(This is a very preliminary draft. Please do not cite. A more complete draft will be posted before the conference)

International maritime shipping decarbonization under alternative technological scenarios: effects on agrifood markets

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

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

13/04/2022

Introduction and objectives

Between 2004 and 2014, the value of agrifood exports has more than doubled, from 644 billion USD to 1471 billion USD (Aguiar et al. 2019). In the same period, the share of agrifood output dedicated to exports has slightly increased from 12% to 13% (Aguiar et al. 2019). This trend has been driven by economic and population growth, advances in transport, information and communication technology, and improvements in market access. In the last two decades, global trade costs have decreased by approximately 15%, with similar reductions across sectors but differences across countries (Rubínová and Sebti 2021; WTO 2021). Decreases have been observed across all determinants of trade costs,[1] including transport and travel costs, which are the most significant determinant of overall trade costs and account for 26% of agricultural trade costs (Rubínová and Sebti 2021; WTO 2021).

Global, route-, mode- and commodity-specific factors will determine the developments of transport costs, which will have ripple effects on the economy. Technological advances such as artificial intelligence, Blockchain technologies, logistics' and engineering improvements, and digitalization will likely continue to reduce international transport costs (Harris, Wang, and Wang 2015; WTO 2018). The opening of new trade routes, such as for example the North Sea Route, could decrease shipping distance between East Asia and Europe, potentially reducing transport costs and diverting trade from other routes (Bekkers, Francois, and Rojas-Romagosa 2018; Zeng et al. 2020). On the other hand, uncertainties regarding potential disruptions to maritime chokepoints (e.g. due to extreme weather events, or political instabilities) (Bailey and Wellesley 2017) and climate change effects on seaport infrastructure (Becker et al. 2012) could exacerbate vulnerabilities in food supply chains and lead to higher transport costs. Moreover, climate change mitigation policies, both in the form of potential market instruments or mandates to reduce emission intensities, will also affect the sectoral cost structures. For instance, maritime transport accounts for over 80% of global international trade by volume and more than 70% by value (UNCTAD 2017). The maritime shipping sector contributed to 2.8% of global greenhouse gas (GHG) emissions in 2018, and emissions have increased in the last years (International Maritime Organization 2020). By 2050, shipping emissions are projected to increase by 0-44% compared to 2018 (International Maritime Organization 2020). The International Maritime Organization (IMO) has expressed its ambition to reduce annual GHG emissions from international shipping by at least 50% by 2050, compared to 2008.[2] The two biggest container shipping companies,

[1] Other determinants part of the decomposition by Rubínová and Sebti (2021) are *information and transaction costs*, *ICT connectedness*, *trade policy and regulatory differences*, *governance quality*.

[2] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx

Mediterranean Shipping Company[3] and Mærsk[4], plan to achieve net zero emissions by 2050 and 2040, respectively. All three strategies propose short-, mid- and long-term measures and targets to reduce their emission intensities and their total emissions. Reducing emissions will require structural and technological transformation within the shipping sector, such as shifts in the fuel mix and improvements in energy efficiency, freight capacity and load factors.

The objective of this study is to investigate how decarbonization in the maritime shipping industry, under alternative technological developments, can affect patterns of agrifood international trade and other national and international agrifood market outcomes. Based on sectoral climate pledges and data obtained from the literature, we analyze decarbonization efforts based on a price instrument along two main dimensions: structural and technological changes in the maritime shipping industry, and changes in countries/regions' logistics performance.

Methods

The research is performed using a modified version of the multi-regional and multi-sectoral recursive dynamic CGE model developed by Clora et al. (2021). The model is based on GTAP-E-RD, previously used by Corong and Strutt (2020), which in turn is a result of integrating the GTAP-E model (Burniaux and Truong 2002; McDougall and Golub 2007) and the recursive dynamic version of the GTAP model named GTAP-RD (Aguiar, Corong, and van der Mensbrugghe 2019). In essence, the GTAP-E-RD is a recursive dynamic version of the static GTAP-E model, allowing to answer dynamic research questions and to capture the trajectory of the economy's reaction to exogenous shocks. Relevantly, the model by Clora et al. (2021) includes non-CO2 emissions in addition to the GTAP-E-RD standard CO2 emissions, and the possibility of implementing different GHG prices (and emission trading systems) for different groups of sectors, within and across countries.

In addition to the features mentioned above, we model substitution across transport modes in bilateral international trade (in the spirit of Avetisyan and Hertel (2021)), and twist parameters in each nest of the production structure, following Clora and Yu (2021). The former addition allows for changes in modal choice in response to changes in the relative cost of different modes of goods' transport (namely changes in maritime transportation relative costs due to decarbonization efforts). The latter addition allows to characterize more precisely changes in the cost structure of individual sectors. For the scope of this paper, twist parameters are used to accurately model technological and structural changes within each sector, e.g. in the fuel mix of the maritime transportation fleet.

