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The changing of the relationships between carbon footprints and final demand: Panel data evidence for 40 major countries

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ABSTRACT

Global warming and environmental pollution have led many countries to begin to implement measures to reduce the use of fossil fuels. However, emissions reductions may have been reached because of the displacement of emissions intensive production. The objective of this study is to analyze the relationships between the emissions caused by countries from a demand point of view, the carbon footprints and the demand for goods and services in these countries, and especially in the European countries. With this aim, a two-step process was carried out. Firstly, carbon footprints were calculated during the 1995–2009 period. Secondly, the EKC hypothesis between these carbon footprints and the total final demands were tested by using panel data and a multilevel mixed-effects model. The results show that the EKC hypothesis is not supported when considering carbon footprints with respect to final demand. It is also shown that carbon footprints are slightly increasing with respect to final demand beyond proportionality. The carbon footprint elasticities are different between countries, their values increasing with the final demand per capita of countries.

1. Introduction

Today, the problems of global warming and environmental pollution have become major concerns among economists and environmentalists. Emissions of CO_2 are considered to be the main contributor, causing problems on a global scale (Fodha and Zaghdoud, 2009; Lau et al., 2014), with the consumption of fossil fuels being the main cause of these emissions. This has led many countries to begin to implement measures to reduce the use of fossil fuels by promoting renewable energy and the application of energy efficiency measures, especially in developed countries. As a consequence, many of these countries, as stated in Kanemoto et al. (2014), have reduced their emissions, and some of them have even fulfilled their Kyoto Protocol CO_2 reduction commitments.

Nevertheless, these countries may have achieved these commitments partly because they have displaced emissions intensive production offshore, in order to reduce costs on environmental controls (Lau et al., 2014). Therefore, polluting industries and businesses have tended to be displaced to developing countries, where environmental standards are relatively low, making the shifting of CO_2 emissions from developed to developing countries a growing problem. Hoekstra et al. (2016) and Malik and Lan (2016) show explicitly that outsourcing occurs predominantly between developed and developing countries. Additionally, Malik et al. (2016) also investigate the geographical bilateral relationships and the commodity content of outsourcing. In some other studies, such as those by Aichele and Felbermayr (2012) and Andrew et al. (2013), it is estimated that around 30% of global emissions are linked to production for export, enlarging the discrepancy between the national emissions and their carbon footprints. Moreover, Kanemoto et al. (2014) verify that emissions from developed countries increase when adjusting for trade. They find that the sectors lowering their domestic emissions are often those that are increasing their imports of embodied CO_2, which suggests a burden shifting of the same emissions-intensive activities, and not cleaner production patterns.

In light of this, the analyses made by many researchers studying the environmental Kuznets curve (EKC) hypothesis, when exploring the relationship between GDP, energy consumption and carbon emissions in different countries and regions, may become meaningless from a global point of view. The EKC hypothesis states that the increase in income of a country will increase its pollution until a certain point of economic development, at which time the relationship between both variables becomes negative, which may be attributed to

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the availability of more technologies that improve energy efficiency, energy saving and renewable energy (Al-Mulali et al., 2015a). Nevertheless, the EKC hypothesis may be verified in a country, at least partially, by displacing emissions-intensive activities, without in fact reducing emissions linked to production. The increased displacement of emissions-intensive activities may be related to international trade development, leading some economists, such as Jebli et al. (2016), to include trade as a control variable when testing the EKC hypothesis. Nevertheless, these studies refer to emissions that have been generated within a country and they do not allow for what is happening behind borders.

The objective of this study is to analyze the relationships between the emissions caused by countries from a demand point of view, the carbon footprints and the demand for goods and services in these countries, and especially in the European countries. Considering carbon footprints and final demand, rather than the CO_2 emissions and GDP (as most often used in other studies when estimating the EKC), allows us to relate the generated emissions with the ultimate purpose of production activities. The carbon footprints that refer to the cumulated CO_2 emissions through a supply chain, or through the life cycle of a product, may correctly attribute the emission sources to consumption activities (Hertwich and Peters, 2009). Therefore, the use of carbon footprints and final demand provides a different perspective on the drivers of emissions at the global level. Thus, while the traditional focus on the emission sources may be useful for compiling statistics and understanding the global carbon cycle, it is considered insufficient to design mitigation policy (Peters et al., 2009). Although supply-side measures, such as technological improvements and renewable energies use, have been reducing emissions, they are not enough to keep emissions at sustainable levels, as stated by Malik et al. (2016). Therefore, demand side measures, or at least knowing how emissions change with this demand, are also necessary to better implement energy and environmental policies oriented to reducing global carbon emissions.

