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The global CO_2 emissions growth after international crisis and the role of international trade

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ABSTRACT

In this paper, we decompose the driving forces of global CO_2 emissions for the post-crisis era 2008–2011 from both production-based and consumption-based aspects. The results suggest that non-OECD economies have become the major drivers for the rapid global growth of CO_2 emissions after the crisis. More specifically, the increasing consumption and investment of non-OECD economies, as well as stagnation of their emission intensity reductions, have largely contributed to global growth of CO_2 emissions after 2009. On the contrary, OECD economies have a less carbon-intensive life style. Coupled with a decrease in investment and stagnation of consumption, the OECD economies have successfully reduced both their production-based and consumption-based emissions. However, the magnitude of their reduction is much lower than the increase led by non-OECD economies. In addition, both OECD and non-OECD economies have started to increase their purchases of intermediate and final products from non-OECD economies. Such changes of international trade caused an additional 673 Mt of global emissions from 2008 to 2011. The results of our decomposition provide both worries about and insights into future global climate change mitigation.

1. Introduction

Despite the global efforts toward climate change mitigation, the global CO_2 emissions from fossil-fuel combustion and cement production have been growing for decades. While previous crises, such as the oil crisis in 1973, the US savings and loan crisis in 1979, the collapse of the Former Soviet Union in 1990, and the Asian Financial Crisis in 1997, seriously slowed down the global growth of CO_2 emissions for several years, the impact of the 2008 financial crisis on emissions has been very short-lived (Peters et al., 2012). The global CO_2 emissions from fossil-fuel combustion only decreased by 1.90%, from 28.87 Gt (Gigatonnes) in 2008 to 28.32 Gt in 2009 and then sharply increased to 29.84 Gt in 2010 – a 5.36% increase – reaching the highest annual growth rate recorded since 2004. Ever since then, the emissions have continued to grow, reaching 32.30 Gt in 2014 (IEA, 2015). Such persistent growth and the potential for even higher future growth of CO_2 emissions has led to extensive worries about the target for limiting global warming to less than 2 °C (see also, Peters et al., 2013; Friedlingstein et al., 2014; Raupach et al., 2014; Rozenberg et al., 2015).

It is interesting to explore what drives the persistent growth of global CO_2 emissions, especially after the financial crisis. In this domain, structural decomposition analysis (SDA) based on input-output tables has been widely employed (see, e.g. Su and Ang, 2012; Wang et al., 2017 for explicit reviews). SDA can break down the changes in CO_2 emissions (or any other variable) over time into its determinants, such as energy intensity, production recipe, final demand structure, affluence, and population growth. Based on a single-region input-output database, for example, the literature reveals extensive use of SDA to identify the drivers behind the changes of CO_2 emissions of a range of countries/regions, such as the USA (Feng et al., 2015), China (Guan et al., 2008; Gui et al., 2014), Norway (Yamakawa and Peters, 2011), the Baltic States (Brizga et al., 2014), Taiwan (Chang et al., 2008), Spain (Cansino et al., 2016), and Brazil (Perobelli et al., 2015), etc.

In addition, there is a growing literature that explores the drivers behind global CO_2 emissions growth by introducing SDA on global multi-regional input-output tables (GMRIO): e.g. Baiocchi and Minx, 2010; Arto and Dietzenbacher, 2014; Owen et al., 2014; Malik and Lan, 2016; Jiang and Guan, 2016; Hoekstra et al., 2016. The SDA based on GMRIO can not only capture the drivers behind CO_2 emissions growth as single-regional IO table captures, such as emission intensity, production recipe, and final demand, but can also trace the changes in international trade patterns of both intermediate and final products (see

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also Wiedmann, 2009; Arto and Dietzenbacher, 2014; Malik and Lan, 2016). The international trade has not only caused a separation of production and consumption of products and embodied emissions (Peters et al., 2011) but has also led to significant net growth of global CO_2 emissions (Arto and Dietzenbacher, 2014; Hoekstra et al., 2016; Malik and Lan, 2016).

