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Regional allocation of CO_2 emissions allowance over provinces in China by 2020

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HIGHLIGHTS

- We explore the approach to realize national CO_2 emissions reduction target of China by 2020.
- The CO_2 emissions allowance is allocated over China's 30 administrative regions.
- Several scenarios of China's regional economy, emission, energy consumption are given.
- The zero sum gains data envelopment analysis model is applied in emission allowance allocation.
- An efficient emission allowance allocation scheme on provincial level is proposed.

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ABSTRACT

The mitigation efforts of China are increasingly important for meeting global climate target since the rapid economic growth of China has led to an increasing share in the world's total CO_2 emissions. This paper sets out to explore the approach for realizing China's national mitigation targets submitted to the UNFCCC as part of the Copenhagen Accord; that is, to reduce the intensity of CO_2 emissions per unit of GDP by 40–45% by 2020, as well as reducing the energy intensity and increasing the share of non-fossil fuel consumption, through regional allocation of emission allowance over China's provinces. Since the realization of China's mitigation target essentially represents a total amount emission allowance allocation problem, an improved zero sum gains data envelopment analysis optimization model, which could deal with the constant total amount resources allocation, is proposed in this study. By utilizing this model and based on several scenarios of China's economic growth, CO_2 emissions, and energy consumption, a new efficient emission allowance allocation scheme on provincial level for China by 2020 is proposed. The allocation results indicate that different provinces have to shoulder different mitigation burdens in terms of emission intensity reduction, energy intensity reduction, and share of non-fossil fuels increase.

1. Introduction

Despite the major energy efficiency improvements achieved during the last decade, the rapid development of the economy, which has undergone extensive industrialization, and conversion technologies, have substantially increased China's primary energy demand and caused serious environmental problems at the regional levels in the country due to harmful emissions such as greenhouse gas (GHG), SO_2, NO_x and particulate matter. Nowadays, China has become the greatest consumer of energy and emitter of CO_2 in the world (Hu and Lee, 2008; Li, 2010; Wang and Watson, 2010; Wang et al., 2012). Furthermore, with the growing emphasis on international environmental issues from public and government, China has already faced enormous pressures in the international negotiation on CO_2 emissions control and climate change mitigation.

Up to March 2010, following the Copenhagen climate conference, forty-two industrialized countries and forty-three developing countries, including all major emitting countries, had submitted their emission reduction or emission control pledges and action plans for 2020 to the United Nations Framework Convention on Climate Change (UNFCCC) secretariat as part of the Copenhagen Accord, and all of these emission reduction and

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control proposals were later included in the Cancún Agreements (as analyzed by van Ruijven et al., 2012). Den Elzen et al. (2011a, 2011b) had assessed the effect of these pledges and actions on GHG emissions, and concluded that they are "not as straightforward as they seems". The Kyoto protocol Annex I countries have defined emission reduction targets relative to different base years, as well as the non-Annex I countries (including China) have proposed commitments in terms of overall intensity targets associated with detailed domestic actions. As Den Elzen et al. (2011b) and van Ruijven et al. (2012) mentioned, the mitigation efforts of China are increasingly important for meeting global climate target, for China's rapid economic growth has led to an increasing share in the total GHG emissions of the world. However, since the income level (GDP per capita) of China is still much lower than that of the industrialized countries, and China has historically contributed less to world's current GHG concentrations than the industrialized countries did, China, at the current stage, is not eager to take on ambitious and absolute emission reduction target. Alternatively, China had proposed a mitigation action plan consists of reducing CO_2 emissions intensity (i.e. CO_2 emissions per unit of GDP) by 40–45% by the year of 2020 based on the 2005 level, which was 2.99 tonnes of CO_2 per 10,000 $RMB_{¥2005}$, and increasing the share of non-fossil fuels in primary energy consumption to around 15% by 2020. This mitigation action plan was internationally submitted to the UNFCCC as part of the Copenhagen Accord and the Cancún Agreements. In addition, as part of China's national plan, the energy intensity (i.e. energy consumption per unit of GDP) reduction target was continuously proposed in China's 11th Five-Year Plan (20% reduction by 2010 compared to 2005) and 12th Five-Year Plan (16% reduction by 2015 compared to 2010) of energy saving and emission reduction.