With this aim, a two-step process was carried out. Firstly, carbon footprints were calculated. The global multi-regional input–output database (MRIO), the World Input–Output Database (Dietzenbacher et al., 2013; Timmer et al., 2015; WIOD, 2015) and the approaches of Serrano and Dietzenbacher (2010) and Rueda-Cantuche (2012) were used. Data from the WIOD database refer to the period 1995–2009 and to forty countries worldwide, including the major economies in the world, covering about 85% of world GDP in 2008 (at current exchange rates). These countries are, all 27 members of the EU, Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and the USA.

Secondly, this study tests the EKC hypothesis where the carbon footprint is the dependent variable and the total final demand is the independent variable, by using panel data techniques referring to the same forty countries and period. The EKC hypothesis was tested taking into account the methodological heterogeneity problems of panel data, which have been highlighted in some previous studies, such as that by Piaggio and Padilla (2012). For that reason, two control variables were included. The first refers to the economic structure of each country, as in previous studies, such as those of Perrings and Ansuategi (2000) and Friedl and Getzner (2003). The second refers to imports, as have been included in previous studies, such as that of Al-Mulali et al. (2015b). Additionally, the EKC was estimated by using a multilevel mixed-effects model which allows flexibility to be added to the estimated function (Rabe-Hesketh and Skrondal, 2008; West and Galecki, 2011; Leckie et al., 2014).

Finally, from the EKC estimates, the elasticity of carbon footprints with respect to total demand was calculated for each year and country. This allowed it to be determined whether, and to what extent, a percentage variation in final demand leads to relative changes in emissions generated by countries, analyzing whether there is a different behavior between countries. These elasticities were calculated following Pablo-Romero and Sánchez-Braza (2015).

The paper is organized as follows. The methodology is explained in Section 2. Section 3 specifies the statistical information sources used. In Section 4, the results of the carbon footprints and the EKC estimates are presented, together with the values of the elasticities calculated from these estimates. Additionally, a discussion and policy implications of the main results are provided in Section 5. Finally, the conclusions of this paper are given in Section 6.

2. Methodology

The economic analysis made in this study combined the use of two different methodologies. On the one hand, the carbon footprints were calculated within a multi-regional framework. On the other hand, the carbon footprints were related to final demand with the aim of testing the EKC hypothesis. Moreover, the household final demand and total final demand were considered in this study to compare the EKC.

2.1. Carbon footprint and total emissions generated by countries

The starting point was the MRIO table at basic prices, which describes the flow of goods and services from all sectors to all intermediate and final recipients. MRIO tables have been widely used to calculate carbon footprints and to analyze the environmental consequences of international trade. Among these studies, it is worth mentioning those by Wiedmann (2009), Wiedmann et al. (2010), Wiebe et al. (2012), Zhang et al. (2013), Kanemoto et al. (2014) and Tang et al. (2015).

Alternative MRIO databases have been used in previous studies, such as EXIOBASE (Tukker et al., 2013), GTAP (Peters et al., 2011; Andrew and Peters, 2013), IDE-JETRO (Meng et al., 2013), Eora (Lenzen et al., 2012; Lenzen et al., 2013) and WIOD (Dietzenbacher et al., 2013; Timmer et al., 2015; WIOD, 2015). In this study, the WIOD MRIO table, which refers to forty countries, was used. Each of these countries have economic activities classified into n industries (35 in this case), and may differ in production technologies and/or emission levels per unit of production.

The Leontief quantity model may be expressed according to Serrano and Dietzenbacher (2010), as $x = Ax + y$ or

$$\begin{bmatrix} x_u \\ x_v \\ \cdots \\ \cdots \\ \cdots \\ \cdots \\ x_r \end{bmatrix} = \begin{bmatrix} A^{uu} & A^{uv} & \ldots & A^{ur} \\ A^{vu} & A^{vv} & \ldots & A^{vr} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ A^{ru} & A^{rv} & \ldots & A^{rr} \end{bmatrix} \begin{bmatrix} x_u \\ x_v \\ . \\ . \\ . \\ . \\ x_r \end{bmatrix} + \begin{bmatrix} y_{uu} + y_{uv} + \ldots + y_{ur} \\ y_{vu} + y_{vv} + \ldots + y_{vr} \\ \cdots \\ \cdots \\ \cdots \\ \cdots \\ y_{ru} + y_{rv} + \ldots + y_{rr} \end{bmatrix}$$

where

u = country 1, v = country 2,..., r = rest of the world (rw).

$A^{uu}, A^{vv},\ldots, A^{rr}$ matrices of domestic technical coefficients of countries u, v,... and rw.

$A^{uv},\ldots, A^{ur}, A^{vu},\ldots, A^{vr}, A^{ru}$ matrices of imported input coefficients between countries.

$y_{uu}, y_{vv},\ldots, y_{rr}$ final domestic demand of countries u, v,... and rw.

$y_{uv},\ldots, y_{ur}, y_{vu},\ldots, y_{vr}, y_{ru},\ldots$ final external demand of each country to each of the remaining countries.

$x_u, x_v,\ldots x_r$ total industry outputs.