, a tax on agricultural GHG emissions is introduced, starting at 300 DKK (40 Euros) per ton CO_2e in 2030 and rising to 750 DKK (100 Euros) per ton CO_2e by 2035. In the second scenario, a gradual economy-wide reduction in land supply of 15% by 2045 is added to represent land retirement. Recognizing that land retirement is expected to target specific fields (particularly the least productive land) the third scenario combines the GHG tax with a reduction in agricultural land use and a concurrent increase in land productivity, based on available estimates.

These policy scenarios are each simulated against 15 alternative baselines, built by combining five SSP-based baselines and three alternative trajectories for international efforts to mitigate agricultural emissions. The five SSP baselines are built using external projections on population and labor force (Kc and Lutz, 2017), GDP (Dellink et al., 2017), and saving rates (Fontagné et al., 2022). Bilateral iceberg trade costs vary across SSPs following estimated relationships between per capita income and logistics performance (Arvis et al., 2016). Common across all baselines, we target exogenously differences in sectoral productivity growth (Bekkers et al., 2019), non-agrifood emissions (Keramidas et al., 2021), and energy efficiency. Owing to the current trade uncertainties, five alternative globalization scenarios (Clora and Yu, 2023) are also mapped on the five different SSP storylines. Given this study's focus on agri-food sectors, crop, meat, and milk yields are also exogenously targeted (OECD and FAO, 2023), and SSP-specific trajectories for food consumption and demand elasticities are incorporated following Bouyssou et al. (2025). Building on these SSP developments, we consider three alternative pathways for agricultural climate change mitigation outside Denmark. In the first pathway, agrifood emissions in the rest of the world are modeled as endogenous and evolve without additional policy constraints. In the other two ones, we impose low- and high-ambition agricultural mitigation targets derived from region-specific emission pathways developed by Jensbye and Yu (2023).

Expected results

This study will quantify both domestic and international impacts of Danish agricultural climate policy, with a particular focus on changes in sectoral and regional production patterns and associated carbon leakage rates. The results will also highlight how sensitive international spillovers are to alternative socioeconomic trajectories and levels of global climate ambition. By providing the first comprehensive analysis of Danish agricultural climate policy in a global context, this paper contributes to the literature on agricultural mitigation and competitiveness and underscores the importance of sensitivity analysis with respect to external socioeconomic and policy developments.

References

Adenauer, M., Adjemian, M.K., Arita, S., Brorsen, W., Cooper, J., Goh, G., Karali, B., Mallory, M.L., Thompson, W., Yu, J., 2025. Impacts of unilateral U.S. carbon policies on agricultural sector greenhouse gas emissions and commodity markets. Environ. Res. Lett. 20, 024022. https://doi.org/10.1088/1748-9326/ada2ac

Aguiar, A., Corong, E., van der Mensbrugghe, D., 2019. The GTAP Recursive Dynamic (GTAP-RD) Model: Version 1.0. Center for Global Trade Analysis, Purdue University, available at https://www. gtap. agecon. purdue. edu/resources/download/9871. pdf.

Akin-Olçum, G., Ghosh, M., Gilmore, E., Johnston, P., Khabbazan, M.M., Lubowski, R., Mccallister, M., Macaluso, N., Peterson, S., Winkler, M., Duan, M., Li, M., Parrado, R., Rausch, S., 2022. A model intercomparison of the welfare effects of regional coalitions for ambitious climate mitigation targets. Clim. Change Econ. 2350009. https://doi.org/10.1142/S2010007823500094

Arvis, J.-F., Saslavsky, D., Ojala, L., Shepherd, B., Busch, C., Raj, A., Naula, T., 2016. Connecting to Compete 2016: Trade Logistics in the Global Economy--The Logistics Performance Index and Its Indicators. World Bank, Washington, DC. https://doi.org/10.1596/24598

Bekkers, E., Sabbadini, G., Koopman, R., Teh, R., 2019. Long run trends in international trade. The impact of new technologies 45.

