Estimating the Uncertainty of Greenhouse Gas Emission Accounts in Multi-Regional Input-Output Modelling

Topic: Input-Output Analysis: Sustainable Production and Consumption Policies - IX
Author: Simon Schulte
Co-Authors: Stefan Pauliuk

Introduction

Global multi-regional input-output (GMRIO) analysis is widely seen as the most appropriate framework to quantify national greenhouse gas (GHG) emissions from a consumption perspective. The robustness of GMRIO-based results, however, has been questioned by several comparative studies between GMRIO databases. Those inter-database comparisons showed partly large deviations in the results of which a considerable part could be attributed to the GHG emission satellite accounts.

Inter-database comparisons, however, only capture the variability caused by the assumptions and data sources that vary between databases. Thus they miss the uncertainty arising from assumptions and data sources that are uniform between databases. Therefore, inter-database comparisons are unsuitable for obtaining a reliable quantitative assessment of the actual uncertainty of GMRIO-based results.

Against this background, we use error propagation methods to quantify the uncertainty of GMRIO-based carbon footprints. We focus on the uncertainty arising from the GHG emission accounts, whereby covering the main GHGs CO2, CH4 and N2O. We use Monte-Carlo simulations to estimate how uncertainty propagates from raw data inputs (i.e. emission inventories) and auxiliary data (e.g. to breakdown emission data to GMRIO sectors) to the final GHG emission accounts, and then further to the GHG footprints.

Material & Methods

We construct GHG emission accounts for the year 2015 for the EXIOBASE industries and regions using emissions data from the UNFCCC national inventories and the EDGAR database. To align the system boundary from the territorial to the residential principle, we use data from Eurostat, the Worldbank and Selin et al. (2021). To allocate aggregate emissions from the UNFCCC/EDGAR sectors to detailed EXIOBASE sectors we use proxy data from the EXIOBASE Supply-Use Tables. The allocation of emissions from road transport to industries and household consumption is largely based on Physical Energy Flow Accounts from Eurostat.

Uncertainty data for emission inventories are extracted from National Inventory Reports (NIR) for the UNFCCC emission inventories, and from Solazzo et al. (2021) for the EDGAR data. We use Dirichlet distributions parametrized in a Maximum Entropy framework to propagate the uncertainty from the (aggregate) UNFCCC/EDGAR sectors to the (disaggregate) EXIOBASE sectors.

Unlike the (few) existing studies that applied error propagation to study the uncertainty of (G)MRIO-based carbon footprints (Karstensen et al., 2015; Lenzen et al., 2010), we also include correlations. By assigning uncertainty values to the raw data instead of to the intermediate model outcomes (i.e. the GHG emission accounts), we implicitly capture all correlations that result from the structure of our model for building the emission accounts. Correlations between raw data points from the emission inventories we model following the assumptions made in Solazzo et al. (2021).

Results

The output of our work are GHG extensions for the year 2015 in the EXIOBASE industry/country resolution that include uncertainty estimates for each coefficient and information on correlation structures between the coefficients. The uncertainties vary widely between sectors, countries/regions and GHGs. Unlike in existing studies, the amount of uncertainty and the sectoral/regional variability is not primarily driven by simplistic assumptions (e.g. power law regression based on the assumption that the uncertainty of a sector depends only/mostly on a sectors absolute size), but explicitly based on the uncertainties of raw data inputs and of models/proxies used to allocate inventory data to EXIOBASE sectors/countries. Moreover, our results contribute to the debate which role correlation structures play in the evaluation of the uncertainty of carbon footprints.

References

Karstensen, J., Peters, G.P., Andrew, R.M., 2015. Uncertainty in temperature response of current consumption-based emissions estimates. Earth Syst. Dyn. 6, 287â€“309.
Lenzen, M., Wood, R., Wiedmann, T., 2010. Uncertainty Analysis for Multi-Region Inputâ€“Output Models â€“ a Case Study of the Ukâ€™s Carbon Footprint. Econ. Syst. Res. 22, 43â€“63.
Selin, H., Zhang, Y., Dunn, R., Selin, N.E., Lau, A.K.H., 2021. Mitigation of CO2 emissions from international shipping through national allocation. Environ. Res. Lett. 16, 045009.
Solazzo, E., Crippa, M., Guizzardi, D., Muntean, M., Choulga, M., Janssens-Maenhout, G., 2021. Uncertainties in the Emissions Database for Global Atmospheric Research (EDGAR) emission inventory of greenhouse gases. Atmospheric Chem. Phys. 21, 5655â€“5683.