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Accounting for China's regional carbon emissions in 2002 and 2007: production-based versus consumption-based principles

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A B S T R A C T

Analysing the characteristics of virtual carbon flows among regions is essential for China to deploy effective regional mitigation strategies. This study established a multi-regional input–output model to assess the characteristics of interregional carbon flows and account for carbon emissions by different regions according to one production-based and two consumption-based accounting principles. Results indicate that interregional carbon flows grew from 136.4 MtC in 2002 to 377.8 MtC in 2007. The proportion of total national emissions represented by interregional carbon flows rose from 15.2% in 2002 to 21.1% in 2007. Therefore, different accounting principles tend to have more and more different impacts on the emission responsibility that a region is assumed to take. According to the results under different accounting principles, the Northeast and Northwest regions will need to assume much greater emission responsibilities under the production-based principle than under either of the consumption-based principles. The Eastern Coastal and Southern Coastal regions, in contrast, will need to assume much greater emission responsibilities under the two consumption-based principles. Moreover, the carbon flows from the Central and Northwest regions to the Eastern Coastal region were the greatest contributors to both the total interregional carbon flows in 2007 and the growth in interregional carbon flows from 2002 to 2007. Given this situation and considering the economic disparity among these regions, methods similar to the Joint Implementation could be considered when discussing the regions' emission responsibilities. Results also indicate that the total use direct emission principle is a more feasible and practical consumption-based choice.

1. Introduction

Since the formation of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the linking of the Kyoto Protocol (KP) to the UNFCCC in 1997, global climate change has attracted increased attention. In 2011, after days of hard negotiations in Durban, the 17th Conference of Parties (COP17) to the UNFCCC finally agreed on a second commitment period of the KP. At the 2012 Doha Climate Change Conference, it was further clarified that the second commitment period would start on January 1, 2013, with a target of reducing overall emissions of Annex I parties by at least 18% below 1990 levels by the year 2020.

Despite having no specific reduction obligations, China, as the world's current largest CO_2 emitter, has been actively addressing climate change. China has announced a series of reduction targets, including reducing its carbon intensity by 17% below 2010 levels by the year 2015 and by 40–45% below 2005 levels by the year 2020 (Cong and Wei, 2010; Lewis, 2011). These targets, though promoted at the national level, need to be realised by the production and residential sectors in the country's different regions.

Deploying regional mitigation efforts could be particularly complicated in China. On the one hand, China is an extremely large country and there are obvious differences in the economic base, industrial structure, resource endowment, and energy utilisation technology of each region. Thus, it would be illogical to set a uniform emission reduction target for all regions. On the other hand, China is a developing country, and economic development is still the main priority for most of its regions. Moreover, it has been emphasised that the comparative advantages of different regions

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should be given full play, and the gap in regional development should be gradually narrowed. The current strategies of Western Development, revitalising the Old Northeast Industrial Bases, promoting the Rise of Central China, and encouraging the Eastern region to take the lead in development are all designed to lead to efficient and coordinated development among different regions in China. Therefore, when deploying regional emission reduction efforts, the characteristics and development strategies of a region should be taken into account to properly define its emission responsibility. A series of key problems are to be settled in this process. Shall the emissions of a region be accounted for based on its production or consumption? Which emission responsibility accounting perspective will be the most fair and allow a region to coordinate its economic growth and emission mitigation? Are the impacts of different accounting principles on the emission responsibility of a region becoming more obvious or less obvious? How can the unfavourable impacts on a region be reduced when switching between accounting principles? The answers to these questions rely on scientific understanding and analysis about carbon emissions at the regional level.

There have been many studies about CO_2 emissions in China at the regional level, most of which have focused on one or several provinces, cities, or other regional units (Bi et al., 2011; Feng et al., in press; Liu et al., 2011, 2012b; Mortimer and Grant, 2008; Shao et al., 2014; Wang et al., 2012). There are far fewer studies that cover all or most of the regions, and such studies are particularly crucial to the comprehensive deployment of regional mitigation efforts.

