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Consumption-based versus production-based accounting of CO_2 emissions: Is there evidence for carbon leakage?

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ABSTRACT

Lately, a controversial debate has evolved regarding consumption-based accounting (CBA) versus production-based accounting (PBA) of CO_2 emissions. So far, the debate has been predominately theoretical and has inspired only a few empirical studies. In this article, we compare production-based versus consumption-based emissions, and for the first time analyze reasons for the differences. In particular, we focus on whether there is evidence for carbon leakage from developed to developing countries. We use the newest available data for 110 countries and analyze whether there are differences between OECD and non-OECD members. Furthermore, we compare the within-country differences for the time span of 1997 to 2011 via fixed effects panel regression models in order to investigate whether increases in GDP per capita result in higher imported emissions. The results suggest that for most countries the differences depending on accounting schemes are small. Furthermore, we find no evidence for carbon leakages. In particular, the ratio of CBA to PBA is not driven by OECD membership or GDP per capita. Instead, the ratio is greater for countries with high energy efficiency and high import rates. Given the small differences between PBA and CBA, we suggest keeping the production-based accounting of CO_2 emissions.

1. Introduction

A controversial debate has recently evolved around the issue of whether national CO_2 emission inventories should be based on territory-related production or consumption (Afionis et al. 2017, Fan et al. 2016, Fernandez-Amador et al. 2017, Davis and Caldeira 2010, Davis et al. 2011, Liu 2015, Peters et al. 2012, Steininger et al. 2015). So far, national CO_2 inventories follow the guidelines of the Intergovernmental Panel on Climate Change (IPCC), which are based on the consumption of fossil fuels within a country. This accounting is called production-based and is relatively straightforward: It estimates the greenhouse gas emissions from all the oil, coal, and gas consumed in a country by private households, industrial production of goods and services, and electricity production. However, production-based accounting has some disadvantages. First, it excludes emissions stemming from international air and sea transportation. Since such emissions do not take place within a specific territory its attribution to specific countries is difficult. Second, energy-intensive industries in countries with strict emission controls, regulations or taxes might move into territories with fewer restrictions and lower energy costs. However, the goods produced in the less restrictive countries might then be exported to the more restrictive countries. Thus, decreasing emissions in one country can be directly linked to increasing emissions in the other country. This type of replacement in response to the environmental policy of a country is often termed “strong carbon leakage”. Third, the emission leakage can also be weak, e.g. if international specialization encourages some countries to outsource the production of carbon-intensive goods to other countries with lower production costs. Strong and weak carbon leakages result only in reallocations of CO_2 emissions, and a decrease in one country is more or less directly related to an increase in another. Consumption-based accounting takes care of these problems. It subtracts from countries all emissions that are contained in exported products, including transportation emissions, and includes the embodied emissions in the inventories of the importing countries (Fan et al. 2016, Peters et al. 2011). If the carbon leakages due to international trade are strong then the difference between consumption-based and production-based emissions might be large. Hence, with respect to production-based

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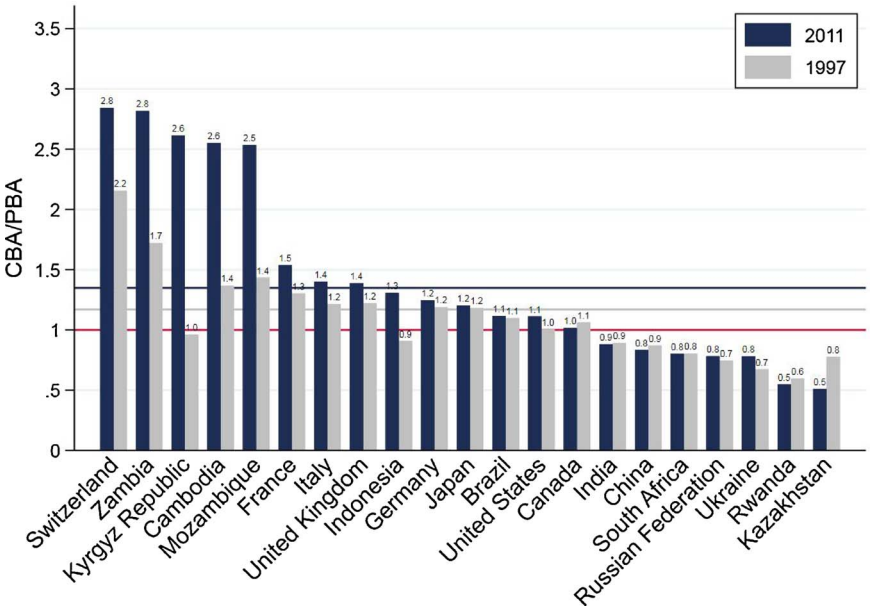

