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# A multi-criteria decision analysis model for carbon emission quota allocation in China's east coastal areas: Efficiency and equity

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ABSTRACT

The allocation of carbon emission quotas is recognized as a fundamental and critical step towards the establishment of an effective nationwide carbon emissions trading (CET) market in China. This paper aims to examine the quota allocation pertaining to China's east coastal areas. These regions are pioneers in reformation and the domestic heavy emitters. In this paper, a multi-criteria decision analysis model is proposed. This model is based on the principles of efficiency and equity. In order to reflect the true efficiency of carbon emissions, a weighted Russell direction distance model is employed. Three criteria, namely capacity, responsibility and potential, are used to evaluate the degrees of equity. Furthermore, different situations are set to evaluate the related indicators. The results indicate the following: (1) Industrial provinces have less carbon emission quota increments. (2) The Yangtze River Delta Economic Zone has notably improved energy efficiency, and future quota increments correspond with the zone's current carbon emissions. (3) Circum-Bohai Sea Economic Zone will be a major buyer of carbon emission quotas, while Pan-Pearl River Delta Economic Zone currently receives surplus quota. (4) The overall allocation of quotas converts from uneven to even as a result of GDP growth. These results provide a reference for collaborative regional reductions in carbon emissions and for the construction of a CET market.



## 1. Introduction

Greenhouse gases (GHGs) are prime contributors to global warming. Green development, such as green industry (Hashim et al., 2015; Hall and Dickson, 2011), green campus (Kamyab et al., 2015), has been received worldwide attentions. The vast majority of emissions are carbon dioxide ($CO_2$). Carbon emissions resulting from the use of fossil fuels are estimated to reach 5 trillion tons, causing global average warming of 6.4–9.5 °C in the future years (Tokarska et al., 2016). The target of attempting to hold the increase in average global temperature below 2 °C has been recognized as crucial (UNFCCC, 2010). Since 2009, China has emerged as the world's largest $CO_2$ emitter, contributing almost 25% of total emissions in the world. Recently the patterns of Chinese carbon emissions changed and the proportion of $CO_2$ emissions induced by consumption grew rapidly (Mi et al., 2017a). China has pledged to reduce carbon intensity ($CO_2$ emissions per unit of GDP) by 40–45% in 2020 and by 60–65% in 2030, respectively (with 2005 as the base year). In 2005, the total $CO_2$ emissions were 5358.09 Mt and carbon intensity was 1.51 kg $CO_2$/2010 USD.[1] In 2014, China vowed to put a peak on its growing $CO_2$ emissions by 2030 (UNFCCC, 2015). This plan has some important impacts on China's society and economics (Mi et al., 2017b).

Carbon emission trading (CET) has been regarded as an effective tool for achieving such targets. Provincial carbon trading is expected to reduce carbon intensity by 19.79%–25.24% in China, thus bringing about a significant Porter Hypothesis effect (Zhang et al., 2016). Since June 2013, China has carried out seven pilot CET markets in Beijing, Tianjin, Shanghai, Chongqing, Shenzhen,

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[1] Data from IEA, http://www.iea.org/statistics/statisticssearch/report/?country=China&product=indicators&year=2005.

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Guangdong and Wuhan (Zhang, 2015). A national CET market is expected to be in place by 2017. Xiong et al. (2017) compared China's pilot CET market programs with international emission trading market, and proposed an analysis framework based on allowance allocation and allowance distribution. The initial allocation of $CO_2$ emission permits is the first step towards establishing a CET market. However, the improper allocation of quotas has become commonplace (Liu et al., 2015). In China, relatively large regional imbalances exist in terms of economic performances, natural resources, and historical emissions (Yu et al., 2012). These imbalances may further hinder the fair and efficient allocation of carbon emission quotas.

In this study, we examine the allocation of carbon emission quotas in China's east coastal areas, which include seven provinces (Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong and Guangdong) and three municipalities (Beijing, Tianjin, and Shanghai). In the east coastal areas, Beijing, Tianjin, Hebei, Liaoning, and Shandong comprise the Circum-Bohai Sea Economic Zone. The Yangtze River Delta Economic Zone includes Jiangsu, Shanghai, and Zhejiang. Fujian and Guangdong are located in the Pan-Pearl River Delta Economic Zone. The locations of these seven provinces and three municipalities are depicted in Fig. 1. Our motivations of exploring the east coastal areas are as follows: (1) China's east coastal areas have been the vanguard of modernization, because of their advanced infrastructure, social system and agglomerations of talent. These characteristics make the east coastal areas the most likely to take the lead in establishing a CET market. (2) From Fig. 2, we can see that the east coastal areas are central to China's efforts in economic development, as well as in reducing energy consumptions and carbon emissions (Gao et al., 2016; Qin et al., 2017). (3) A special analysis of China's east coastal areas offers a reference for the regional study of carbon emission quota allocation and facilitates the construction of a national CET market.

