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Analysis

'Environmental load displacement' from the North to the South: A consumption-based perspective with a focus on China

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ABSTRACT

Quantifying environmental load displacement from developed countries (the North) to developing countries (the South) is of particular importance for understanding the environmental implications of consumption in the North and global sustainability. Based on a global input–output model, this paper estimates emissions transfers between the North and the South for eight types of air pollutants from a consumption perspective, with a focus on emissions transfers between the North and China. The results show that 14%–30% of air pollutant emissions in the South were caused by consumption in the North in 2007. There is a large 'pollution deficit' between the North and South, which significantly increased during the period 1995–2007, that favors the theory of ecologically unequal exchange. Although the emissions per capita of the North from production for most air pollutants decreased over this period, the emissions per capita from consumption increased or decreased more mildly. The decomposition of emissions transfers further shows that South–South trade in intermediates has played an increasingly important role in environmental load displacement from the North to the South. It is important to assess the sustainability of so-called 'weightless economies' in the North from a global perspective that takes environmental load displacement into account.

1. Introduction

With international trade, consumption of goods and services can be separated geographically from the environmental burdens of production. The developed world (hereafter, the North) is the major consumer of natural resources in the world, whereas developing countries (hereafter, the South) are major producers and suppliers of natural resources (von Weizsäcker et al., 1995; Hart, 1997). North–South trade is a critical channel through which the consumption activities in the North affect the environment and natural capital of the South. Analyzing how consumption in the North affects the environment in the South is of great importance in assessing the global environmental effect of the postindustrial service economy in the developed world and its sustainability (Proops et al., 1999). Quantifying the biophysical content of North–South trade can also help to discuss the theory of ecologically unequal exchange between core countries (developed countries) and peripheral ones (developing countries) (Andersson and Lindroth, 2001; Dorninger and Hornborg, 2015; Hornborg, 2014; Moran et al., 2013; Rice, 2007).

Environmental load displacement from the North to the South has been observed and analyzed in many studies. Based on material flow accounting, some studies have found a substantial 'ecological deficit' of the North with the South (Giljum and Eisenmenger, 2004; Muradian and Martinez-Alier, 2001). Raw materials and energy embodied in trade have been quantified by recent research to test the hypothesis of the theory of ecologically unequal exchange between the North and the South (Dorninger and Hornborg, 2015; Moran et al., 2013). In addition, air pollutant emissions embodied in North–South trade were also estimated to reveal the 'environmental load displacement' from the North to the South (Muradian et al., 2002). Recently, many studies have given special attention to greenhouse gas (GHG) emissions transferred from developed countries to developing countries (e.g., Davis and Caldeira, 2010; Davis et al., 2011; Du et al., 2011; Kagawa et al., 2015; Kanemoto et al., 2014; Liu et al., 2010; Peters and Hertwich, 2008; Peters et al., 2011b; Tan et al., 2013; Wiebe et al., 2012).

The analysis of resource/pollution embodied in North–South trade is of particular importance, which traces both the direct and indirect environmental impact generated by the production of the trade sector. With the development of manufacturing in the South, many developing countries, particularly the BRIC countries (Brazil, Russia, India, and China), have become major exporters of manufactured goods rather than natural resources. However, the upgrade of the North–South trade structure may alleviate environmental burdens for the South but

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never eliminate them. Natural resources are now consumed by domestic industries in the countries of the South and embodied in the goods exported to the North. In other words, the natural resources are exported indirectly to the North. The ecological metabolism of export sectors may still generate serious environmental problems in the South. For example, approximately one-third of GHG emissions in China were generated because of its production of exports (e.g., Pan et al., 2008; Weber et al., 2008).

Input–output analysis has been widely used in the literature to estimate the embodied material or pollution in trade and consumption (Wiedmann, 2009; Wiedmann et al., 2007). In general, three types of input–output models are used in the literature: the single region input–output (SRIO) model, the emissions embodied in bilateral trade (EEBT) model, and the multi-regional input–output (MRIO) model (Peters, 2008).[1]

Domestic technology assumption (DTA) is often applied when the SRIO model is used to estimate emissions embodied in imports, which may cause severe bias because of the varieties of technology in different countries (Andrew et al., 2009; Lenzen et al., 2004). EEBT and MRIO models avoid the use of DTA and consider trade linkages among countries because two or more countries' input–output data and environmental data are used in these models. The EEBT model cannot yet capture the full feedback loop in trade and cannot appropriately allocate intermediate imports to final consumers in different countries according to international production chains of final products (Peters, 2008). These problems can be resolved by using the MRIO model, which directly models the production structures of different countries and trade networks of intermediate and final products across countries. MRIO analysis is of great importance because the production of many goods consumed in the North is fragmented in different countries. For example, suppose that South country A exports raw oil to South country B, which uses the oil to produce final goods exported to North country C. With the EEBT model, there would be no raw oil embodied in the exports of country A to country C because no direct trade occurs between them. However, the trade of raw oil between countries A and B will be accounted for in the MRIO model, quantifying the total energy use induced by the consumption of country C. Therefore, the MRIO model is recommended as a useful tool to analyze global environmental loads from consumption (Peters, 2008; Wiedmann, 2009).

The data requirement for MRIO analysis is significantly higher than that for the SRIO and EEBT models. Thanks to the development of international input–output databases in recent years (see Tukker and Dietzenbacher (2013) for an overview), MRIO models have been increasingly used by a growing number of researchers (e.g., Arto et al., 2014; Davis et al., 2011; Hertwich and Peters, 2009; Kanemoto et al., 2014; Liu and Wang, 2015; Moran et al., 2013; Muñoz and Steininger, 2010; Peters et al., 2011a, 2011b; Wiebe et al., 2012; Wiedmann et al., 2010; Xu and Dietzenbacher, 2014).