The GTAP Power v10 (Chepeliev 2020b) and the GTAP non-CO2 v10 (Chepeliev 2020a) datasets are used in this analysis. The regional aggregation reflects the main global agrifood exporters and the remaining world regions. The sectoral aggregation covers the main agrifood goods, energy commodities, three transportation modes, and the rest of the economy.

The datasets, of which the base year is 2014, are updated towards 2040 in annualized steps. Our baseline construction follows standard methods described in the JGEA special issue on recursive dynamic CGE baseline development (Dellink, van der Mensbrugghe, and Saveyn 2020). On macroeconomic development, we target population and labor force projection consistent with the middle-of-the-road Shared Socioeconomic Pathway (SSP2) (Kc and Lutz 2017). GDP developments

[3] https://www.msc.com/che/sustainability/enabling-logistics-decarbonisation

[4] https://www.maersk.com/news/articles/2022/01/12/apmm-accelerates-net-zero-emission-targets-to-2040-and-sets-milestone-2030-targets

follow historical data between 2014 and 2019, post-COVID-19 forecasts between 2021 and 2027 (IMF 2022), and SSP2 projections onwards (Dellink et al. 2017). We also target different sectoral productivities, and autonomous annual energy efficiency improvements across countries and sectors. Economy-wide regional GHG emissions towards 2040 are exogenously targeted, as global maritime shipping emissions in line with SSP2 developments also are.

Against the baseline, we study three main scenarios. The first scenario is based on the emission targets stated by the IMO,[5] which aims at reducing CO2 emissions from maritime transportation by 50%, compared to 2008, by 2050. Global maritime transportation emissions in this scenario follow a pathway consistent with this goal, with a 40% reduction by 2040. The reduction is modeled by implementing a global emission trading system covering the maritime transportation sector. The second scenario sets an exogenous carbon price at the level of scenario 1. In addition, in scenario 2, we make use of sector-specific data on technological changes that ambitious efforts by the sector could achieve. The simulation is informed by the literature, and changes in energy efficiency, fuel mix, and other relevant productivity variables are exogenously targeted. Finally, scenario 3 builds on the second scenario. In addition to the carbon price and the sector-specific technological changes towards decarbonization, an improvement in logistic performance along bilateral trade routes is assumed. To do so, we use of the Logistic Performance Index, introduced by the World Bank (Arvis et al. 2014; 2016; 2018), which measures the “logistics friendliness” of 160 countries, using both qualitative and quantitative measures. We assume a convergence towards the efficiency frontier in the period 2014-2040.

Expected findings

This study investigate how decarbonization in the maritime shipping industry, under alternative technological developments, can affect patterns of agrifood international trade and other national and international agrifood market outcomes. To address the objectives of the paper, results from the simulations will show changes in production and trade patterns of selected agrifood products (with a focus on animal food products), for selected regions and worldwide. Changes to aggregate welfare measures will also be provided. Finally, climate impacts will be measured by changing emissions in the agrifood and transport sectors.

[5] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx

References

Aguiar, Angel, Maksym Chepeliev, Erwin Corong, and Robert Mcdougall. 2019. "The GTAP Data Base: Version 10." *Journal of Global Economic Analysis* 4 (1): 27.

Aguiar, Angel, Erwin Corong, and Dominique van der Mensbrugghe. 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*.

Arvis, Jean-François, Lauri Ojala, Christina Wiederer, Ben Shepherd, Anasuya Raj, Karlygash Dairabayeva, and Tuomas Kiiski. 2018. "Connecting to Compete 2018: Trade Logistics in the Global Economy." Washington, DC: World Bank. https://doi.org/10.1596/29971.

Arvis, Jean-François, Daniel Saslavsky, Lauri Ojala, Ben Shepherd, Christina Busch, and Anasuya Raj. 2014. "Connecting to Compete 2014 : Trade Logistics in the Global Economy--The Logistics Performance Index and Its Indicators." Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/20399.

Arvis, Jean-François, Daniel Saslavsky, Lauri Ojala, Ben Shepherd, Christina Busch, Anasuya Raj, and Tapio Naula. 2016. "Connecting to Compete 2016: Trade Logistics in the Global Economy--The Logistics Performance Index and Its Indicators." Washington, DC: World Bank. https://doi.org/10.1596/24598.

Avetisyan, Misak, and Thomas Hertel. 2021. "Impacts of Trade Facilitation on Modal Choice and International Trade Flows." *Economics of Transportation* 28 (December): 100236. https://doi.org/10.1016/j.ecotra.2021.100236.

