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Designing an emissions trading scheme for China with a dynamic computable general equilibrium model

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HIGHLIGHTS

- A dynamic CGE model is built for emissions trading scheme (ETS) in China.
- A new ETS module is formulated and introduced to capture diverse ETS designs.
- Designs for carbon cap, permit allocation and supplementary policy are considered.
- Different designs are simulated to give helpful insights into China's ETS policy.

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ABSTRACT

To fulfill its Copenhagen pledges to control carbon emissions and mitigate climate change, China plans to establish a nationwide emissions trading scheme (ETS) in 2016. This paper develops a multi-sector dynamic computable general equilibrium model with an ETS module to study the appropriate ETS policy design, including a carbon cap, permit allocation and supplementary policies (e.g., penalty policies and subsidy policies). The main results are as follows. (1) To achieve China's Copenhagen pledge, the equilibrium nationwide carbon price is observed to be between 36 and 40 RMB yuan per metric ton. (2) The ETS policy has a cost-effective mitigation effect by improving China's production and energy structures with relatively little economic harm. (3) Various ETS sub-policies should be carefully designed to balance economic growth and carbon mitigation. In particular, the carbon cap should be set according to China's Copenhagen pledge. A relatively large distribution ratio of free permits, the output-based grandfathering rule for free permits, a penalty price (on illegitimate emissions) slightly above the carbon price, and a sufficient subsidy (from ETS revenue) are strongly recommended in the early stages to avoid significant economic loss. These designs can be adjusted in later stages to enhance the mitigation effect.

1. Introduction

As the world's largest carbon emitter, China is now confronting the pressure of carbon mitigation at both global and domestic levels, and is currently looking at a market-based instrument – the carbon emissions trading scheme (ETS). At the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change in Copenhagen, Denmark, China made a promise to reduce its carbon intensity by 40–45% by the year 2020, relative to 2005 levels. In October 2015 in the Thirteenth Five-year Plan (2016–2020), the Chinese government issued another emissions reduction goal concerning carbon emissions peak around 2030. To achieve the joint goal of emissions reduction and economic growth, China has recently implemented a series of mitigation instruments, including an ETS. In November 2011, China's National Development and Reform Commission (NDRC) approved five ETS pilot programs in the cities of Beijing, Tianjin, Shanghai, Chongqing and Shenzhen, and two in the provinces of Guangdong and Hubei. In September 2014, China's NDRC proposed the National Climate Change Plan for 2014–2020 and planned to establish a nationwide carbon trading market in 2016 based on the experience of the above pilots.

Compared with other mitigation measures, ETSs have been widely considered to be cost-effective instruments that offer flexibility via a market mechanism instead of compulsory regulations (Dales, 1968). In an ETS mechanism, each participant (represented by a firm, a sector, a region, a country or a set of countries) is allocated a certain quota of emissions permits for a given period, and can buy further additional allowances (or sell

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Table 1
Main policy designs for China's seven ETS pilots for the years 2013–2015.

Pilot	**Mean carbon price in 2015** (RMB per metric ton)	**Sub-policy**				
		Carbon Cap (million)	**Distribution ratio** (%)		**Allocation rule of free permits**	**Supplementary policy**
			For free	For auction		
Beijing	52.58	70	100	0	Grandfathering/ Benchmarking	Penalty policy
Tianjin	18.95	150	100	0	Grandfathering	–
Shanghai	19.60	150	100	0	Grandfathering/ Benchmarking	–
Guangdong	17.66	350	97	3	Grandfathering/ Benchmarking	Penalty policy
Hubei	27.50	120	80	20	Grandfathering	–
Chongqing	24.00	100	100	0	Grandfathering	–
Shenzhen	43.92	30	100	0	Grandfathering/ Benchmarking	Penalty policy

redundant allowances) in the ETS market (Braun, 2009; Jaehn and Letmathe, 2010). Accordingly, the ETS mechanism, a cap-and-trade policy, covers a set of sub-policies, for example, a carbon cap (for determining total permit supply), carbon allocation (in terms of distribution ratios and allocation methods for free permits), and supplementary policies (to regulate the ETS mechanism and avoid market instability) (Tang et al., 2015a). Deliberate ETS designs in terms of the above sub-policies can effectively guarantee the mitigation effect and alleviate any economic losses caused by the ETS policy (Hübler et al., 2014). Therefore, this paper largely focuses on China's ETS design for a series of ETS sub-policies.

