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Provincial responsibility for carbon emissions in China under different principles

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HIGHLIGHTS

- We link regional environmental responsibility to seven benefit principles.
- We analyze provincial responsibility for carbon emissions in China.
- We also report provincial carbon multipliers under different principles.
- We compare the seven principles from the regional perspective.
- Policy implications of the study are discussed.

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ABSTRACT

By applying a multi-regional input–output model, the study compares the provincial responsibility for carbon emissions and provincial carbon multipliers in China under seven responsibility-allocating principles, including three basic principles, the production, income and consumption principles, and four shared responsibility principles, the income-weighted, consumption weighted, comprehensive, and weighted comprehensive principles. Empirical results indicate that carbon multipliers of provinces under these principles are significantly different from one another. The carbon multipliers of provinces with higher ratios of carbon intensive sectors in their outputs are also larger. At the same time, the carbon multipliers of the same sector in the provinces are significantly different from one another. Changing the principle causes significant changes in the responsibility for carbon emissions of some provinces, but only slight changes in the responsibilities of some other provinces. However, the responsibilities of provinces with large economic sizes (output) are always the largest, whereas provinces with the smallest economic sizes are always the smallest regardless of the principles. Further, this study proposes a series of regional policies for carbon mitigation according to provincial carbon multipliers and responsibility allocation features under the different principles.

1. Introduction

The National Development and Reform Commission of China released *The National Plan for Addressing Climate Change* (2014–2020) on September 2014. Through this program, the government pledged to improve the regional policies for addressing climate change. Mainland China has 31 provinces that have close economic linkages with one another. As such, the implementation of policies by one province affects the carbon emissions within that area and those in other regions. The government must therefore appropriately evaluate the regional responsibility for carbon emissions (RCE) to design rational regional polices for addressing climate change.

Environmental responsibility (ER) allocation has been discussed in the literature. Zhang (2013) finds that ER can be measured using at least seven principles, namely, production, income, consumption, income-weighted, consumption-weighted, comprehensive, and weighted comprehensive principles. The production principle, also known as territorial principle (Eder and Narodoslawsky, 1999), states that the agent must bear its ER in accordance with the emissions that are directly caused by its production activities. The production principle is the most popular principle of ER that is embodied in various environmental statistical systems worldwide (Gallego and Lenzen, 2005). However, the production principle fails to consider the economic linkages

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among agents and the indirect environmental effect of each agent.

Income and consumption principles can be used to calculate the indirect environmental effect of agents. Proposed by Lenzen and Murray (2010), Marques et al. (2012), and Marques et al. (2013), the income principle suggests that the agent must bear its ER according to the downstream emissions that are "activated" by its income. By contrast, the consumption principle suggests that the agent must bear its ER according to the upstream environmental effect that is caused by its consumption (Munksgaard and Pedersen, 2001). The consumption principle has been widely used in studies that have audited carbon emissions that are embodied in inter-regional trade (e.g., Wyckoff and Roop, 1994; Shui and Harriss, 2006; Andrew and Forgie, 2008; Tunç et al., 2007; Li and Hewitt, 2008).

Production, income, and consumption principles can be regarded as the basic principles for allocating ER; these principles are combined and extended by four other principles, which are also called the shared responsibility principles (Zhang, 2013). The income- and consumption-weighted principles were proposed by Gallego and Lenzen (2005) and were developed by Lenzen et al. (2007) and Lenzen (2008). Income-weighted principle implies that both the product supplier (income receiver) and the buyers, who will receive the income from product sales and consume the products, respectively, share the downstream environmental effect of the supplied product. Consumption-weighted principle suggests that the consumers and product suppliers share the upstream environmental effect of the consumed product. Rodrigues et al. (2006) propose the comprehensive principle, which states that the appropriate ER of an agent is the average of its income and consumption ER. Similarly, the weighted comprehensive principle defines the ER of an agent as the average of its income- and consumption-weighted ER. The accounting methods of the shared responsibility principles have also been developed in previous studies (Ferng, 2003; Bastianoni et al., 2004; Gallego and Lenzen, 2005; Rodrigues et al., 2006; Lenzen et al., 2007).

