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The allocation of carbon emission quotas to five major power generation corporations in China

Chao-Qun Ma [a, b], Yi-Shuai Ren [a, b, d], Yue-Jun Zhang [a, b, *], Basil Sharp [c, d]

[a] Business School, Hunan University, Changsha 410082, China
[b] Center for Resource and Environmental Management, Hunan University, Changsha 410082, China
[c] The University of Auckland, Auckland 1142, New Zealand
[d] The Energy Centre, University of Auckland, 12 Grafton Rd, Auckland 1010, New Zealand

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ABSTRACT

The five major power generation corporations dominate the power industry in China, and play vital roles in China's carbon trading scheme. Under this circumstance, this paper studies the allocation of carbon emission quotas to China's five major power generation corporations based on the fairness and efficiency principles, which proves the primary prerequisite for setting up the national carbon market. Specifically, a bi-level programming model is developed to optimally allocate carbon emission quotas to the corporations, and then a zero sum gains data envelopment analysis (ZSG-DEA) model is adopted to evaluate the efficiency of the allocation so as to adjust towards the optimal solution. The results indicate that power generation has significantly positive influence on the allocation of carbon emission quotas. Moreover, the difference between the sum of optimal carbon emissions and the sum of carbon quotas allocated is 1.431 billion tons, which implies that the emission reduction potential of the five major power generation corporations is tremendous. Finally, the bi-level model in this paper can well capture the context of China's power industry and provide effective results for the allocation of carbon quotas.

1. Introduction

Carbon dioxide as the main greenhouse gas (GHG) has contributed the most to an increase in average global temperature of 0.85 °C over the period 1880 through 2012 (IPCC, 2014). As a result, controlling CO_2 emissions now becomes a major focus of policies aimed at moderating the increase in global temperature (Stern, 2007; Wei et al., 2008). According to the BP statistics, China emitted 9.1 billion tons of CO_2 in 2016, almost 27.3% of global emissions, larger than the total emissions of the US and India (BP, 2017). Under this circumstance, in order to achieve the resource-conservative and environment-friendly society, and the sustainable economy, the Chinese government has proposed to decrease CO_2 emission intensity by 40%–45% by 2020 and 60%–65% by 2030.

As a dominant industry of energy consumption and carbon emission in China, the power industry is one of the key industries that are covered by the carbon emission trading scheme. Power generation in China is dominated by coal, a major source of GHG emissions and likely to remain so in the near term. As the mainstay of power industry and emission-intensive state-owned corporations, the five major power generation corporations, namely, China Huaneng Group (CHNG), China Datang Corporation (CDTC), China Huadian Corporation (CHDC), China Guodian Corporation (CGDC), and China Power Investment Corporation (CPIC), occupy the central position in China's carbon emission trading system, thus it is necessary and meaningful to study the allocation of carbon emission quotas to the five major power generation corporations in China. Moreover, the National Development and Reform Commission (NDRC) released China's national carbon emission trading scheme of the power generation industry on December 19, 2017, which marks the beginning of China's national carbon emission trading market based on the previous seven pilot carbon markets, so the research on carbon emission quota allocation to the five major power generation corporations in China becomes urgent and imperative.

First, by focusing on the power industry, three basic conditions for establishing a carbon market are satisfied, namely that emissions are measurable, reportable and verifiable (MRV). The European Union Emissions Trading Scheme (EU ETS) and the Regional

* Corresponding author. Business School, Hunan University, Changsha 410082, China.
E-mail address: zyjmis@126.com (Y.-J. Zhang).

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Greenhouse Gas Initiative (RGGI) in the US also started with the power industry. Therefore, due to its large and concentrated source of carbon emissions and the availability of data obtained from systematic metering, the power industry is recognized as an early candidate for inclusion into the carbon emission trading scheme in China.

Second, the power industry is China's largest emitter of carbon dioxide emissions from coal consumption. In fact, China generated 6.1 trillion kWh of electricity in 2016 that reached 24.8% of the world total electricity generation (BP, 2017). According to China Electricity Council's statistics, thermal power takes up a dominant share (71.6%) of full-aperture power generation, and the power industry accounts for about 50% of national CO_2 emissions.[1] Compared with other industries of China, the power industry is more worthy of being paid attention and all-round studied. Industrialization and urbanization have increased rapidly since 2003, which leads to an increase in CO_2 emission in China from 4582 million tons in 2003 to 9018 million tons in 2012, with an annual growth rate of 7.8%. Meanwhile, the CO_2 emissions from the power industry have grown from 2240 million tons in 2003 to 4833 million tons in 2012, with an annual growth rate of 8.9% (see Fig. 1). Moreover, as the backbone of China's power generation, the five corporations account for more than 95% of China's thermal power capacity and more than 70% of total power generation, which means the five major power generation corporations essentially cover the entire carbon emissions of China's power industry. Besides, economic growth proves an important factor in the increase of China's carbon emissions (Zhang and Da, 2013; Mi et al., 2017). Meanwhile, carbon emissions are expected to increase with economic growth and the inevitable increase in electricity demand, therefore, balancing economic growth and environmental protection has now become an important priority for China (Day, 2005; Zhang and Da, 2015).