In the present study, we also carry out an analysis using a MRIO model on environmental load displacement from the North to the South, with a focus on emissions transfers between the North and China. We add new insight into the previous analysis in three respects. First, in addition to three types of GHG emissions (CO_2, CH_4, and N_2O), we estimate the amounts of five types of non-GHG air pollutants (NO_x, SO_x, CO, NMVOC, and NH_3) transferred between the North and the South. Most previous studies have only considered GHG emissions transfers. The patterns and dynamics of emissions transfers for non-GHG pollutants may be different from those of transboundary GHG emissions, which are not legally controlled in most developing countries. Second, we depict the correlations between the emissions transfers and income as well as technology and discuss their implications. Third, emissions transfers from some South regions to the North are decomposed into direct emissions exports and indirect emissions exports to reveal the environmental effect of South–South trade induced by the consumption of the North. The decomposition helps explain the influence of growing international production fragmentation on environmental load displacement from the North to the South.

The remainder of the paper is structured as follows. Section 2 describes methods for constructing emissions transfers from a consumption-based perspective in an MRIO framework. Section 3 describes the data used in this paper. Section 4 reports our main results. In the final section (Section 5), we discuss policy implications of the results. We also discuss the major limitations of the methodology and material used in the present study in this section.

2. Methodology

2.1. Indicators of Emissions Transfers From a Consumption-based Perspective

In the present study, emissions transfers between the North and the South are estimated using the MRIO model. The primary identity of an MRIO model with m countries is

$$\begin{pmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \\ \vdots \\ \mathbf{x}_m \end{pmatrix} = \begin{pmatrix} \mathbf{A}_{11} & \mathbf{A}_{12} & \cdots & \mathbf{A}_{1m} \\ \mathbf{A}_{21} & \mathbf{A}_{22} & \cdots & \mathbf{A}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{A}_{m1} & \mathbf{A}_{m2} & \cdots & \mathbf{A}_{mm} \end{pmatrix} \begin{pmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \\ \vdots \\ \mathbf{x}_m \end{pmatrix} + \begin{pmatrix} \sum_i \mathbf{y}_{1i} \\ \sum_i \mathbf{y}_{2i} \\ \vdots \\ \sum_i \mathbf{y}_{mi} \end{pmatrix} \tag{1}$$

where $\mathbf{x}_i$ is the output vector of country i. The diagonal sub-matrix $\mathbf{A}_{ii}$ in the block matrix represents the inter-industry requirements of domestic production in country i, whereas the off-diagonal sub-matrix $\mathbf{A}_{ij}$ denotes the inter-industry requirements from region i to j, which represent the intermediate product imports of country j from i. $\mathbf{y}_{ii}$ is the domestic final demand of country i, and $\mathbf{y}_{ij}$ is the country's exports of the final product to country j.

If we decompose the output of each country according to the final demand of each country, then Eq. (1) can be rewritten as

$$\begin{pmatrix} \mathbf{x}_{11} & \mathbf{x}_{12} & \cdots & \mathbf{x}_{1m} \\ \mathbf{x}_{21} & \mathbf{x}_{22} & \cdots & \mathbf{x}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{x}_{m1} & \mathbf{x}_{m1} & \cdots & \mathbf{x}_{mm} \end{pmatrix} = \begin{pmatrix} \mathbf{I}-\mathbf{A}_{11} & -\mathbf{A}_{12} & \cdots & -\mathbf{A}_{1m} \\ -\mathbf{A}_{21} & \mathbf{I}-\mathbf{A}_{22} & \cdots & -\mathbf{A}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ -\mathbf{A}_{m1} & -\mathbf{A}_{m2} & \cdots & \mathbf{I}-\mathbf{A}_{mm} \end{pmatrix}^{-1} \begin{pmatrix} \mathbf{y}_{11} & \mathbf{y}_{12} & \cdots & \mathbf{y}_{1m} \\ \mathbf{y}_{21} & \mathbf{y}_{22} & \cdots & \mathbf{y}_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{y}_{m1} & \mathbf{y}_{m1} & \cdots & \mathbf{y}_{mm} \end{pmatrix} \tag{2}$$

where $\mathbf{x}_{ij}$ is the part of the total output of country i induced by the final demand of country j. The total output of country i is the sum of induced output by all countries, that is, $\mathbf{x}_i = \sum_j \mathbf{x}_{ij}$.

In the MRIO framework, the benchmark for quantifying emissions transfers between countries is the destination of final consumption (Arto et al., 2014; Davis and Caldeira, 2010; Muñoz and Steininger, 2010; Wiebe et al., 2012).[2] The emissions exports (EE) of country i to country j are emissions occurring within country i that are induced by the final demand of country j, which can be calculated by

$$E_{ij} = \mathbf{f}_i'\mathbf{x}_{ij} \tag{3}$$

where $\mathbf{f}_i$ is the emissions intensity vector of country i, that is, the direct emissions per unit of output in each sector. $\mathbf{f}_i'$ is the transposition of vector $\mathbf{f}_i$. The EE of country i to country j equal emissions imports (EI) of country j from country i.

The production-based emissions (PBE) of country i, E_i^P, are *domestic* emissions from industrial production within country i that are caused by output $\mathbf{x}_i$, whereas the consumption-based emissions (CBE) of country i, E_i^C, are *global* emissions from industrial production in all of the countries induced by the final demand of country i (Andrew et al.,

[1] The EEBT model extends traditional SRIO model by linking input–output tables of multiple countries and data of bilateral trade among them (Peters, 2008).

[2] The theoretical differences between emission transfers-/consumption-based emissions constructed by an MRIO model and those by an EEBT model were discussed in detail in Peters (2008) and Kanemoto et al. (2012).