Bouyssou, C.G., Clora, F., Jensen, J.D., Yu, W., 2025. A taste of tomorrow: Predicting food demand elasticities under different Shared Socioeconomic Pathways. Global Environmental Change 94, 103049. https://doi.org/10.1016/j.gloenvcha.2025.103049

Britz, W., 2022. Disaggregating Agro-Food Sectors in the GTAP Data Base. Journal of Global Economic Analysis 7, 44–75. https://jgea.org/ojs/index.php/jgea/article/view/143

Chepeliev, M., 2020. GTAP-Power Database: Version 10. Journal of Global Economic Analysis 5, 110–137. https://doi.org/10/gm2n3p

Clora, F., Yu, W., 2023. Modeling The Impacts of Alternative Globalization Scenarios on International Agricultural And Food Markets (Presented at the XVII EAAE Congress).

Clora, F., Yu, W., Corong, E., 2023. Alternative carbon border adjustment mechanisms in the European Union and international responses: Aggregate and within-coalition results. Energy Policy 174, 113454. https://doi.org/10.1016/j.enpol.2023.113454

Clora, F., Yu, W., Jensbye, L., Bouyssou, C.G., Jensen, J.D., 2024. Assessing sectoral impacts of agrifood emission targets under alternative SSPs with improved substantiation of food demand and globalization patterns. Presented during the 27th Annual Conference on Global Economic Analysis (Fort Collins, Colorado, USA).

Corong, E., Thomas, H., Robert, M., Tsigas, M., Van Der Mensbrugghe, D., 2017. The Standard GTAP Model, version 7. Journal of Global Economic Analysis 2, 1–119. https://doi.org/10/gf9zt9

Danish Council on Climate Change, 2025. Afgift på alle landbrugets udledninger.

Danish Council on Climate Change, 2023. Landbrugets omstilling ved en drivhusgasafgift [WWW Document]. URL https://klimaraadet.dk/da/analyse/landbrugets-omstilling-ved-en-drivhusgasafgift (accessed 1.6.26).

Danish Government, 2024a. Aftale om et Grønt Danmark.

Danish Government, 2024b. Aftale om Implementering af et Grønt Danmark [WWW Document]. URL https://www.regeringen.dk/nyheder/2024/bred-politisk-aftale-om-den-groenne-trepart-indgaaet-den-stoerste-forandring-af-det-danske-landskab-i-over-100-aar/ (accessed 11.23.24).

Dellink, R., Chateau, J., Lanzi, E., Magné, B., 2017. Long-term economic growth projections in the Shared Socioeconomic Pathways. Global Environmental Change 42, 200–214. https://doi.org/10.1016/j.gloenvcha.2015.06.004

Fontagné, L., Perego, E., Santoni, G., 2022. MaGE 3.1: Long-term macroeconomic projections of the World economy. International Economics 172, 168–189. https://doi.org/10.1016/j.inteco.2022.08.002

Frank, S., Havlík, P., Stehfest, E., van Meijl, H., Witzke, P., Pérez-Domínguez, I., van Dijk, M., Doelman, J.C., Fellmann, T., Koopman, J.F.L., Tabeau, A., Valin, H., 2019. Agricultural non-CO2 emission reduction potential in the context of the 1.5 °C target. Nature Clim Change 9, 66–72. https://doi.org/10.1038/s41558-018-0358-8

Fujimori, S., Wu, W., Doelman, J., Frank, S., Hristov, J., Kyle, P., Sands, R., Van Zeist, W.-J., Havlik, P., Domínguez, I.P., Sahoo, A., Stehfest, E., Tabeau, A., Valin, H., Van Meijl, H., Hasegawa, T., Takahashi, K., 2022. Land-based climate change mitigation measures can affect agricultural markets and food security. Nature Food 3, 110–121. https://doi.org/10.1038/s43016-022-00464-4

