Energy Policy 102 (2017) 30–40

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Carbon allowance auction design of China's emissions trading scheme: A multi-agent-based approach

Ling Tang[a,b], Jiaqian Wu[c], Lean Yu[b,*], Qin Bao[d]

[a] School of Economics and Management, Beihang University, Beijing 100091, China
[b] School of Economics and Management, Beijing University of Chemical Technology, Beijing 100029, China
[c] Institutes of Science and Development, Chinese Academy of Sciences, Beijing 100190, China
[d] Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, China

ARTICLE INFO

Keywords:
Emissions trading scheme (ETS)
Carbon auction market
Allowance allocation
Emissions reduction
Multi-agent-based model

ABSTRACT

In this paper, a multi-agent-based ETS simulation model is proposed for carbon allowance auction design in China. In the proposed model, two main agents, i.e., the government (the ETS implementer) and the firms in different sectors (the ETS targets), are considered. Under the ETS policy, all agents make various decisions individually according to their own goals, and interact with each other through three main markets: the commodity market, the primary carbon auction market and the secondary carbon trading market. Different popular auction designs are introduced into the ETS formulation to offer helpful insights into China's ETS design. (1) Generally, the ETS would lead to positive effects on China's carbon mitigation and energy structure improvement, but a negative impact on economy. (2) As for auction forms, the uniform-price design is relatively moderate, while the discriminative-price design is quite aggressive in both economic damage and emissions reduction. (3) As for carbon price, the uniform-price auction might generate a slightly higher market clearing price than the discriminative-price auction, and the prices under two auction rules fluctuate about RMB 40 per metric ton. (4) As for carbon cap, the total allowances in the carbon auction market should be carefully set to well balance economic growth and mitigation effect.

1. Introduction

To effectively control carbon emissions, a cost-effective mitigation measure, emissions trading scheme (ETS), has aroused a world-wide attention. Different from other mitigation tools, ETS is a flexible approach using the market-driven mechanism rather than compulsory regulations (Egenhofer, 2007; Bredin and Muckley, 2011). In an ETS mechanism, each participant (usually represented by a firm) is allocated a certain quota of emissions permits in the primary ETS market, and trades with other participants in the secondary ETS market for additional permits to support its production or for benefit if redundant permits are left (Tang et al., 2016; Zhang et al., 2015). Since the first ETS market was built in the EU in the year 2005, the ETS has been popularly introduced as the most promising mitigation tool, such as in the Regional Greenhouse Gas Initiative (RGGI) of the U.S. in 2009, the New Zealand ETS in 2010, and the Domestic Emissions Reduction Scheme of Australia in 2012. As the largest carbon emitter, China announced seven ETS pilots in Beijing, Tianjin, Shanghai, Guangdong, Hubei, Chongqing and Shenzhen in 2011, and planned to build a nationwide ETS mechanism in 2017. Given that China's current ETS policy varies largely across different pilots (see Table 1), an interesting question is raised concerning an appropriate ETS policy design for China. Under such a background, this study especially focuses on China's nationwide ETS, as well as the corresponding economic impact and mitigation effect, which reveals helpful policy implications for China's ETS design.

As a market-driven mitigation approach, the primary ETS market for initial allowance allocation may be the most important part in the ETS design (Zhang et al., 2014; Zhang and Hao, 2016). Table 1 lists the related information about the initial allowance allocation in the EU ETS and China's seven ETS pilots. According to the existing ETS policies and the related studies, the carbon allowance allocation methods can generally fall into history-based methods (e.g., grandfathering approach and benchmarking approach), auction-based methods (e.g., single-round auction and multi-round auction) and combinations coupling any two or more of above approaches. In current application, the history-based methods have widely been utilized for allocating free carbon permits, e.g., in the EU ETS and China's ETS pilot programs. However, for this market-driven tool of ETS, the auction-based methods possess their unique merits and have aroused

* Corresponding author.
E-mail addresses: tangling@mail.buct.edu.cn (L. Tang), wujiaqian@casipm.ac.cn (J. Wu), yulean@amss.ac.cn (L. Yu), baoqin@amss.ac.cn (Q. Bao).

http://dx.doi.org/10.1016/j.enpol.2016.11.041
Received 24 June 2016; Received in revised form 22 October 2016; Accepted 26 November 2016

Table 1
Related information about the initial carbon allowance allocation in the EU ETS and China's ETS pilots. (Source: Zhang et al. (2015), Tang et al. (2016), Xiong et al. (2017) and the Climate Action of European Commission (http://ec.europa.eu/clima/))

ETS market		Ratio of the corresponding permits to total carbon cap (%)			Allocation method for free permits		
		For free	For auction	At fixed prices	GF	BM	SD
China	Beijing	≥95%	< 5%	< 5%	√	√	
	Shanghai	100%	0%	0%	√	√	
	Tianjin	100%	0%	0%	√	√	
	Shenzhen	≤95%	≥3%	≥2%		√	
	Chongqing	100%	0%	0%			√
	Guangdong	≤97%	≥3%	0%	√	√	
	Hubei	≥90%	≤3%	< 7%	√	√	
EU ETS	Phase1	≥95%	≤5%	0%	√	√	
	Phase2	≥90%	≤10%	0%	√	√	
	Phase3	≤50%	≥50%	0%		√	

Notes: GF, BM and SD are the abbreviations for grandfathering, benchmarking and self-declaration methods, respectively; and the symbol "√" denotes the corresponding method is used.