According to China's current ETS policy in the different pilots, the sub-policies of carbon cap, permit allocation and supplementary policy vary greatly, as listed in Table 1. As for the carbon cap, based on different mitigation targets, different pilots hold different levels. In particular, the total number of carbon permits supplied in the ETS markets of Beijing, Tianjin, Shanghai, Guangdong, Hubei, Chongqing and Shenzhen represent 70, 150, 150, 350, 120, 100 and 30 million metric tons, respectively, for 2013–2015. Regarding permit distribution, the five pilot programs in Beijing, Tianjin, Shanghai, Chongqing and Shenzhen allocate all carbon permits for free, while the two in Hubei and Guangdong assign 80% and 97% of carbon permits, respectively, for free and the rest by auction. Concerning the allocation methods for free permits, three pilots (i.e., Tianjin, Hubei and Chongqing) have implemented the grandfathering rule for all sectors, while the other four in Beijing, Shanghai, Guangdong and Shenzhen adopt different methods for different sectors. For example, in Beijing's ETS, the benchmarking rule is used for the heat and coal electricity sector, while the grandfathering rule is used for other sectors. Regarding supplementary policies, a penalty policy is commonly employed to guarantee the mitigation effect of an ETS. For example, Beijing, Guangdong and Shenzhen all impose penalties for illegitimate emissions (i.e., extra emissions beyond the permits) at a penalty price approximately three to five times higher than corresponding mean annual carbon prices.

An interesting question is then raised regarding which design might be more suitable for China at a national level, given the discrepancies among the seven ETS pilots. Furthermore, as China plans to build a nationwide carbon trading market in 2016, it is imperative to estimate the potential impacts of the different ETS designs. We can then identify the optimal scheme to ensure the effectiveness of the ETS and attenuate mitigation costs (Tang et al., 2015a; Hübler et al., 2014). At present, existing studies on China's ETS policies are somewhat insufficient, and the related literature has not yet conducted a thorough comparison of the different designs for various sub-policies via a quantitative analysis. Therefore, the present study attempts to fill this void by investigating the potential impacts of different ETS designs (with different sub-policies) on China's economy. This will provide insight into the implications of China's ETS mechanism design. In particular, a multi-sector dynamic computable general equilibrium (CGE) model is developed with a new ETS module that describes such a cap-and-trade policy. Different ETS sub-policies scenarios, that is, carbon caps, distribution ratios of free permits (or auctioning permits), allocation methods for free permits, penalty prices, and ETS revenue distributions (e.g., via subsidies), are carefully designed and simulated to explore the most suitable ETS design for China.

Generally, the main aim of this paper is to build a CGE model with an ETS module to study the impacts and effectiveness of an ETS in China and to find the most appropriate nationwide ETS design for China. Compared with existing research, this paper contributes to the literature from two main perspectives: (1) concerning model formulation, an ETS module comprehensively capturing various sub-policies is developed and introduced to the typical CGE model; and (2) regarding design exploration, in contrast to existing studies that focus on one or just a few sub-policies, this study attempts to conduct a thorough comparison among different ETS designs including carbon caps, allocation ratio of free allowances (or auctioning allowances), allocation rule for free permits, penalty price, and ETS revenue distribution (e.g., subsidy policy). This analysis will reveal the policy implications of China's ETS design.

The remainder of the paper is organized as follows. A literature review of China's ETS policy analysis is presented in Section 2. The CGE model with an ETS module is formulated in Section 3. Section 4 reports and discusses the simulation results. Section 5 concludes the paper and outlines the possible problems of further research.

2. Literature review

Since the concept of ETSs was first proposed by Dales (1968), market-based mitigation policies such as these have attracted increasing attention from both theoretical and practical perspectives. Regarding basic theoretical research, Braun (2009) analyzed the development of European Union-based ETSs and summarized the advantages of such climate policies. Zhang (2016) reviewed related studies on carbon trading market mechanisms and discussed current limitations. Concerning practical research, an abundance of studies have been conducted to design a unified international ETS mechanism (e.g., Grubb, 2003), evaluate the economic and environmental impacts of ETSs (e.g., Sterner, 2002; Lee et al., 2008; Zhao et al., 2010) and make various optimal decisions under ETSs (e.g., Tietenberg, 1985; Rong and Lahdelma, 2007; Li et al., 2014).

As for China's ETS policy, existing studies, based on qualitative analyses, have mainly focused on the challenges of implementing an ETS mechanism in China. For example, Zhang et al. (2014a) presented a historical tour of China's climate policies and a comprehensive overview of China's seven ETS pilot programs. The authors argued that formulating a national carbon emissions trading market in China