The most important feature of a quota allocation system is the trade-off between efficiency and equity (Rose and Tietenberg, 1993). Efficiency relates to the allocation of limited carbon emission quotas in pursuit of a cost-effective outcome. Equity refers to the fair distribution of the carbon emission quotas throughout society, without compromising the cost-effective outcome (Zhang and Hao, 2016). Some studies have been conducted to investigate the quota-based allocation schemes both theoretically and practically. However, many of those studies often only focus on either equity (Pan et al., 2014; Han et al., 2016) or efficiency (Miao et al., 2016; Liu and Lin, 2017) of allocation results. This study aims to explore the carbon emission quota allocation in China's east coastal areas based on both the principles of efficiency and equity. It is expected to offer a reference for the regional study of carbon emission quota allocation and facilitate the establishment of a national CET market. Instead of single indicator approach, a multi-criteria decision analysis approach is used to integrate the criteria. Three criteria, namely capacity, responsibility and potential, are used to measure equity. In addition, a weighted Russell direction distance model is adopted to represent the aspects of efficiency. The features of this paper can be summarized as follows: (1) this paper focuses on the allocation of carbon emission quotas in China's east coastal areas, due to their referential significance to China's inland areas and national CET market. (2) A multi-criteria decision analysis model is proposed as a means to trade off efficiency and equity in the allocation of carbon emission quotas. (3) To measure the true efficiency of carbon emissions, a weighted Russell direction distance model is employed to measure the technical inefficiency in each input or output indicator, rather than total factor energy efficiency (Zhang and Jiang, 2016). (4) In order to accurately calculate the levels of carbon emissions, we combine the criteria published by IPCC (2006) and the adjusted data from the Department of Climate Change, National Development & Reform Commission of China (NDRC-DCC, 2014).

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature pertaining to the allocation of $CO_2$ emissions quotas. Section 3 explains the data and methods used in this paper. Our results and discussions appear in Section 4. Section 5 concludes our paper and offers policy implications.

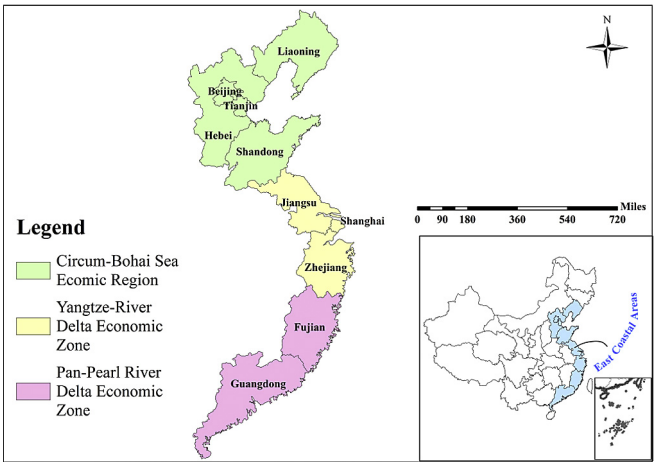


**Fig. 1.** Location of China's east coastal areas.

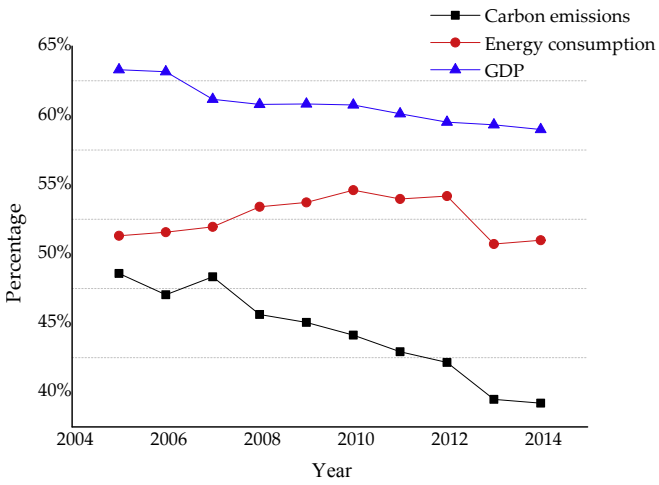


**Fig. 2.** Carbon emissions, energy consumptions and GDP in China's east coastal areas. Data source: China Statistical Yearbook (2006–2015) and China Energy Statistical Yearbook (2006–2015).

## 2. Literature review

Equity and efficiency are the principles of governing the allocation of quotas and the first issue in determining emission permits. Ringius et al. (1998) deconstructed the general principles of equity into egalitarian, sovereign, horizontal, vertical, and polluter-pays equity. Further, Vaillancourt and Waaub (2004) proposed additional principles, including the right to emit, basic needs, historical accountability, ability to pay, comparable costs, willingness to pay, and merit. The criterion of merit as a measure of efficiency has also gained prominence among scholars (Zhang and Jiang, 2016). Thus far, some methods have been proposed to deal with carbon emission quota allocation from the principle of equity and/