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Structure decomposition analysis of embodied carbon from transition economies

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ABSTRACT

In this study, we created a model based on input-output and carbon dioxide emissions data from WIOD (World Input-Output Database) to investigate the role of transition economies and developed economies in global carbon emissions during 1995–2014. The results show that for transition economies, the carbon emissions calculated based on the production side are higher than those estimated by the consumer side, indicating that the transition economies shoulder more indirect carbon emissions responsibility than developed countries. Subsequent analysis has found that China exports carbon to developed economies, while imports carbon from other transition economies and the rest of world. Finally, the structural decomposition analysis (SDA) shows that the change of export carbon emissions of transition markets during 1995–2014 is mainly affected by the high-carbon sectors and the export scale has the most significant impact on export carbon emissions.

1. Introduction

The current goal of economic development in northeast Asia has shifted from pure pursuit of GDP growth to sustainable development; the proportion of tertiary industry is also increasing every year. The industrial sector still produces large amounts of harmful by-products, causing serious pollution and ecological risk (Choi et al., 2013). For example, in 2011, China suffered from continual droughts and floods, resulting in heavy casualties and economic losses. Consequently, environmental degradation, such as land degradation, farmland abandonment (Xie et al., 2013), etc., has become increasingly prominent with the increase of regional economic aggregate (Zhang and Choi, 2014). The extreme climate change caused by carbon emissions or carbon dioxide emissions has become an important global environmental problem (Song et al., 2015). Moreover, considerable pressure has been brought to reduce CO_2 emissions in many industries, not only in developed countries but also in developing countries. Hence, how to maintain the national competitive advantage in the international division of labor under the premise of protecting the environment is an urgent issue for all countries in the region. As the largest and most influential economic entity in this region, China's economic transformation is crucial to the development for itself and the neighbors. Since 2007, China has been the largest contributor of CO_2 emissions to the world. Scale-oriented economic development in China has given rise to the problems associated with high energy consumption and serious environmental pollution. At the same time, its environmental responsibilities are one of the themes discussed from the past to the current. In recent years, the mitigation of climate change in China has caused growing concern. In addition, the transition economies include most of the developing countries in the world. According to the classification of Goldman Sachs report in 2014, BRIC (Brazil, Russia, India, China) was considered to be the nations with the most investment value and development potential. Therefore, research on the BRIC countries represented by China has unique theoretical and practical significance not only to northeast Asia but also to the whole world.

Over the last two decades, from Kyoto Protocol to Copenhagen Accord, then to Paris Agreement, the issue has frequently triggered many debates on the right to development and the responsibility for reducing emissions in global governance. While in the sustainable development goals (SDGs) set by the United Nations in 2016, Climate Action (Goal 13) has been highlighted as one of the seventeen SDGs and set up with all the detail target, including reducing carbon emissions from all over the world.

In the era of globalization, how to divide the responsibilities for

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different economies in corresponding actions such as reduce carbon emission is one particular topic in the discussion of various types of global governance. In fact, there has been a long history on such topic in the academic field for the global carbon issue. Near thirty years ago, researchers have doubted the unequal distribution of carbon emissions responsibility due to the worldwide trade. As a result, two concepts emerged: embodied carbon and carbon footprint. However, due to the large-scale use of the input-output framework in economics, more studies begin to employ the input-output table combined with structure decomposition analysis (SDA) proposed by Grossman, analyzing the carbon and embodied carbon emission of each country in the international trade. In the past decade, transition economies like BRIC countries were given more priority in the world economy and international trade, accompanied by an increase in carbon emissions, which makes these countries be thrown into passivity in the carbon emission consultation of global climate governance.

However, when facing the challenge brought by global climate change, should the transition economies on the production side or the energy supply side of the global value chain bear the principal responsibility for reducing emissions? In the new century's global trade, what is the change and shift of embodied carbon? Correspondingly, what policies need to be taken to counter the unique situation between the transition economies represented by the BRIC countries and the developed economies represented by the OECD? This article discusses such a well-studied topic in the new period. Our study, therefore, contributes to the literature in the following perspectives. First: we construct an MRIO model from the perspective of global trade, not only examining the embodied carbon emissions within the BRIC countries but also studying the embodied carbon emissions between BRIC and the OECD. Second, most of the previous studies use data until 2011. We update the time period to 2014 with the 2016 version of WIOD. Last, when decomposing the driving forces of changes in embodied carbon emissions, we have aggregated sectors into high-carbon and low-carbon sector and examined their impact on the final change of embodied carbon emission.

The rest of this paper is arranged as follows: Section 2 reviews current studies on this issue. Section 3 describes the model and data set. Section 4 presents the empirical results and makes a distinction between the technical levels of energy consumption in SDA, and focuses on the impact of the technological progress. Section 5 discusses policy implication & concludes.