an increasingly large interest. First, the auction markets for carbon allowances can effectively avoid the intrinsic shortcomings of the centralized allocation methods (particularly the history-based methods), i.e., political misallocation and regulatory distortion (Dewees, 2008; Dormady, 2014). Second, the auction-based methods can generate a higher surplus for consumers and a lower price level of products, compared with the grandfathering method (Goeree et al., 2010). Third, through market-based instruments, the auction-based methods cannot only reduce tax distortions but also provide greater incentive for technology innovation (Cramton and Kerr, 2002). To sum up, the history-based methods have led to inefficiencies in carbon market development, therefore, the auction-based methods are increasingly becoming the preferred allocation mechanism of policy-makers. For example, in the EU ETS and the four China's ETS pilots of Beijing, Shenzhen, Guangdong and Hubei, a certain proportion of carbon allowances are allocated via the auction-based methods. The RGGI allocates nearly 100% of carbon permits via the auction-based method (Dormady, 2014). Given such circumstances, the auction-based methods might be employed for allocating an increasingly larger proportion of emissions permits or even a 100% proportion in the later stages. Therefore, this paper specially focuses on the auction-based allocation methods and explores appropriate carbon allowance auction designs for China's ETS policy.

The auction forms can be generally divided into two main categories: static (or namely sealed and single-round) form and dynamic (or clock and multi-round) form. For carbon allowances, even though the question which auction form is better still remains a hot debate, an abundance of studies supported the former, due to its unique merits—simplicity of implementation, effectiveness in price discovery, and low transaction cost. For example, Cramton (1998) argued that due to the simplicity of implementation and bid evaluation, the sealed-bid auction can be considered as an effective auction form. Cong and Wei (2010) demonstrated that the static auction form with the virtue of simplicity outperforms the dynamic auction for carbon permits auction. Mandell (2005) argued that the multiple-round auction may be more conductive to collusion, while the single-round auction outperforms the multiple-round auction in terms of efficiency. Similarly, Burtraw et al. (2009) suggested that the clock auction is more likely to facilitate collusion than the sealed auction. Besides, due to a larger number of transactions, the multiple-round auction undoubtedly generates a much higher transaction cost than the single-round auction (Mandell, 2005; Klemperer, 2002). Goeree et al. (2013) suggested that the single-round form, e.g., the discriminatory price auction, can bring larger revenue for auctioneer than the clock auction. Similarly, Burtraw et al. (2001) confirmed the superiority of the single-round auction over the clock auction, in terms of high revenue. Therefore, the simple but effective auction form, the single-round auction, is especially considered here for China's ETS design.

As for analysis techniques, the most popular numerical tools for investigating the ETS policy are simulation models, optimization programming models and experimental analysis methods. For simulation models, Edwards and Hutton (2001) examined the effects of various economic instruments for carbon emissions reduction, by employing the computable general equilibrium (CGE) model. Cong and Wei (2010) proposed a multi-agent-based simulation model to explore which carbon auction rule (the uniform-price or discriminative-price rule) is better. Similarly, Tang et al. (2015) developed a multi-agent-based simulation model for carbon emissions trading scheme, and evaluated its impacts on China's economy and environment. Tang et al. (2016) explored China's ETS based on a dynamic CGE model. As for optimization methods, Haita (2014) proposed an optimization model based on game theory to analyze the endogenous market power of an ETS auction market. As for experimental analysis, Cong and Wei (2012) compared uniform-price auction, discriminative-price auction and English clock auction in terms of carbon price, auction efficiency, demand withholding and fluctuations of power supplies. Similarly, Dormady (2014) studied the carbon emissions market via an experimental analysis approach. Among these above techniques, the typical bottom-up analysis technique, i.e., the multi-agent-based approach, possesses its unique merits for investigating the market-driven mitigation tool of ETS (Tang et al., 2015). In particular, the multi-agent-based model can effectively capture the activities and interactions between various specific agents in the economic system, in which a group of heterogeneous agents make independent decisions based on their respective goals and adjust their actions according to the changes of the external environment. Therefore, this study especially employs the multi-agent-based model to simulate the market-driven mitigation tool of ETS policy.

However, the existing numerical studies were mainly limited to one or some ETS-related sectors, which cannot capture the general impact of ETS on a nationwide scale. For example, Demailly and Quirion (2008) investigated the impacts of ETS only on iron and steel industry, Dormady (2014) for energy sector, Pentelow and Scott (2011) for tourism industry, Anger (2010) for aviation industry, Szabó et al. (2006) and Deja et al. (2010) for cement industry, and Cong and Wei (2010) for power sector. Nevertheless, given that China tends to establish a nationwide ETS in 2017, an overall evaluation for the impact of ETS on China's whole economy and environment becomes an urgent task (Tang et al., 2015). Therefore, this study tries to formulate a nationwide ETS simulation model covering different sectors in China's economic system, to explore an appropriate carbon allowance auction design for China's ETS policy.

Generally speaking, this study tries to build a nationwide ETS simulation model via the multi-agent-based approach, in which the auction-based allowance allocation is especially analyzed for China's ETS investigation. The major innovations of this paper can be summarized into the following three aspects. First, given that the ETS policy is a market-driven mitigation instrument, the most typical bottom-up analysis technique, i.e., the multi-agent-based model, is implemented to effectively capture the activities and interactions among various heterogeneous agents under the ETS, rather than the CGE approach (a typical top-down model) which conducts analyses at a whole sectoral level and fails to simulate the microscopic behaviors in the ETS market (such as carbon bidding, bidding strategy adjustment and speculation). Second, different from most existing numerical models focusing on certain ETS-related sectors, the proposed model covers all the sectors in China's economic system to provide a general analysis from the macroscopic perspective. Third, different designs in the carbon auction market, in terms of different auction forms and carbon caps, are investigated, which can offer helpful insights into