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Emissions reduction allocation and economic welfare estimation through interregional emissions trading in China: Evidence from efficiency and equity

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ABSTRACT

Establishing an equal and effective emissions trading system is a long-term strategy to promote sustainable environmental protection and stronger economic growth. Due to regional divergences in economic development, resource endowment and geographical CO_2 emissions space, this paper focuses on a comprehensive emissions reduction allocation solution based on the Shapley value method and estimating economic welfare effects through interregional emissions trading in China. Our empirical results verify that the Shapley value-based allocation criterion is an equal and effective emissions reduction target allocation. The Eastern and Southern coast, and the Northeastern and Middle Yellow River regions are the main emissions permit buyers, and they incur windfall economic losses because of greater marginal abatement cost, while the Southwest, Northwest, Northern coast and Middle Yangtze River regions are the main emissions permit sellers, and they earn windfall economic benefits because of the emissions reduction potential of energy-intensive industries.

1. Introduction

The Chinese government has committed itself to a 40–45% reduction target of CO_2 emissions per unit gross domestic product (GDP) by 2020 relative to the 2005 level. To achieve this ambitious target, the Chinese government has adopted an Action Plan of Air Pollution Prevention, Comprehensive Work Plan and the Twelfth Five Year Plan (2011–2015) in energy saving and emissions reduction. Those master plans strengthen the government and enterprises' environmental management responsibility and promote quick transformation in industrial structure and economic development.

China has delivered strong signals of introducing a nationwide carbon emissions trading system. The National Development and Reform Commission of China (NDRCC) has announced seven emissions trading pilot markets including the cities of Beijing, Tianjin, Shanghai, Chongqing, Shenzhen, Guangdong and Wuhan since December 2013. Interim measures of emissions trading management were announced by the NDRCC on December 10, 2014, China will commit itself to establishing a pilot nationwide emissions trading market by 2017 and then establish a unified emissions trading market by 2020 [1]. The emissions trading system (ETS) effectively plays a decisive role in optimizing resource allocation and reflecting the market scarcity of emissions permits.

Based on interim measures of emissions trading management, the State Council of China determines regional differences of carbon emissions reduction, comprehensively considering cumulative CO_2 emissions, economic growth, energy consumption patterns and industrial structure. However, China has a vast territory, and different regions have vast divergences in resource endowment, energy consumption patterns and economic development levels, which imply marginal abatement costs (MAC) in different regions have greater divergences [2]. Emissions permits are tradable commodities in the ETS, and different interest groups with higher abatement costs will spend money to purchase emissions permits, while interest groups with lower abatement costs are being

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rewarded for selling more emissions permits [3]. An emissions trading system is an effective and market-driven instrument to achieve an ambitious emissions reduction target and economic outcome; therefore, how to establish a scientific, effective and equal emissions trading system is an important issue for solving a dilemma regarding both greenhouse gas emission-reduction targets and sustainable economic growth.

An attractive feature of an emissions trading system is that it allows for the simultaneous pursuit of efficiency and equity [4]. An effective and equal emissions trading system for controlling CO_2 emissions reduction has been paid increasing attention in different countries and regions. Many scholars have conducted studies on theoretical and application aspects of quota-based allocation schemes and proposed a variety of allocation schemes with different criteria. The per capita emission-based allocation reflects the concept that everyone possesses equal emissions allocation rights and the equal value of all humans [5,6]. A country's responsibility for global climate change is generally described by its contribution to the temperature rise, sea level rise or cumulative CO_2 emissions; accordingly cumulative CO_2 emissions are a more reasonable criterion to design the future space allocation responsibility [7,8]. Per capita accumulated emissions are the best way to represent the principle of "common but differentiated responsibility" and the rule of equity and integrity [9]. Cumulative per capita emissions are better indicators for incarnating equity and historical responsibilities when sharing emissions reduction among developed and developing countries [10,11]. The per unit GDP-based emissions allocation is considered an efficient solution, in which all countries are assumed to have similar emissions per unit GDP [12]. Richer countries and regions should undertake a heavier emissions reduction burden, and the per capita GDP allocation principle should be efficiently treated with an increase in economic level [13,14]. In brief, GDP, cumulative CO_2 emissions, CO_2 emissions intensity and energy efficiency are the most significant indicators affecting initial regional emissions permits and emission reduction targets allocation; those allocation methods must fully consider different historical responsibility, economic levels, energy consumption patterns and regional development needs [15].