Fig. 1. The ratio of consumption- and production-based CO_2 emissions per capita (CBA/PBA) for 1997 and 2011.
Note: The figure shows the top 5 and the bottom 5 countries with respect to the ratio of CBA to PBA, the five largest emitters of CO_2, and members of the G7 or BRIICS if not already included by the other criteria. Data source is the Emissions Database for Global Atmospheric Research (Olivier et al. 2016) for production-based accounting and the Global Carbon Atlas (Peters et al. 2011) for consumption-based accounting of CO_2. The horizontal grey line denotes the average CBA/PBA ratio for 1997, and the blue line the average for 2011.

inventories, low emission countries might look less "clean" in the consumption-based framework and high emission countries might in reality produce goods for the living standard of low emission countries. Obviously, the difference in accountability of emissions might also have political implications.

In this paper we will take a look at the differences between consumption-based and production-based accounting of emissions. First, after a short literature review in Section 2, we describe the differences by using the most up-to-date data for the 110 countries for which both inventories are available in Section 3. Second, we also analyze the differences by using fixed effects panel regression models for the period of 1997 to 2011 for these 110 countries in this section. Proponents of the consumption-based method often assume (more or less explicitly) that developing countries produce carbon emissions mainly for exports into developed countries. Hence, the former would profit from deducting emissions contained in exports with respect to their CO_2 footprint. In contrast, developed countries might only have low emissions because of leakages and this bias would be corrected by consumption-based accounting. We wonder how big these differences are and whether or not they are driven by GDP. Third, and also in that section, we take a look at the development of the differences of the two inventories for the available time period. If leakages are responsible for the difference, then they should increase over time since regulations became stricter and specialization has also increased over time. The final section concludes with a discussion of the advantages and disadvantages of the consumption-based approach.

2. Literature review

In recent years a number of studies have called attention to the fact that a substantial amount of CO_2 emissions are embodied in international trade. Thus, Davis and Caldeira (2010) report that in 2004 23% of global CO_2 emissions were contained in exports stemming predominantly from developing countries (e.g. China) to developed nations (e.g. Switzerland, Sweden, UK, or the USA). An analysis by Peters et al. (2012) suggests that the proportion related to international trade is increasing over time (to 26% in 2008). These findings have inspired a controversial discussion about the extent to which CO_2 emissions are outsourced by developed nations to developing countries. Some authors propose that since both consumers and producers of goods and services are equally responsible for CO_2 emissions, they should also share mitigation responsibilities (e.g. Steininger et al. 2014, Jakob et al. 2014). How this could be accomplished and whether switching from production-based accounting to consumption-based accounting is beneficial with respect to the efficiency of CO_2 abatement policies is an ongoing debate (e.g. Liu 2015). The consideration of switching to consumption-based accounting depends also on empirical assessments of the size of carbon leakages, and on the reasons for them. So far such empirical investigations are still sparse. Some studies compare consumption-based emissions of Annex I countries (those who committed themselves to CO_2 reductions in the Kyoto Protocol) before and after the commitment. They find very small or no evidence for strong carbon leakages. Similar results hold for studies investigating EU countries before and after the implementation of the European Union Emissions Trading System (EU ETS) (for a review see Branger and Quirion 2014). However, the authors of these studies point out that carbon prices in the EU have been very low so far providing only small incentives for a reallocation of carbon intensive industries such as cement or aluminum production. Furthermore, energy intensive industries received generous emission permits by the EU to avoid reallocation. Hence, outsourcing might increase when the supply of pollution permits is reduced to meet the emission targets.

Other recent empirical studies investigate the question of whether the predictors of CO_2 depend on the accounting scheme. Econometric analyses of production-based emissions usually find that national CO_2 emissions are predominantly driven by population size, GDP, and the energy intensity of a nation's economy. Moreover, further but smaller predictors are countries' commitment to environmental protection (measured by ratification of international agreements), non-fossil energy sources, and energy prices (see Franzen and Mader 2016). Fernandez-Amador et al. (2017) compare the effects of GDP per capita on CO_2 per capita of models using production-based data with those of