To realize sustainable development, improve energy utilization efficiency, and protect the environment, the central government of China has put forward a strategic target of constructing an environment-friendly and resource-saving society. Therefore, the 40–45% emission intensity reduction target, 15% non-fossil fuel share target, and the energy intensity reduction targets were all formally announced by the State Council of China, and were listed in the National Economic and Social Development Medium- and Long-term Plans so as to be given a legal force.

While the authorities at the provincial level (provinces, autonomous regions, and municipalities) have been required to adjust their economic growth mode and restructure their policies, this may not guarantee that local efforts on energy saving and emission reduce are in line with the national target. Lack of accountability for reduction efforts at the provincial level may lead to poor implementation of national policy. Therefore, it is particularly important for China efficiently to disaggregate the national target into the provincial target for each province. In addition, given the diversity of economic and social developments in different Chinese administrative regions, regional allocation of CO_2 emissions allowance requires an effective and efficient method to measure the relevant parameters at regional level such as emission intensity, energy intensity, energy consumption structure (i.e. shares of coal, petroleum, natural gas and non-fossil fuels in primary energy consumption), and energy and/or emission efficiency which could be evaluated through the application of data envelopment analysis (DEA) based optimization models and the utilization of regional GDP, population, energy consumption, and CO_2 emissions data. This explains the necessity for efficiency analyses and scientific assessments of the regional allocation of CO_2 emissions allowance over provinces in China.

The aim of this paper is to disaggregate China's national CO_2 emissions intensity reduction target at the regional level, i.e. to allocate China's national CO_2 emission allowance over Chinese provinces by 2020. Since the energy intensity reduction target and the share of non-fossil fuels in primary energy consumption increase target are parts of China's national mitigation plan, both of the issues are taken into account in our study when allocating the CO_2 emissions allowance. In this study, we first discuss the total emission control problem and analyze the existing emission allowance allocation approach. Then we utilize an improved zero sum gains data envelopment analysis (ZSG-DEA) model, which belongs to optimization method and could deal with constant total amount resources allocation problem, to allocate China's CO_2 emission allowance over provinces. Based on several specified scenarios of the economic and social development of China and its 30 regions in 2020, an ideally efficient resource reallocation scheme is presented. After that, the CO_2 emissions allowance allocation results and the related values of emission intensity, energy intensity, and share of non-fossil fuels for China by 2020 are discussed and compared both at the national and the provincial levels.

The remainder of this paper is organized as follows. Section 2 identifies the potential problems of total CO_2 emissions control and critically analyzes the main approaches to CO_2 emissions allowance allocation in the literature. In Section 3, the CCR-DEA model and the original ZSG-DEA model are introduced, and then the improved ZSG-DEA model for emission allowance allocation in China is proposed. Section 4 first presents the historical data of China's economic and social development, and then proposes one baseline scenario and three reference scenarios, in which the data on China's national and regional GDP, population, energy consumption and CO_2 emissions are projected, for energy and emission performance evaluation and emission allowance allocation. Section 5 first illustrates the implementation of the proposed ZSG-DEA model and the iteration and adjustment process of the reallocation, presents the regional emission allowance allocation results, and then gives a comparison and discussion on the emission intensity and energy intensity reduction burdens for China's 30 regions by 2020. The sensitivity analysis of the regional CO_2 emissions allowance allocation based on different scenarios is also presented in Section 5. The final section concludes the paper.

2. Literature review: total emission control and emission allowance allocation approaches

CO_2 emissions allowance trading is an effective mechanism for emission control, and the initial emission allowance allocation is the key to and premise of this trading. Various emission allowance allocation approaches have been proposed to cope with emission control at international level. Before the Kyoto Protocol, Grubler and Nakicenovic (1994) proposed that the emission allowance allocation should follow the principle that all countries should be assigned an equal GHG emission reduction rate. Allocating emission allowance equally among countries, coupled with the ability to trade those allowances, is a simple scheme; yet it is fraught with inequities as it ignores the inherent relation between emissions and population or human activities. Westing (1989) suggested land area as a measurement for allocating emission rights. This straightforward basis has a number of advantages, such as the stability of national land area as a measure, ease of measurement and application, no requirement for monitoring, and avoidance of verification difficulties; however, it favours large but sparsely populated countries and discriminates against small, densely populated countries. Grubb (1990) suggested a modified form of per capita allocation, signifying that everyone should have an equal right to an identical emissions quota. Per capita emissions are perceived to be more equitable than the method mentioned previously; however, this