Hasegawa, T., Fujimori, S., Havlík, P., Valin, H., Bodirsky, B.L., Doelman, J.C., Fellmann, T., Kyle, P., Koopman, J.F.L., Lotze-Campen, H., Mason-D'Croz, D., Ochi, Y., Pérez Domínguez, I., Stehfest, E., Sulser, T.B., Tabeau, A., Takahashi, K., Takakura, J., Van Meijl, H., Van Zeist, W.-J., Wiebe, K., Witzke, P., 2018. Risk of increased food insecurity under stringent global climate change mitigation policy. Nature Climate Change 8, 699–703. https://doi.org/10.1038/s41558-018-0230-x

Henseler, M., Delzeit, R., Adenäuer, M., Baum, S., Kreins, P., 2020. Nitrogen Tax and Set-Aside as Greenhouse Gas Abatement Policies Under Global Change Scenarios: A Case Study for Germany. Environ Resource Econ 76, 299–329. https://doi.org/10.1007/s10640-020-00425-0

Ivanic, M., Beckman, J., J. Nava, N., 2023. Estimation of the value-added/intermediate input substitution elasticities consistent with the GTAP data. JGEA 8, 136–161. https://doi.org/10.21642/JGEA.080204AF

Jensbye, L., Clora, F., Yu, W., 2023. Modelling the potential to abate greenhouse gases from agriculture using detailed abatement technologies in a CGE model (Presented during the 26th Annual Conference on Global Economic Analysis (Bordeaux, France)). Global Trade Analysis Project (GTAP), Department of Agricultural Economics, Purdue University, West Lafayette, IN.

Jensbye, L.G., Yu, W., 2023. Agricultural emission reduction targets at country and global levels: a bottom-up analysis. Climate Policy 0, 1–17. https://doi.org/10.1080/14693062.2023.2267021

Kc, S., Lutz, W., 2017. The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. Global Environmental Change 42, 181–192. https://doi.org/10.1016/j.gloenvcha.2014.06.004

Keramidas, K., Fosse, F., Diaz Vazquez, A., Dowling, P., Garaffa, R., Després, J., Russ, H.P., Schade, B., Schmitz, A., Soria Ramirez, A., 2021. Global Energy and Climate Outlook 2021: advancing towards climate neutrality. Publications Office of the European Union.

Lungarska, A., Chakir, R., 2018. Climate-induced Land Use Change in France: Impacts of Agricultural Adaptation and Climate Change Mitigation. Ecological Economics 147, 134–154. https://doi.org/10.1016/j.ecolecon.2017.12.030

Mardones, C., Lipski, M., 2020. A carbon tax on agriculture? A CGE analysis for Chile. Economic Systems Research 32, 262–277. https://doi.org/10.1080/09535314.2019.1676701

Matthews, A., 2022. Trade policy approaches to avoid carbon leakage in the agri-food sector.

OECD, Food and Agriculture Organization of the United Nations, 2023. OECD-FAO Agricultural Outlook 2023-2032, OECD-FAO Agricultural Outlook. OECD. https://doi.org/10.1787/08801ab7-en

Sørensen, P.B., Beck, U.R., Berg, A.K., Christiansen, S., Jørgensen, C.L., Kirk, J.S., Stewart, L.B., Stephensen, P.P., 2025. The effects of unilateral climate policy towards agriculture: A case study of Denmark. Journal of Agricultural Economics 76, 3–23. https://doi.org/10.1111/1477-9552.12624

Tabeau, A., Helming, J., Philippidis, G., 2017. Land supply elasticities: overview of available estimates and recommended values for MAGNET. Publications Office, LU.

US EPA, 2019. Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation Potential: 2015-2050 (No. EPA-430-R-19-010).

Zhang, Q., Li, B., Liu, J.-Y., Deng, Y., Zhang, R., Wu, W., Geng, Y., 2024. Assessing the distributional impacts of ambitious carbon pricing in China's agricultural sector. Ecological Economics 217, 108082. https://doi.org/10.1016/j.ecolecon.2023.108082