Third, with the appearance of “Air Pollution Prevention and Control Action Plan” in 2013 and "Some Opinions on Further Deepening the Reformation of Power System” in 2015 in China, the Chinese government seeks to further strengthen and improve energy efficiency and carbon emissions reduction in the power industry. Moreover, the National Development and Reform Commission (NDRC) in China released a notice "On priorities for starting the national carbon emissions trading market” on January 19, 2016, which particularly emphasized that power industry is covered as one of the key industries in the national carbon emissions trading system. Therefore, under the background of global climate change and the low-carbon development, the discussion on the allocation of carbon emission quotas within the power industry has valuable significance for solving the coordinated development between power system reform and national carbon trading market in China, and it is an extremely urgent realistic challenge for starting the national carbon trading market in China. The results of carbon emission quotas allocation can provide important decision-making reference and support for the top-level design of the carbon emission trading system and the perfection of relevant legislations.

China has launched its pilot regional emission trading systems (ETS) in seven provinces and cities since 2011 (Zhang et al., 2017). In the existing carbon emission trading systems, an outstanding issue always wells up on how to allocate carbon emission quotas among the ETS-covered corporations at the beginning of each trading period (Zetterberg et al., 2012). This outstanding issue has a direct effect on the operations of carbon trading market, also on the enthusiasm of those corporations to join in carbon trading market and to reduce carbon emissions. Specifically, the power generation

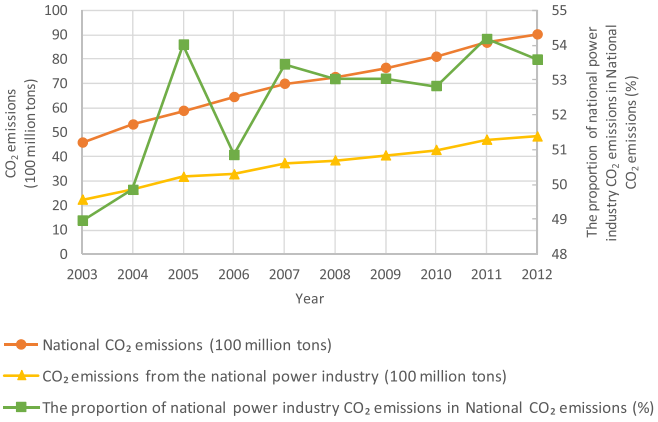

Fig. 1. CO_2 emissions trends in the nation and power industry from 2003 to 2012.

corporations may act differently depending on the allocation of carbon emission quotas, which may bring various impacts on the real economy ultimately (Ahn, 2014). Therefore, the reasonable and effective mechanism of carbon emission quotas allocation among the five major power generation corporations is one of the sternest issues that China faces.

To solve this, a bi-level programming (BLP) model is developed to allocate carbon emission quotas from the fairness principle in this paper based on the actual conditions and policies of China. Meanwhile, since the total carbon emission quotas of the power industry are relatively stable, thus the allocation of carbon emission quotas in the power industry usually requires a game among the five major power generation corporations and every major corporation asks for more carbon quotas, in case the nation designs carbon emission trading system from the industry level and considers the allocation of carbon emission quotas.[2] Therefore, the allocation result can be seen as the equilibrium solution of the game. In other words, the allocation of carbon emission quotas to the five power generation corporations seems competitive under a definite total amount of carbon emission quotas, which means that the increase of carbon emission quotas for a power generation corporation indicates the decrease of carbon emission quotas for other power generation corporations. This shows the idea of "zero-sum gain” based on the total quantity of carbon emission quotas unchanged. Given this, a zero sum gains data envelopment analysis (ZSG-DEA) model is employed to see how the allocation results vary under the situation of a zero-sum game and examine whether or not the allocation is efficient. In brief, taking into account the principles of both fairness and efficiency, this paper allocates the carbon emission quotas to the five major power generation corporations in China, by a combination of the BLP model and ZSG-DEA model.

This paper contributes to existing relevant literature in the following aspects. First, this paper simultaneously considers the fairness and efficiency principles for carbon emission quotas allocation, which supplements previous relevant studies because they mostly lay emphasis on the fairness and efficiency principles separately. Second, it adopts the advantages of both carbon emissions and carbon intensity in order to realize the maximum

[1] http://www.cpnn.com.cn/sd/gn/201502/t20150226_784495.html.

[2] In fact, a working panel was set up in 2015 for carbon emission trading in the electricity industry, led by China Electricity Council. The main task of the working panel is to establish carbon emission trading communication and coordination mechanism at the industry level, and strengthen the exchange of experience and information related with participating in carbon emission trading and implementing carbon emission reduction for power corporations.