Some studies have empirically analyzed the differences among the various principles for allocating Andrew and Forgie (2008) compare the production-, consumption-, and consumption-weighted RCE of New Zealand. Peters (2008) examines the national RCE using the production and consumption principles. Zhang (2013) analyzes the sectoral RCE in China. The findings of these studies indicate that the above principles can significantly affect ER at the sectoral, national, and international levels.

Many studies on the regional responsibilities in China have been published over the recent years. Most of these studies (Liang et al., 2007; Meng et al. 2011; Guo et al., 2012; Meng et al. 2013; Shi et al., 2012; Xiao et al., 2014) have analyzed the characteristics and transfer of regional and inter-regional carbon emissions as well as discussed the regional responsibilities according to the production and consumption principles. Several studies (Xu and Zhang, 2013; Zhao and Hao, 2013) have empirically analyzed the regional responsibilities using the shared responsibility principle. Zhang (2014) compares the regional responsibilities for energy consumption in China under all seven principles for ER allocation, but fails to analyze the regional RCE.

We aim to contribute to the literature in two ways. First, we empirically analyze the provincial RCE that is related to both the regional upstream and downstream linkages by combining the seven principles of Zhang (2013, 2014) with the latest multi-regional input–output (MRIO) tables for China in 2007 and 2010. To our knowledge, few studies have analyzed the regional RCE that is related to downstream economic linkage by using the income principle and have failed to discuss the income-weighted, comprehensive and weighted comprehensive principles. Second, we summarize the linkage and differences of several principles from the regional perspective. The rest of this study is divided into four sections. The second section describes the methods for accounting the provincial RCE under various principles, the third section reports and discusses the empirical results, and the final section concludes the study.

2. Methods

Regional RCE accounting focuses on the evaluation of the inter-regional interaction on carbon emissions. Two approaches can be used to solve such problem (Wiedmann et al., 2007; Peters, 2008). The first one considers the emissions that are embodied in the bilateral trade approach according to the single–regional input–output model, while the second approach is the environmental extended MRIO model. However, only the MRIO model considers the spillover and feedback effects from inter-regional trade on emissions (Peters, 2007; Turner et al., 2007; Wiedmann et al., 2007). Therefore, we adopt the MRIO model to build the regional RCE accounting system in this study.

For convenience, we assume that a closed economy consists of k regions and n sectors in each region. Based on previous studies (such as Turner et al., 2007 and Miller and Blair, 2009), we can use an environmental extended MRIO table to describe the closed economy, as shown by Table 1. The variables in Table 1 are defined as follows: $\mathbf{x^r}$ is the output vector of region r, and its element x_j^rrepresents the output of sector j of region r; $\mathbf{y^{rs}}$ is the final demand vector from region r to *region s*, and its element y_i^{rs} represents the final demand of *region s* supplied by sector i of region r; $\mathbf{Z^{rs}}$ is the intermediate use matrix from region r to *region s*, and its element Z_{ij}^{rs} represents the intermediate use supplied by sector i of region r to sector j of *region s*; $\mathbf{q^r}$ is the carbon emission vector or region r and its element q_j^rrepresents the direct carbon emissions of sector i of region r; and finally, $\mathbf{v^r}$ is the value added vector or region r, and its element v_j^r represents the value added of sector i of region r.

From the perspective of supply, the total output of a region is divided into two parts, namely, intermediate use and final use (demand). Part of the intermediate use is the input of the region

Table 1
Scheme representation of environmental extended MRIO table.

		Intermediate use			Final use			Total output
		Region 1	⋯	Region k	Region 1	⋯	Region k	
Intermediate input	Region 1	$\mathbf{Z^{11}}$	⋯	$\mathbf{Z^{1k}}$	$\mathbf{y^{11}}$	⋯	$\mathbf{y^{1k}}$	$\mathbf{x^1}$
	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋮
	Region k	$\mathbf{Z^{k1}}$	⋯	$\mathbf{Z^{k1}}$	$\mathbf{y^{k1}}$	⋯	$\mathbf{y^{kk}}$	$\mathbf{x^k}$
Value added		$(\mathbf{v^1})^T$	⋯	$(\mathbf{v^k})^T$				
Total input		$(\mathbf{x^1})^T$	⋯	$(\mathbf{x^k})^T$				
Emissions		$(\mathbf{q^1})^T$	⋯	$(\mathbf{q^k})^T$				