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A study of allocative efficiency of $PM_{2.5}$ emission rights based on a zero sum gains data envelopment model

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ABSTRACT

It is an urgent task for China to control haze emission in environmental treatment. Emission right trading is a feasible way to achieve the reduction of pollutant emission on the premise that the total pollutant emission amount is under control, and the allocation of initial emission rights based on the target total amount is the key to emission right trading. In this paper, via the input-oriented ZSG-DEA model, the inter provincial allocative efficiency of $PM_{2.5}$ emission rights is investigated under the condition that the target total amount is fixed. The results showed that (1) after initial emission rights were allocated in accordance with the ZSG-DEA model, $PM_{2.5}$ emission amounts of all provinces would be in a new common DEA frontier so as to realize the overall Pareto optimality with a set total amount; (2) two factors, namely land areas and atmospheric environmental capacities of all provinces, were considered in the actual allocation to avoid the homogenization of all evaluated units found in the previous evaluation literature on allocative efficiency, thereby making the evaluation results more in line with the actual situations in all provinces. Such an investigation approach can provide guidance on the allocation of initial emission rights in emission right trading; and the research results can offer empirical support for haze-reducing work load conducted by central and local governments of China.

1. Introduction

In recent years, foggy and hazy days have greatly increased in China, arousing widespread concern at home and abroad (Yu et al., 2011). In January 2013, 30 provinces (autonomous regions and municipalities) in China were four times haze-shrouded, and Beijing only had five haze-free days. On January 14, 2014, the research report entitled "Towards an Environmentally Sustainable Future: A National Environmental Analysis of People's Republic of China" pointed out that only less than 1% of the 500 largest cities in China had achieved the air quality standards recommended by the World Health Organization; and seven out of the ten cities most polluted in the world belonged to China (Zhang and Crooks, 2012). Lelieveld et al. (2015) and Yang et al. (2013) estimated the premature deaths etc. that were caused by outdoor air pollution, mostly by $PM_{2.5}$. The outdoor pollution contributes to 3.3 (95% CI, 1.61–4.81) million premature deaths per year worldwide, predominantly in Asia. In China, the premature deaths hit 1.36 million, accounting for 41.2% of the world total.

Attaching great importance to the prevention and control of haze, our government has successively introduced a series of important policy-type documents, such as "A Comprehensive Working Scheme of Saving Energy and Reducing Emission in the Period of 'Twelfth Five'" (2011), "Planning of Prevention and Control of Atmospheric Pollution in the Key Areas in the Period of 'Twelfth Five'" (2012), "An Action Plan of Prevention and Control of Atmospheric Pollution"(2013) and the newly revised "Environmental Protection Law" (2015) and so on, in all of which the establishment of a regional coordination mechanism to coordinate regional environmental treatment has been proposed. In addition, the State Council has also signed target responsibility contracts with all provincial governments so as to conduct annual assessment and investigate accountability strictly. But from the perspective of treatment practice, haze treatment force fully promoted through

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the use of administrative power can exert some effect only in the short run. Shutting down factories temporarily can only bring about transient haze reduction. Once the reins are loosened, hazy days will increase rapidly. “APEC Blue” in Beijing, 2014 and “Youth Olympic Blue” in Nanjing, 2014 are just two such cases (there are great differences of Chinese air quality before and after “APEC Blue”, see Huang et al., 2015). In the long run, giving full play to market mechanism may be another way of effective haze treatment.

Recently, the emission right of air pollutants such as carbon and sulfur dioxide has opened up trade, both at home and in abroad. Naturally, as haze is an air pollutant just like carbon and sulfur dioxide, the emission right trading on haze is expected to be opened up as well. For instance, by analogy with the international mature experience and practice on carbon emission right trading we can control the total emission amount of haze typical components, allocate the initial emission rights at the local level, and trade surplus emission rights on the market. Such an approach takes into account both the overall target and the actual situations of all provinces, thus putting into play the autonomy of provinces. In contrast with the simple shutting down of pollution-eliciting enterprises, this approach is more feasible in haze control in the long run.

However, what amount will the initial haze emission right be for each province respectively? This is a gap in the current literature and practice. Different from carbon emission, the total amount of haze emission is difficult to calculate, and consequently, the development of certain indices utilized to calculate haze emission rights becomes one priority. Moreover, methods used to evaluate the haze emission efficiency of each province are desired.

Fortunately, $PM_{2.5}$ can serve as a representative variable of haze for all provinces (autonomous regions and municipalities) in China, and hence as an evaluation unit.

