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China's inter-regional spillover of carbon emissions and domestic supply chains

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HIGHLIGHTS

- An IO model is used to measure China's inter-regional spillover of CO_2 emissions.
- We focus on the relationship between CO_2 emissions and domestic supply chains.
- New indexes for identifying the consumer–producer responsibility are proposed.
- A region's emission depends on its position and participation level in supply chains.

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ABSTRACT

In this study, we apply the inter-regional input–output model to explain the relationship between China's inter-regional spillover of CO_2 emissions and domestic supply chains for 2002 and 2007. Based on this model, we propose alternative indicators such as the trade in CO_2 emissions, CO_2 emissions in trade and the regional trade balances of CO_2 emissions. Our results do not only reveal the nature and significance of inter-regional environmental spillover within China's domestic regions but also demonstrate how CO_2 emissions are created and distributed across regions via domestic and global production networks. Results show that a region's CO_2 emissions depend on its intra-regional production technology, energy use efficiency, as well as its position and participation degree in domestic and global supply chains.

1. Introduction

China has exhibited a high rate of economic growth during the last three decades. Its economic scale in real terms expanded almost 2.6-fold from 1987 to 1997 and jumped 2.6-fold again from 1997 to 2007.[1] In 2010, China's nominal GDP surpassed that of Japan, becoming the second largest economy in the world.[2] The most important factors that enabled China to achieve such high economic growth are generally considered to be its domestic market-oriented economic reforms, ongoing urbanization, industrialization, increasing complexity of domestic supply chains, and active participation in global supply chains. The interactions between these forces provide a powerful engine to support the so-called "China Miracle."

However, China has paid a great environmental cost during the period of its rapid economic growth, such as pollution (air, water, ground, and noise) induced health problems and decreasing people's quality of life as well as CO_2 emissions, which are the primary source of greenhouse gases. At present, China is one of the countries with the largest area exposed to acid rain (Xue and Zhao 2012). In addition, China's emissions of organic wastewater, sulfur dioxide, and various greenhouse gases are the highest in the world. China also leads in CO_2 emission intensity (CO_2 emissions per GDP at constant prices) with a rate more than 6 times larger than that of the OECD countries in 2008.[3] Therefore, China has been referred to as the "Black Cat" rather than "White Cat", when applying the famous pragmatic theory of "Black Cat and White Cat" made by the former Chinese leader Deng Xiaoping (Hu, 2011).

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[1] Based on the IMF statistics, China's GDP values at constant prices (1990 base) are 1.609 trillion RMB for 1987, 4.149 trillion RMB for 1997, and 10.691 trillion RMB for 2007.

[2] Based on the IMF statistics, China and Japan's GDP values at current prices in 2010 are respectively 5930.393 and 5495.387 billion US$.

[3] OECD/IEA data: CO_2 emissions from fuel combustion highlights 2010.

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On the other hand, Chinese government has made great efforts toward energy saving and slowing down of the increasing rate of CO_2 emissions in response to global climate change. Since 1998, China has enacted a variety of laws and regulations to foster a low carbon economy (Xue and Zhao 2012). During the period of the 11th Five Year Plan (2006–2010), China's energy-use intensity showed a decline by 19.1%, fulfilling the Plan's basic requirement (Industrial Efficiency Policy Database (IEPD), 2012). As Garnaut (2008) noted, China has put in considerable efforts in dealing with climate change, but little is known because China did not fully integrate itself into the international system. In 2009, China has committed to reduce its carbon emissions per unit of GDP by 40–45% by the end of 2020, relative to the 2005 level (Su, 2010) at the Copenhagen Conference (COP 15). To achieve this goal, governments at different levels, diverse sectors, major industries, and companies must adopt a series of relevant policies and stringent regulations.

To analyze China's environmental problems, low carbon and sustainable economic development, as well as its green growth strategy, a number of studies have been conducted using different approaches, such as approaches from low-carbon related economic growth and development theories (Arayama and Miyanaga, 1996; Liu and Diamond, 2005; Zhang, 2009; Xue and Zhu; 2012, Wang et al., 2012A); low-carbon econometrical models (China AIM Project Team, 1996; Jiang et al., 2000); viewpoints of low-carbon international economics (Garnaut, 2008; McKibbin and Wilcoxen, 2008); approaches of low-carbon international trade theory (Ahmad and Wyckoff, 2003; Wang and Watson, 2007; Pan et al., 2008; Nakano et al., 2009) as well as the perspectives from tariff theory, domestic finance and taxation (Wei et al., 2010A), low-carbon business models (Independent Evaluation Group (IEG), 2010), and so on.[4] However, most of the above approaches treat China as a whole rather than focusing on its domestic regions. Because of the great variation in economic size, industrial structure, energy-use efficiency, and overseas dependency across regions within China, there is a need for more regional level analyses to improve the understanding of production and distribution of CO_2 emissions. In addition, regional level analyses provide important information and reference points for local governments, who are the actual executors of the central government's environmental policies.