Despite such extensive literature, the growth of CO_2 emissions after the financial crisis in 2008–2009 is barely discussed. The current literature has either analyzed the annual growth of growth of CO_2 emissions before the crisis (see, e.g. Arto and Dietzenabcher, 2014; Hoekstra et al., 2016; Jiang and Guan, 2016), or analyzed the growth from 1990 to 2010 into several sub-periods (Malik and Lan, 2016; Malik et al., 2016). One pioneering work focusing on growth of CO_2 emissions after the financial crisis might be Peters et al. (2012). They estimated both the production-based and consumption-based CO_2 emissions after the global financial crisis, and found that, from the consumption-based aspect, economic activities, including large government investment and growing consumptions in emerging countries, were the major drivers for the rapid rebound of global CO_2 emissions from 2008 to 2010. From the production-based aspect, the researchers found that developed countries became temporarily less dependent on imports, hence slowing down the emissions embodied in international trade, and increased their production/territorial-based emissions.

In this study, we employed SDA based on a global inter-country input-output table that compiled by OECD and decomposed the global growth of CO_2 emissions, with a special focus on the post-crisis era 2008–2011. One of the advantages of the OECD-ICIO table over the other available databases[1] is that it distinguishes processing exports and normal productions for China and Mexico. Based on single-country input-output tables, the literatures have widely acknowledged that the production recipes and emission intensity of processing exports and normal productions are highly different in China (see, e.g. Dietzenbacher et al., 2012; Su et al., 2013; Jiang et al., 2016; Su and Thomson, 2016). By employing the OECD-ICIO table, our paper thus differs from the literatures that use either single-country input-output table or other GMRIO databases, in that it focuses on the impact of different trends of processing exports, with normal production in China and Mexico, on the global CO_2 emissions. In addition, we adopt Hoekstra et al.'s (2016) decomposition idea, and isolate the impact of the changing pattern of international trade on CO_2 emissions by income group in the decomposition process. As found by Peters et al. (2012), developed countries turned to support domestic activities, with the result that international trade experienced a serious drop during the 2008–2009 financial crisis. Besides, there are signs of a further geographic shift of trade to less-developed countries in South Asia and Africa after the financial crisis, to seek lower labor costs (see also, Lehmann, 2012; Stratfor, 2013; AfDB et al., 2014). It is also interesting to explore the extent to which such a change of international trade patterns influenced the global CO_2 emissions after the crisis.

Our article is organized as follows. In Section 2 we introduce our methods and data sources; in Section 3 we present our decompositions' results, at both aggregate and individual region/industry level. Some policy-related implications of our findings are discussed in Section 4.

2. Methodology and data

2.1. Global Multi-Regional Input-Output (GMRIO) framework and data source

The GMRIO has been widely accepted in tracing the CO_2 emissions footprint along global production chains (see Wiedmann (2009) and Minx et al. (2010) for reviews). Table 1 presents the GMRIO framework employed in this paper. The diagonal matrices of intermediate use give the intra-regional intermediate deliveries, that is, the elements z_{ij}^{rr} of matrix $\mathbf{Z}^{rr}$ give the intermediate deliveries from industry i in region r to industry j in region r, with i, j = 1,…,m, where m is the number of industries, and r = 1,…,n, where n is the number of regions. The non-diagonal matrices indicate inter-regional intermediate deliveries, that is, the elements z_{ij}^{rs} of matrix $\mathbf{Z}^{rs}$ indicate the deliveries of products from industry i (= 1,..,m) in region r (= 1,..,n) for input use in industry j (= 1,..,m) in region s (= 1,..,n; ‡ r). The matrices of final demand $\mathbf{F}^{rs}$ (r, s = 1,…,n) are divided into consumption $\mathbf{F}_{cons}^{rs}$(r, s = 1,…,n) (including consumption by households, governments, and non-government organizations), and investment $\mathbf{F}_{inv}^{rs}$ (r, = 1,…,n) (i.e. fixed capital formation). $\mathbf{X}^{r}$ (r = 1,…,n) represents the total output in region r (= 1,..,n).

According to Table 1, we have row equilibrium in matrix notation as follows:

$$\begin{bmatrix} \mathbf{Z}^{11} & \cdots & \mathbf{Z}^{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{Z}^{n1} & \cdots & \mathbf{Z}^{nn} \end{bmatrix} + \begin{bmatrix} \mathbf{F}^{11}+\cdots+\mathbf{F}^{1n} \\ \cdots \\ \mathbf{F}^{n1}+\cdots+\mathbf{F}^{nn} \end{bmatrix} = \begin{bmatrix} \mathbf{X}^{1} \\ \vdots \\ \mathbf{X}^{n} \end{bmatrix} \tag{1}$$

The direct input coefficients can then be obtained by normalizing the columns in the IO table; that is:

$$\mathbf{A}^{rs} = \mathbf{Z}^{rs}(\hat{\mathbf{X}}^{s})^{-1} \tag{2}$$

where r, s = 1,…,n, and $(\hat{\mathbf{X}}^{s})^{-1}$ denotes the inverse of a diagonal matrix of total outputs in region s.