The allocation is controversial from the perspectives of equity and efficiency. A good many comprehensive and complex allocation methods have been developed due to the shortcomings of previous allocation methods. Phylipsen et al. (1998) present an assumed weight sum model integrating per capita CO_2 emissions, per capita GDP and carbon intensity [16]. Wei and Rose (2009) present a nonlinear programming model to minimize the total energy conservation cost and then propose an interregional energy conservation-quota trading system in an efficient and equitable way in China [17]. Yi et al. (2011) develop a CO_2 intensity allocation model and then propose a regional allocation considering equity, intensity reduction target fulfillment, economic difference and reduction potential among provinces [18]. Wei et al. (2012) present the CO_2 abatement capacity index based on weighted equity and efficiency indexes, and then, they find that there exists a large gap in potential reduction capacity and marginal abatement costs among the eastern, middle and western regions [19]. Yu et al. (2012) explore the regional characteristics of interprovincial CO_2 emissions using the most important indicators of CO_2 emissions intensity and per capita emissions in the rational distribution of emissions intensity reduction in China [20]. Yu et al. (2014) investigate the emissions reduction burden decomposition being determined by four key factors that decelerate CO_2 emissions growth rate, energy endowments, living standards and emissions intensity of each province in China [21]. In brief, those results in the above literature verify that economic growth, carbon intensity, accumulated CO_2 emissions and industrial structure are the most significant factors affecting regional emissions reduction permit allocation; meanwhile, those allocations should consider different energy structures, industrial structure and per capita resident income of different provinces or regions in China.

The market design and economic efficiency of the emissions trading scheme has received increasing attention in different countries and regions. Different countries or regions attain economical and environmental gains from regional and international emissions trading markets [22–24]. Higher allowances prices translate into stronger incentives for the demand-side energy efficiency in the energy sectors, strongly passing through the extra costs [25]. Under the EU emissions trading scheme, CO_2 emissions costs are the key factors in selecting aircraft; the CO_2 emissions cost trends and the changes of profits of flight routes appear to be similar [26]. Most airlines' efficiencies have increased in the European Union emissions trading scheme, and the average efficiency of European airlines is much higher than that of non-European airlines [27]. A stricter allocation shifts abatement efforts and compliance costs to energy-intensive industries covered by the EU emissions trading scheme [28]. One half-double auction resale markets lead to lower efficiency than the monopsony resale regime in an auction-based emissions trading scheme [29]. A full-infinite fuzzy stochastic programming method can increase the abilities of reflecting complexities for dynamics of capacity expansion and interaction of multiple uncertainties in municipal electric power systems [30]. Institutional and technological uncertainties significantly influence regional or country's benefits from the emissions trading market; meanwhile, uncertain emissions permits may significantly affect operational decisions [31,32]. Emissions trading system may slightly improve the flexibility of emissions reduction permits, increase total production cost in energy-intensive industries, and then improve economic restructuring [33–35]. The emissions trading system may decrease total emissions abatement costs, improve economic efficiency and environmental effectiveness, and then achieve regional emissions reduction targets [2,36,37]. Several policy designs such as different quotas allocation methods, market stabilization measures and price mechanisms in the emissions permits and energy markets are significant details for achieving emissions trading market efficiency and abatement targets [38,39].

Different emissions allocation options have significant impacts on China's power sectors; emission-based allocation causes higher electricity and carbon prices than output-based allocation [40]. Emissions reduction target constraints and the emissions trading system have significant economic impacts on the refinery, iron, steel, power and cement sectors [41]. However, emissions permits also create an incentive to reduce output and emission-reduction efficiency [42]. Grandfathering can also be used to avert the relocation of firms to non-covered countries with lower carbon prices, while auctions, as the new allocation rule, are likely to increase the distortions of competition, worsening rather than improving allocation transparency and granting harmonization of higher rules [43–45]. The emissions trading scheme has a potential impact on competitiveness risk, relocation risk and emission-reduction efficiency in highly CO_2-intensive and trade-exposed industries including the power, cement, paper, iron and steel sectors [46–49]. Efficient permit allocation rules, carbon-motivated border tax adjustment, industry exemptions from carbon regulation, and formal international cooperation are cost-effective carbon leakage instruments, and border carbon adjustments are more effective in leakage reduction than exemptions and efficient permit allocation [50,51].

Relevant previous studies primarily focused on emissions reduction permit allocation and the environmental and economic effectiveness analysis of emissions trading systems in different countries and regions. Zhou et al. (2013) conduct the initial quotas