Journal of Cleaner Production 194 (2018) 12–22

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Comparative analysis of regional carbon emissions accounting methods in China: Production-based *versus* consumption-based principles

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ARTICLE INFO

Article history:
Received 29 November 2017
Received in revised form
23 April 2018
Accepted 2 May 2018
Available online 7 May 2018

Keywords:
CO_2 emissions embodied
Input-output analysis
Accounting principle

ABSTRACT

The analysis of the characteristics of carbon flows between regions is critical for China to deploy effective regional mitigation strategies. Different accounting principles exert a significant influence on China's regional carbon emissions, especially the fairness of carbon emission reduction targets, and the responsibility for reducing emissions. An input-output model was established, based on the input-output data of 2007 and 2012, to evaluate the characteristics of regional carbon flow and the change in carbon emission from different industries, and to analyse the changes in carbon emissions under production-based, and consumption-based, principles in 30 provinces. The results show that the carbon emissions in each region and sector are different: from the eastern region to the western region they show a downward trend, and the embodied carbon flow accounts for a large proportion of the total. Secondary industries are a major contributor to carbon emissions and there is a signifiant influence exerted on the results of carbon emission accounting in various provinces of China under different accounting principles. Therefore, to meet national emission reduction targets, the provinces need to pay considerable attention to the choice of accounting principles and achieve the principle of fairness and impartiality. It will provide a reference for the future division of responsibility for carbon emissions in provinces of China.

1. Introduction

Since the United Nations Framework Convention on Climate Change (UNFCCC) has been established in 1992 along with the Kyoto Protocol (KP), the supplementary provisions were signed in 1997; global climate change has raised widespread attention. In 2012, the Doha Climate Change Conference had come to an agreement that by 2020, Annex I Parties should reduce their overall emissions by at least 18 percent relative to those in 1990. The Intergovernmental Panel on Climate Change (IPCC) released the first report of fifth assessment in September 2013, which further raised confidence that global warming was being triggered by human activities.

Despite its lack of the specific emissions reduction responsibility, China has adopted a positive response to climate change with a range of emissions reduction obligations, including a 17% drop in its carbon intensity by 2015 compared to 2010 levels, and its carbon intensity will be 40–45% lower by 2020 than in 2005 (Cong and Wei, 2010; Lewis, 2011). In 2015, China announced “Intensify Actions to Address Climate Change-China's National Autonomous Contribution” at the climate conference in Paris, promising to reduce the intensity of CO_2 emissions by 60%–65% of the 2005 level by 2030. According to “The 13th Five-Year Plan for National Economic and Social Development”, by 2020, CO_2 emissions will drop 18% from 2015, and the total carbon emissions will be controlled. Although these goals are promoted at the national level, it needs to be coordinated by different departments in different regions of the country.

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https://doi.org/10.1016/j.jclepro.2018.05.018
0959-6526/

China's deployment of regional mitigation is particularly complex. Firstly, China has a vast land area, in which each region's economic situations, such as: industrial structure, resource endowment and so on are significantly different. Therefore, setting uniform emissions reduction targets is unfair for all regions. Secondly, China is a fast-growing country, of which the economic growth rate remains the top position in most states. Thirdly, China emphasises that each region should bring its comparative advantages into play to narrow regional development disparities at a gradual rate. To achieve efficient and coordinated development in different regions, China implemented many strategies such as developing her western regions, revitalising the north-eastern industrial base, promoting the rise in central regional growth, as well as giving priority to the development of the eastern region. Therefore, the deployment of regional emissions reductions should take regional characteristics and development strategies into account to determine their emissions responsibilities (Feng et al., 2014). It has to be mentioned that developed regions effectively reduce emissions by cutting the number of high-energy consuming industries, mainly capital-intensive industries, by transferring them to developing regions, causing inequality in the distribution of carbon emissions from manufacturing industries (Chen et al., 2017; Xia and Tang, 2017) In addition, most of the research on CO_2 emissions in China is concentrated at provincial level (Bi et al., 2011; Feng et al., 2015; Liu et al., 2012, 2017, 2011; Mortimer and Grant, 2008; Shao et al., 2014; Wang et al., 2012): however, far fewer studies cover all regions in China, which is crucial for the allocation of regional mitigation responsibility.

