ESEE 2015: Special Session “Trade in transformation: Accounting for global resource use”

Title

Effect of aggregation and disaggregation on embodied material use of products in input-output analysis

Summary

Consumption based material footprints calculated with multi-regional Input-Output Analysis (mrIOA) can be influenced by the sectoral, spatial and material aggregation used in the mrIOAs. This study investigates the effect of resolution in mrIOAs on consumption based material footprints and material embedded in trade. The effect of aggregation was investigated by making different input-output tables with different spatial, product and material category resolution and comparing the calculated material footprints. Our results indicate that the material footprints of countries calculated with the different mrIO models are in general in the order of a few percentage with outliers in the order of 25% difference. For some product categories the results are structurally inaccurate. This result suggests that the material data used to create the material extensions for the IO framework should be collected at the highest resolution that is practically feasible.

Abstract

Multi-regional IO systems are currently recognized as providing a state-of-the art system for the calculation of economy-wide environmental impacts of consumption, including carbon, water, land and material footprints. Different multi-regional IO systems (mrIOs) exist, and they differ in resolution with respect to material categories, products/industries and countries. Currently, efforts are being made to estimate via similar approaches footprint type indicators of material usage for policy applications. An important example of such an effort is ongoing work of the United Nations Environment Program International Resources Panel (UNEP IRP) to develop a harmonized resource extraction database covering almost all countries in the world. In this context the question is at stake what factors are relevant for creating robust estimates of material footprints. Since the UNEP IRP effort will harmonize much of the primary extraction data, the question we put central in this research is: what is the impact of data resolution and aggregation on estimates of material footprints with mrIOs. We focus on this specific question within three particular domains; 1) the resolution of information on material extracted from the environment; 2) the resolution of product groups tracked in the input-output system; 3) the geographic resolution. By investigating these aspects, we seek to provide an answer to what is a reasonable level of resolution required in mrIO work in order to get representative results, and what areas are most critical to provide detail on in either creating or utilizing mrIO data.

We set this research question in a broader context by calculating both material and carbon footprints. The results on the variance of the calculated material footprints will be compared to the

calculated carbon footprint of countries and products/industries. The carbon footprints serve as a reference to which the material footprints are compared. Is the effect of resolution on the material footprint smaller or larger than on the carbon footprint? The carbon footprint is a useful reference because of the wealth of other studies which have focused on the effect of resolution on carbon footprints. Further greenhouse gas emissions are also emitted by many sectors of the economy, providing a counterfactual to material extraction, which is by and large concentrated in the agriculture, forestry and mining sectors, leading to a much higher concentration in supply chains.

This study is carried out with the recently published version 2 of EXIOBASE. The available multi-regional Supply-Use tables (mrSUTs) at the highest level of detail were used as the starting material. Subsequently this set of mrSUTs was transformed into different mrIOs each representing a scenario. The default scenario used the mrSUT at its highest resolution of 200 product groups, 48 countries and 46 material categories. The product aggregation scenario aggregated the 200 product groups into 60 product groups. The spatial aggregation scenario aggregated the 48 countries into 4 regions. The material aggregation scenario aggregated the 46 material categories into 16 material categories. These scenarios allowed us to investigate the effect of 1) reduced product resolution 2) reduced spatial resolution and 3) reduced material category resolution. The basic comparison between the scenarios is total material and carbon footprint of countries/regions, the embodied material use and carbon emissions of products per million Euro of that product, and the material and carbon embodied in trade.

We find that the differences between the material footprint of a country calculated with mrIO models that differ in product resolution and spatial aggregation are in general in the order of a few percentage. However outliers in the order of a 25% difference are possible. The effect of having aggregated material categories is more influential on the material footprint of countries, the difference can be in the order of 30% when aggregating the original 46 material categories into 16 material categories. This result strongly suggests that the material data used for to create the extensions for the IO framework should be collected at the highest resolution that is practically feasible. Since many of the original data sources used to compile material extension databases, like the International Energy Agency database (energy carriers), FAOSTAT (agricultural products) and the US Geological Survey (USGS; materials) are already at a high level of detail, we strongly recommend to stay as close as possible to the detail in such original sources.

The effects of product aggregation, spatial aggregation and material category aggregation on the calculated total embodied material use of individual product groups is for many product groups limited. However, for several individual product groups the difference can be in the order of 100% or more, see Figure 1. Particularly affected are primary sector products. The use of IO models with a low product category resolution (e.g. 60 product categories) to calculate the embodied material use of individual products will likely result in estimations of the total embodied material that are for some product categories structurally inaccurate. This limits the possibilities to use IOA in detailed MFA studies, if the IOA uses a relatively aggregated product resolution.

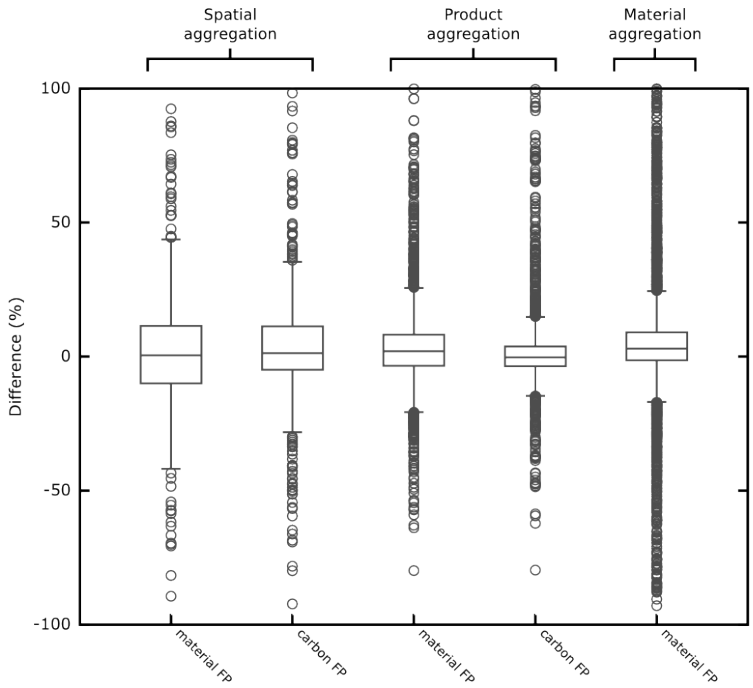

Figure 1: Effect of aggregation on the calculated carbon emissions and material use embedded in products for three different aggregation scenarios. The difference between the values calculated with the most detailed mrIO and the aggregated mrIO is given in Box and Whisker plots. The box indicates the interquartile range, the lower whisker is defined by the 1st quartile - 1.5 x IQR, the upper whisker is defined by the 3rd quartile + 1.5 x IQR, the median is indicated by the bar within the box. Outliers are indicated by the ○ symbol. Outliers with a difference larger than 100% are not shown.

The effect of aggregation on the material footprint is significantly larger than the effect on carbon footprints which is also visible in Figure 1. This result shows that it is important to specifically investigate the effect of aggregation on different indicators. An aggregation level that is acceptable for one environmental or economic indicator might be unacceptable for another indicator or purpose.