Since the recent improvement of China's provincial environment related statistics, regional level studies on CO_2 emissions have been carried out. For example, Liang et al. (2007) employed the multi-regional Input–Output (I/O) model to measure China's regional energy requirements and CO_2 emissions for 2010 and 2020. Their empirical results demonstrated that by 2020, improvement in energy end-use efficiency for each region could generate intra-regional energy savings; population growth in one region will not only significantly affect that region's energy requirements but also increase other regions' energy-use. Feng et al. (2009) studied how population, affluence, and emission intensity have contributed to the growth of CO_2 emissions in five regions of China. Their results concluded that China must ensure that people's lifestyles are changing to more sustainable ways of living. By applying index decomposition technique, Liu et al. (2010) analyzed China's carbon emission changes during 1997–2007 for 30 domestic provinces. They identified the most important regions that cause higher CO_2 emissions from end-use energy consumption and emphasized that the decline in energy intensity has the greatest impact on CO_2 emissions. Meng et al. (2011) analyzed the characteristics of China's regional CO_2 emissions, the effects of economic growth and energy intensity using panel data from 1997 to 2009. Wang and Shi (2012) used the I/O-based carbon footprint model to analyze China's provincial carbon footprint and inter-provincial transfer. In addition, at more detailed regional (city) level, some valuable researches have attracted great attention. For example, Shao et al. (2011) used time series data to estimate Shanghai's energy-related industrial CO_2 emissions (ICE) and identify the ICE's determinants based on an ICE-STIRPAT (stochastic impacts by regression on population, affluence and technology) model. Their results showed that energy efficiency exerts a more efficient control over ICE than R&D (Research and Development) intensity; the ICE intensity is regulated more easily than ICE scale. Wang et al. (2012B) also empirically studied the influences of urbanization level, economic level, industry structure, energy intensity and R&D output on CO_2 emissions in Beijing using improved STIRPAT model. Their results showed that urbanization level is the main driving factor of CO_2 emissions for Beijing, and tertiary industry proportion is the main inhibiting factor.

Most studies undertaken at the regional level of China focus on measuring energy and CO_2 emission intensities, influencing factors in CO_2 emissions change, and the embodied CO_2 emission in trade. Our study differs in the way in which we focus on clarifying the relationship between China's inter-regional spillover of CO_2 emissions and domestic supply chains. The inter-regional spillover of CO_2 emissions and its changing pattern depend on a combination of factors. These factors include not only regional economic scales, regional industry structure, scales of energy-use and CO_2 emissions, and efficiency of energy-use, but also a region's position and participation level in domestic and global supply chains. To explain the CO_2 emissions spillover from the perspective of supply chains or inter-regional production networks, we apply both the traditional I/O-based measure, "CO_2 emissions in trade" (CEiT), and the newly developed measure, "trade in CO_2 emissions" (TiCE) to China's interregional frameworks (eight regions) for 2002 and 2007.

The CEiT measures embodied CO_2 emissions in trade (international trade or interregional trade in goods and services). This measure is based on a single national or regional I/O table in which the international or inter-regional trade in intermediate and final goods and services is treated as exogenous variables. This indicator is easy to be measured with limited data (i.e. only national or regional I/O table is available) and it is able to capture the embodied emissions in goods and services along the whole domestic supply chain. On the other hand, the TiCE measures a region's CO_2 emissions caused by other regions' total final demand through interregional supply chains within China. This indicator follows the recently proposed concept of "Trade in Value-Added" (TiVA) (Johnson and Noguera, 2011) based on an international I/O framework in which the international trade in intermediate goods and services is treated as endogenous variables. Meng et al. (2012A) apply the TiVA concept to Chinese regional economies to analyze China's domestic value chains. In the current paper, we follow Meng et al. (2012A) and apply the TiCE concept to China's domestic supply chains. The TiCE indicator can avoid double counting in measuring bilateral trade balance and associated CO_2 emissions across regions since the intermediate products may flow through region's borders multiple times to produce final products. Although both CEiT and TiCE are based on the I/O model, they focus on the induced CO_2 emissions from different viewpoints and treat interregional trade in intermediate goods and services in different ways.[5]

The rest of this study is organized as follows. Section 2 explains how we use the I/O model to measure the inter-regional spillover

[4] For the comprehensive introduction on China-related low-carbon analyses, one can refer to Wei et al. (2010B), and Xue and Zhu (2012).

[5] For more detailed explanation about the relationship and difference between CEiT and TiCE, one can refer to Stehrer (2012) and Meng et al. (2012B).