There are two methods for estimating carbon emissions: production-based principle and consumption-based principle (Liu and Fan, 2017; Senbel et al., 2003; Shigeto et al., 2012; Tian et al., 2014; Wang et al., 2018; Wei et al., 2012). CO_2 emissions based on production accounting refer to emissions from domestic production, including exports (Peters, 2008). This method calculates the CO_2 emissions based on production, regardless of where the product is used, or who accounts for the final demand (Atkinson et al., 2011; Steininger et al., 2014). The production principle is extensively used in global climate change agreements. In contrast, under the consumption-based accounting method, all emissions from production are allocated to the final consumer of the product (Feng et al., 2014; Wiedmann et al., 2011). According to this method, emissions from imported products are distributed to their area(s) of origin. Thus, consumption-based emissions include imports but exclude exports, while production-based emissions provide for exports and ban imports (Peters and Hertwich, 2008a,b). There are several studies which have illustrated the advantages of consumption-based accounting after comparing the two approaches (Girod et al., 2014; Peters and Hertwich, 2008a,b; Jakob et al., 2014; Steininger et al., 2015). For instance, Liu and Fan (2017) hold the view that the production-based CO_2 emissions accounting system can easily lead to a "carbon leakage" issue. The accounting of consumption-based carbon emissions and carbon emissions embodied in international trade has received considerable research attention. Steininger et al. (2014) argue that a consumption-based principle is beneficial to cost-efficiency and justice: Guan et al. (2014) also concludes that this method can be helpful to global air pollution mitigation. Also, Larsen and Hertwich (2009) point out that it can provide useful indicators for assessing local emission reductions. Peters and Hertwich (2008a,b) also think that it has some advantages, such as increasing mitigation options, addressing carbon leakage, as well as promoting comparative environmental advantages.

Are a region's emissions calculated based on production or consumption? Which mitigation responsibility allocation method is the fairest? Whether, or not, to allow a part to coordinate economic development with emissions reduction? Whether the impact of different accounting principles on regional emissions mitigation responsibility has become more, or less, visible? How to reduce the adverse effects on the region when accounting principles have changed?

Nowadays in China, most multi-regional studies are conducted based on the production principle; however, the emissions from one area may not only meet their own consumption needs due to interregional trade. In other words, consumption in other regions may promote emission production of the region. Thus, considering this reasonable concern, the definition of emissions responsibilities for each region is more complicated. In fact, fair consideration has attracted wide attention internationally, which led to a range of studies on consumption-based principles as well as interregional carbon transfer (Homma et al., 2012; Mózner, 2013; Steininger et al., 2014; Wiedmann et al., 2011). While in China, research into the transfer of emissions at the regional level is still relatively limited and needs to be improved. For example, Liang et al. (2007) and Su and Ang (2014) both use data from 1997, however, in the intervening years, China's economic situation underwent significant change: due to the unique regional characteristics of China, that is, the economy of each province's industrial structure, resource endowment, and energy technology are different, it is necessary to calculate the difference of each province by using various accounting principles. It has an essential role in future emissions allocation, however, the difference is caused by the flow of embodied emissions. As a result, the regional carbon transfer in China is calculated in 2007 and 2012 with single input-output data. Here we analyse the trend in embodied carbon emissions in China from provinces, sectors, and give a comprehensive reviewthereof, then calculate the change in carbon emissions and the intensity of carbon emissions in different provinces. The research can help to analyse the evolution of carbon emissions in different provinces from the perspective of the whole country, especially in recent years when China's rapid growth in carbon emissions from the provinces has resulted in reduced levels of responsibility. On the other hand, this research provides a valuable reference for each province to set up fair emission reduction targets. The rest of this article is structured as follows: in Section 2, the models are explained, the data are presented in Section 3, Section 4 includes main results and discussion, and the conclusions and future research priorities are presented in Section 5.

2. Methodology

In this study, we use input-output (IOA) analysis to calculate the carbon emissions from the production-based and consumer-based respectively. IO was first analysed by Professor Wassily Leontief in the late 1930s (Miller and Blair, 2009). The IO method includes the establishment of a mosaic input-output table and the corresponding linear algebraic equations. IO tables and equations reflect the flow of currency between different sectors of the economy, thus revealing the distribution of sectoral output and the composition of sectoral inputs. IO analysis is a useful tool for describing the interaction between sectors and regions so that emissions from various economic activities can be explained from different perspectives. IOA is increasingly used in the study of carbon footprint calculations (Wiedmann et al., 2011; Wang and Yang, 2016). Liu et al. (2017) argue that IOA is used for embodied energy accounting as well as for environmental impact assessment of 24 kinds of pollutants in their region of interest. Therefore, IOA was chosen as the core tool in this study.

The basic algebraic relationship in a single region input-output model is shown in Eq. (1):