Define the input coefficients matrix $\mathbf{A} = \begin{bmatrix} \mathbf{A}^{11} & \cdots & \mathbf{A}^{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{A}^{n1} & \cdots & \mathbf{A}^{nn} \end{bmatrix}$, where $\mathbf{A}^{rs}$ is the input coefficient from region r to region s. Then, the Leontief inverse can be calculated as $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$; that is, $\mathbf{B} = \begin{bmatrix} \mathbf{B}^{11} & \cdots & \mathbf{B}^{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{B}^{n1} & \cdots & \mathbf{B}^{nn} \end{bmatrix} = \begin{bmatrix} \mathbf{I} - \mathbf{A}^{11} & \cdots & -\mathbf{A}^{1n} \\ \vdots & \ddots & \vdots \\ -\mathbf{A}^{n1} & \cdots & \mathbf{I} - \mathbf{A}^{nn} \end{bmatrix}^{-1}$, where $\mathbf{I}$ is the identity matrix, with diagonal elements as ones and non-diagonal elements as zeros. The Leontief inverse describes both the direct and indirect linkages across regions and industries.

Using $\mathbf{Q}_{carbon}^{r}$ to denote the matrix of production-based CO_2 emissions by industry group in region r and $\mathbf{EI}^{r} = \mathbf{Q}_{carbon}^{r}(\hat{\mathbf{X}}^{r})^{-1}$ to denote the matrix of carbon emissions intensity per unit of output by industry group in region r, the CO_2 emissions generated along global production chains can be traced as follows:

$$\begin{bmatrix} \mathbf{Q}^{11} & \cdots & \mathbf{Q}^{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{Q}^{n1} & \cdots & \mathbf{Q}^{nn} \end{bmatrix} = \begin{bmatrix} \hat{\mathbf{EI}}^{1} & 0 & 0 \\ 0 & \cdots & 0 \\ 0 & 0 & \hat{\mathbf{EI}}^{n} \end{bmatrix} \begin{bmatrix} \mathbf{B}^{11} & \cdots & \mathbf{B}^{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{B}^{n1} & \cdots & \mathbf{B}^{nn} \end{bmatrix} \begin{bmatrix} \mathbf{F}^{11} & \cdots & \mathbf{F}^{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{F}^{n1} & \cdots & \mathbf{F}^{nn} \end{bmatrix} \tag{3}$$

where the elements Q_{io}^{rs} of matrix $\mathbf{Q}^{rs}$ indicate the production-based emissions of industry i (= 1,..,m) in region r (= 1,..,n) led by the final demand type o (= cons, inv) in region s (= 1,..,n). The summation of $\mathbf{Q}^{rs}$, $\sum_{s}\mathbf{Q}^{rs}$ and $\sum_{r}\mathbf{Q}^{rs}$ will give the production-based emissions of region r and consumption-based emissions of region s, respectively.

Recent years have seen a proliferation of GMRIO tables that are available to analyze the global energy use and emissions issues, such as Eora, WIOD, EXIOBASE, OECD-ICIO, GTAP-MRIO (see Tukker and Dietzenbacher (2013) for a review). Despite difference recipes to construct the data, the insights from different GMRIO tables are similar. Moran and Wood (2014), for example, compared the results of consumption-based carbon accounts based on four GMRIOs: Eora, WIOD, EXIOBASE, and the GTAP-based OpenEU databases. They found that carbon footprint results for most major economies disagree by < 10% between GMRIOs, and the results for the temporal change across models appear to agree. As mentioned, our GMRIO database is an inter-country input-output database compiled by OECD. It covers 62 regions (34 OECD regions and 28 non-OECD regions) and 34 industries, and

[1] Some other popular GMRIO databases include Eora, EXIOBASE, OECD-ICIO, GTAP-MRIO. Please refer to Tukker and Dietzenbacher (2013) for an explicit review.