2. Literature review: trace the carbon

Embodied carbon is the amount of carbon (CO_2 or CO_2 emission) to produce a material, which can date to one meeting in 1974 of International Federation of Institutes for Advanced Study where the embodied energy, the sum of all the energy required to produce any goods or services, considered as if that energy was incorporated or 'embodied' in the product itself, is proposed (Chen and Chen, 2011; Jiang and Murphy, 2008; Peters, 2010; Sato, 2014).

2.1. Input-Output (IO) Framework and SDA

The IO model is widely confirmed as an effective tool to evaluate the number of resources or pollution embedded in goods and services from a micro perspective (Choi et al., 2015; Leontief, 1974). According to its applied area, IO can be separated to Single-Region Input-Output Model (SRIO Model) (Shuzhong and Chen, 2010; Wilting et al., 2009), Bilateral Trade Input-Output Model (BTIO) (Nakano et al., 2009) and Multi-Region Input-Output Model (MRIO Model) (Sato, 2014). Comparing to the former two, MRIO extends one country's scope and form a worldwide IO relationship involving multiple industries in many countries (or regions) based on the IO tables of various nations to internalize the import and export relations of different production sectors in multiple countries (Liu and Wang, 2009; Xie et al., 2014; Xie and Wang, 2015). It has gradually become the mainstream method for studying the embodied carbon emission in the international trade in recent years due to its relative accuracy when estimating the impact of global trade on carbon emissions in the world or some regions(Ahmad and Wyckoff, 2003; Peters and Solli, 2010; Rodrigues et al., 2011).

Structure decomposition analysis (SDA) (Grossman and Krueger, 2000) is one powerful tool to decompose the driving forces in the embodied carbon research (Song et al., 2011; Xia et al., 2015; Zhang and Qi, 2010). The scale of embodied carbon emission is dependent on the scale of export, product structure of export and carbon emission per unit production, i.e., scale effect, composition effect and technology effect. Among these, we want to focus on technology effect. As we all know, technological progress has contributed a lot to the global economic development. However, the technology effect in SDA is not clear. Sometimes the technology effect is negative, indicating that technological progress is environmentally friendly, that is, green technology (Qiu and Qing-Qing, 2012; Zhao et al., 2014a). Conversely, if technological progress is non-environmentally friendly, the technical effect is positive and leads to an increase of the carbon embodied in the export. Therefore, for BRIC countries with different technological accumulations and development paths (Zhao et al., 2014b), it is essential to examine the technology effect for different economies in different periods to provide guidance for later policy recommendations. In general, SDA can help us to avoid the errors caused by important variables missing and decomposition residual (Copeland and Taylor, 2013). Until now, there are dozens of studies of SDA on the embodied carbon. And the research objects include China (Choi et al., 2012; Song et al., 2013; Zhang and Choi, 2013), Taiwan (Chia-Yon Chen, 1990; Yih and Chang, 1998), Japan (Yabe, 2004), United States (Rose and Chen, 2005), etc.

2.2. Research of embodied carbon

Since its advent, plenty researchers have employed the MRIO model and SDA on the embodied carbon emission in the international trade for all over the world. In the earlier period, studies mostly focused on the developed countries or areas, like the United States and Europe (Lenzen, 1998; Mongelli et al., 2006; Peters and Hertwich, 2006; Schaeffer and Sa, 1996). For example, Wyckoff et al. calculated the embodied carbon emission of the imported goods of the six largest OECD countries and examined the role played by the international agreement on greenhouse gas emissions (Wyckoff and Roop, 1994). In recent years, with the economic development of transition countries, like BRIC, research priorities also gradually shift (Mukhopadhyay and Forssell, 2005; Pan et al., 2015; Su and Ang, 2014; Tolmasquim and Machado, 2003). Pan calculated the embodied carbon in export and import of China and discussed the responsibility China should bear (Pan et al., 2008). Shui examines the influence of US-China trade on national and global emissions of carbon dioxide (Shui and Harriss, 2006). After China became the world's second-largest economy, research on China's embodied carbon has become a hot topic (Arce et al., 2016; Liu et al., 2017; Ning et al., 2016; Su and Thomson, 2016; Xie et al., 2015). Furthermore, some scholars have begun to study the carbon flow within China to guide sector transfer (Wu et al., 2015; Zhong et al., 2014).

2.3. Research summary

By combing the relevant literature in this field, we found that the researchers always focused on the high-growth economies in their observation period and the overwhelming consensus is usually that a rapidly growing country tends to be a net exporter while developed countries are mostly net importers in the global trade, i.e., transition economies have greatly increased their energy consumption, and carbon dioxide emissions as their economic and trade surpluses have increased and have assumed more responsibility for the carbon consumption in developed countries. Also, the investigation focused on the trade between target economy and developed countries while lacking