Bailey, Rob, and Laura Wellesley. 2017. *Chokepoints and Vulnerabilities in Global Food Trade*. https://www.deslibris.ca/ID/10091331.

Becker, Austin, Satoshi Inoue, Martin Fischer, and Ben Schwegler. 2012. "Climate Change Impacts on International Seaports: Knowledge, Perceptions, and Planning Efforts among Port Administrators." *Climatic Change* 110 (1): 5–29. https://doi.org/10.1007/s10584-011-0043-7.

Bekkers, Eddy, Joseph F. Francois, and Hugo Rojas-Romagosa. 2018. "Melting Ice Caps and the Economic Impact of Opening the Northern Sea Route." *The Economic Journal* 128 (610): 1095–1127. https://doi.org/10.1111/ecoj.12460.

Burniaux, Jean-Marc, and Truong Truong. 2002. "GTAP-E: An Energy-Environmental Version of the GTAP Model." GTAP Technical Paper 16. Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=923.

Chepeliev, Maksym. 2020a. "Development of the Non-CO2 GHG Emissions Database for the GTAP Data Base Version 10A." *GTAP Research Memorandum* 32: 22.

———. 2020b. "GTAP-Power 10 Data Base: A Technical Note." *GTAP Research Memorandum* 31: 24.

Clora, Francesco, and Wusheng Yu. 2021. "GHG Emission, Trade Balance, and Carbon Leakage: Insights from Modeling Thirty-One European Decarbonization Pathways towards 2050." Presented during the 24th Annual Conference on Global Economic Analysis (Virtual Conference). Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6339.

Clora, Francesco, Wusheng Yu, and Erwin Corong. 2021. "Alternative Border-Carbon-Adjustment Mechanisms in the European Union and Responses: Aggregate and within-Coalition Results." Presented during the 24th Annual Conference on Global Economic Analysis (Virtual Conference). Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6305.

Corong, Erwin, and Anna Strutt. 2020. "Exploring the Impacts of Changing Energy Costs on New Zealand Agriculture to 2030: A GTAP-E-RD Application." Presented during the 23rd Annual Conference on Global Economic Analysis (Virtual Conference). Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=6119.

Dellink, Rob, Jean Chateau, Elisa Lanzi, and Bertrand Magné. 2017. "Long-Term Economic Growth Projections in the Shared Socioeconomic Pathways." *Global Environmental Change* 42 (January): 200–214. https://doi.org/10.1016/j.gloenvcha.2015.06.004.

Dellink, Rob, Dominique van der Mensbrugghe, and Bert Saveyn. 2020. "Shaping Baseline Scenarios of Economic Activity with CGE Models: Introduction to the Special Issue." *Journal of Global Economic Analysis* 5 (1): 1–27. https://doi.org/10.21642/JGEA.050101AF.

Harris, Irina, Yingli Wang, and Haiyang Wang. 2015. "ICT in Multimodal Transport and Technological Trends: Unleashing Potential for the Future." *International Journal of Production Economics* 159: 88–103. https://doi.org/10.1016/j.ijpe.2014.09.005.

IMF. 2022. "World Economic Outlook (January 2022) - Real GDP Growth." 2022. https://www.imf.org/external/datamapper/NGDP_RPCH@WEO.

International Maritime Organization. 2020. "Fourth IMO Greenhouse Gas Study 2020." https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx.

Kc, Samir, and Wolfgang Lutz. 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 (January): 181–92. https://doi.org/10.1016/j.gloenvcha.2014.06.004.

McDougall, Robert, and Alla Golub. 2007. “GTAP-E: A Revised Energy-Environmental Version of the GTAP Model.” GTAP Research Memorandum 15. Department of Agricultural Economics, Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP). https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2959.

Rubínová, Stela, and Mehdi Sebti. 2021. “The WTO Trade Cost Index and Its Determinants,” 28.

UNCTAD. 2017. *Review of Maritime Transport 2017*.

WTO. 2018. “World Trade Report 2018 - The Future of World Trade: How Digital Technologies Are Transforming Global Commerce.”

———. 2021. “WTO Trade Cost Index: Evolution, Incidence and Determinants.” *Background Note*, March. http://tradecosts.wto.org/docs/Trade_Cost_Index_Background_Note_24-03-2021.pdf.

Zeng, Qingcheng, Tingyu Lu, Kun-Chin Lin, Kum Fai Yuen, and Kevin X. Li. 2020. “The Competitiveness of Arctic Shipping over Suez Canal and China-Europe Railway.” *Transport Policy* 86 (February): 34–43. https://doi.org/10/ghxqcs.