Under the condition that the nationwide total emission amount of $PM_{2.5}$ is fixed, indices such as the land area and the atmospheric environmental capacity are also considered to reallocate $PM_{2.5}$ emission rights of all provinces, thereby offering empirical support for $PM_{2.5}$ emission right trading and new ideas for our government's haze treatment.

2. Literature review

Generally speaking, there are two types of regulation on such public goods as air pollutants: one is tax regulation (Baumol and Oates, 1988), and the other is emission right trading (Nordhaus, 2005).

Many scholars have studied the effect of tax regulation on pollutant emission (Ruth and Amato, 2002; Malcolm and Zhang, 2006; Fischer and Newell, 2008; Rive, 2010; Pelin and Kesidou, 2011). Although tax regulation is simple and practicable and causes area relatively small loss of GDP, in view of its poor and uncertain effect on emission reduction, it is difficult to ensure the realization of emission reduction targets by relying singly on carbon tax policy (Shi et al., 2013).

For the emission right trading its theoretical basis includes “Property Rights Theory” and “Coase Theorem” put forward by Coase (1960). Afterwards, Dales (1968) for the first time formulated the concept of emission right trading. He suggested that emission rights of economic entities can be stipulated in the form of emission permits, and surplus emission rights can also be traded. For that matter, the method of stipulating emission rights in the form of permits is known as the initial allocation of emission rights (Burton and Sanjour, 1969, 1970). Based on the Dales' theory of emission right trading, the National Environmental Protection Agency of the United States formulated and promulgated the “Control of Total Amount and Trade” rule in the late 70s, and implemented the “Acid Rain Program” in early 1995. After entering into the twenty-first century, a growing number of scholars have paid attention to the allocation and trading of air pollutant emission rights (Mackenzie et al., 2008, 2009; Chavez et al., 2009; Pickl et al., 2010). Many scholars have also suggested that the Chinese government control air pollution by issuing emission permits (Wu and Wang, 2010; Zhang and Peng, 2011; Jin et al., 2011; Wei et al., 2011). On November 10, 2007, the first emission right trading center was established and went public in Jiaxing, Zhejiang, China. In May 2008, Tianjin Climate Exchange was jointly set up by Tianjin Property Rights Exchange, CNPC Assets Management Co., Ltd. and Chicago Climate Exchange. These activities have played a certain role in promoting market trading of air pollutant emission rights. However, the actual trading activities of haze emission rights have not come into existence in China so far. One of the main reasons is the lack of quantitative assessment aiming at the allocation of haze initial emission rights in China, which comprises the precise purpose of this study.

The allocative efficiency of emission rights is an important factor in measuring the fairness and reasonability of emission right allocation. Domestic scholars Chen et al. (1998) and Ma et al. (1999, 2006) applied the linear programming method to the study of air pollutant allocation, but the interprovincial allocative efficiency of pollutant emission rights was not evaluated. Since air pollutant emission belongs to undesirable output, the more such output means the lower allocative efficiency and the less such output means the higher allocative efficiency. In contrast, the traditional DEA model presupposes output as desirable, so the more output means the higher allocative efficiency and the less output means the lower allocative efficiency. In order to make it possible for the DEA model to measure the environmental efficiency that even covers undesirable output, some scholars made favorable improvements on the traditional DEA model (Färe et al., 1989; Hailu and Veeman, 2001; Seiford and Zhu, 2002; Tone, 2004). However, these improved DEA models treat the DMUs as independent decision making units, which have limitations in the allocation of emission-reducing responsibility based on the target total amount. They fail to take into consideration the cooperation or competition among DMUs. Nevertheless, the allocation of emission-reducing responsibility based on the target total amount requires interdependent allocation of undesirable output among DMUs. Therefore, if some inefficient DMU wants to improve efficiency and reduce undesirable output, other DMUs are inevitably required to increase their undesirable output. At this moment, the original DEA model is inappropriate. In view of this situation, Lins et al. (2003) proposed the ZSG-DEA model (Zero-sum Gains Data Envelopment Analysis, or ZSG-DEA for short) by considering the competition, cooperation and allocation of undesirable output among DMUs. This model can revise the allocation scheme of undesirable output in line with the DEA efficiency of each DMU, thereby further improving its DEA efficiency. Based on the framework of Kyoto Protocol, Gomes and Lins (2008) applied this model to reallocate the CO_2 emission right of each country. This method has been widely used in the evaluation of allocative efficiency among multiple decision making units when the total emission amount is set (Singh and Surya, 2014; Chiu et al., 2013; Lin and Ning, 2011; Zheng, 2012; Wang et al., 2013; Miao et al., 2013; Hu and Fang, 2010; Sun et al., 2012). Given that the distribution of each province's $PM_{2.5}$ emission rights is based on the decrease of total emissions, such a method will be adopted in this paper as well.