Among the studies on multiple regions, some analysed the spatial distribution of CO_2 emissions. For example, Du et al. (2012) found that whereas both per capita and aggregate CO_2 emissions have been continuously growing in all provinces since 1995, there are clear differences among regional emission levels. They found that the east region is the largest emitter both at the per capita and aggregate levels, whereas the emissions of the middle and west regions are much lower. Geng et al. (2011) also found that CO_2 emissions were noticeably unequal across provinces, decreasing from north to south and from east to west. Zhao et al. (2012) found that the emission growth rates of the coastal provinces were lower than those of the interior provinces from 2005 to 2009, although the absolute emissions of the latter were generally low. Zhao et al. also compared the distribution of regional emissions by sector and found that the contributions of residential and commercial activities to total emissions were larger for interior provinces than for coastal provinces. Yu et al. (2012) concluded that the two most important indicators characterising carbon emissions in China's various regions were CO_2 emission intensity and per capita emissions. Geng et al. (2011), however, observed no significant differences in CO_2 intensity across regions.

Some existing studies provided a rationale for regional emission distributions by assessing and comparing the factors that drive carbon emissions in different regions. Most studies identified the economic status of a region, either aggregate or per capita, as the dominant factor (Geng et al., 2011; Li et al., 2012; Liu et al., 2010; Zhang et al., 2011; Zhao et al., 2012). Technological advances also constituted an important factor. Whereas some studies found their mitigation effect to be significant (Guo et al., 2011; Liu et al., 2010; Zhang et al., 2011), others determined that technological advances can only produce a small emission reduction in most regions and can actually increase CO_2 emissions in high-emission regions due to the enlarged production scale (Li et al., 2012). A disparity in technology levels among regions was identified as a primary barrier to China's CO_2 mitigation (Guo et al., 2011; Liang et al., 2007; Liu et al., 2012a). Other factors identified include the energy structure (Guo et al., 2011; Zhang et al., 2011) and industrial structure (Li et al., 2012; Zhang et al., 2011).

Moreover, some studies directly addressed the mitigation potential and cost of different regions to inform the implementation of regional emission responsibilities. For example, using an extended Slacks-Based Measure model incorporating an undesirable output, Wei et al. (2012) estimated the CO_2 reduction potential and marginal abatement costs for 29 provinces from 1995 to 2007. Their results show that a large gap exists between the eastern, middle and western regions in terms of the potential reduction capability and marginal abatement costs; for example, the eastern region had the highest marginal abatement cost, whereas the western region had the largest potential reduction capability and the lowest marginal cost. Based on equity principles and using per capita GDP, accumulated CO_2 emissions, and energy consumption per unit of industrial value added as indicators for emission reduction capacity, responsibility, and potential, respectively, Yi et al. (2011) found that the regions of Shanghai, Hebei, Shanxi, Shandong, Guangdong and Liaoning must undertake a greater share of the burden to achieve the 45% intensity reduction target by 2020 for all the analysed choice preferences.

Most existing multi-regional studies about China have been performed from a production perspective, i.e., they have accounted for the emissions that have actually occurred in each region. However, due to the existence of interregional trade, the emissions actually occurring in a region are not necessarily generated to satisfy the consumption needs of that region. One region's production could also be driven by consumption in other regions. This situation has complicated the task of defining the emission responsibility for a region out of a concern for fairness. Indeed, fairness considerations have been attracting more attention in discussions of emission accounting and responsibility at the international level and have led to a series of studies about consumption-based principles and interregional carbon transfers (Homma et al., 2012; Mózner, 2013; Steininger et al., 2014; Wiedmann, 2009). Research focussing on emission transfers among regions within China is still relatively limited and needs improvement. When predicting the future carbon emissions of eight economic regions of China, Liang et al. (2007) calculated the differences between the emissions driven by one region and those that occurred in that particular region, and they found that such differences clearly exist in most regions. Combining the HEET approach and SWD-EET analysis, Su and Ang (2014) found that the developed regions in China are generally net importers whereas the developing regions are net exporters of emissions, revealing "carbon leakage" from the former to the latter. Both the studies of Liang et al. (2007) and Su and Ang (2014) are based on the data from 1997. In subsequent years, however, particularly from 2000 to 2005, the economic situation in China changed significantly. To grasp the more recent characteristics of interregional carbon flows in China, based on the 2002 and 2007 multi-regional input–output tables of China, this study established a related model and calculated the interregional carbon transfers in China in the years 2002 and 2007, as well as the emissions of different economic regions under different accounting principles.

The remainder of this paper is organised as follows: the model and data source are described in Section 2 and Section 3, respectively. Major results and discussions are presented in Section 4. Finally, Section 5 and Section 6 presents the conclusions and suggests additional work to be performed, respectively.

2. Methodology

This study employed the multi-regional input–output (IO) analysis.

The IO analysis is an analytical framework developed by Professor Wassily Leontief in the late 1930s (Miller and Blair, 2009).