China's Carbon Emissions Trading:

Lessons from the Pilot Systems

by Zhoudan Xie

This paper examines China's seven carbon emissions trading pilot systems, which launched beginning in 2013 to inform the design of China's upcoming nationwide carbon emissions trading system. It analyzes the seven pilots' policy features and performance through a comprehensive review of prior studies, existing regulations, and empirical data. Finally, it highlights several lessons learned from the pilot systems and their ramifications for the implementation of the national carbon emissions trading system.

I. INTRODUCTION

The increasing severity of China's environmental problems has prompted the government to implement a variety of top-down "command and control" (C&C) measures to reduce pollution. As in many other countries, C&C has been the conventional approach to addressing environmental issues in China. However, economists widely agree that C&C measures are often associated with a higher marginal abatement cost (the cost of reducing one additional unit of emissions) and lower social efficiency (the extent to which resources are optimally distributed in society). In line with its growing commitment to combat climate change, China is exploring market-based instruments (MBIs) such as carbon emissions trading to meet its carbon dioxide (CO_2) reduction targets under the United Nations Framework Convention on Climate Change (UNFCCC).

MBIs are policy instruments that attempt to internalize environmental and other negative externalities by providing economic incentives for pollution control. Examples of MBIs include pollution charges, corrective taxes, subsidies, and tradable permits (Stavins 1998). Emissions trading, or "cap and trade," is an MBI that allows trading of pollutant emission permits between firms to meet a prescribed emission limit (ICAP 2016a). Cap and trade is considered more efficient than the conventional C&C approach because it provides firms with the flexibility to exercise pollution control at the lowest possible cost to society while stimulating technological innovation (Stavins 1998).

Following the State Council[1] of China's October 2010 declaration on carbon emissions trading, China's 12th Five-Year Plan[2] (2011-2015) announced plans to establish carbon emission trading systems (ETS) as an integral part of China's greenhouse gas (GHG) emissions reduction strategies (State Council 2011). The National Development and Reform Commission (NDRC), a central economic planning agency under the State Council, has administrative and planning control over the ETS (NDRC 2011). To prepare for a national carbon emission trading market, the NDRC authorized seven ETS programs for a pilot phase from 2013 to 2015 (Qi and Cheng 2015). Five cities—Beijing, Chongqing, Shanghai, Shenzhen, and Tianjin—as well as two provinces—Guangdong and Hubei—were selected as pilot sites (NDRC 2011). At the beginning of 2015, NDRC officials revealed that the national ETS would be initiated in 2016 (People's Daily 2015).

In June 2015, China submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC, outlining ambitious post-2020 actions to cut carbon emissions (NDRC 2015). China's INDC sets two primary goals for the year 2030: achieving peak CO_2 emissions and reducing CO_2 emissions per unit of GDP by 60 to 65 percent from 2005 levels (NDRC 2015). The INDC also reiterates China's pledge to implement a nationwide carbon ETS (NDRC 2015). During his state visit to the US in September 2015, Chinese President Xi Jinping issued the US-China Joint Statement on Climate Change, formally announcing that the national ETS would be launched in 2017 (White House 2015).

The seven pilot systems were created to determine the policy features best suited to a nationwide ETS. To that end, the NDRC selected pilot locations representing a wide range of economic, social, and demographic circumstances in China. The seven pilots cover emitters responsible for 1,250 megatons of CO_2 equivalent ($MtCO_2e$), making China the second-largest carbon market in the world after the EU Emissions Trading System (EU ETS)

1 The State Council is the chief administrative authority of the People's Republic of China. It is responsible for carrying out the laws and regulations adopted by the congress.

2 China's Five-Year Plans establish the nation's social and economic development agendas and goals for every five years. The 12th Five-Year Plan was adopted by the congress in 2011, setting the nation's course for 2011-2015.

(World Bank 2014). Following the June 2013 launch of the first pilot in Shenzhen, the remaining pilots were introduced throughout the following year. All seven pilots have now been implemented for at least one year, enough time for an initial evaluation.

A thorough understanding of the successes and challenges in the pilot phase is crucial for both China's implementation of a national ETS and global knowledge about carbon market development. Therefore, this paper will answer three research questions:

1. What are the policy features of each ETS pilot?
2. How have the seven ETS pilots performed?
3. What lessons can be drawn from the pilot systems to guide the national ETS?

To answer these questions, this paper will first describe the major policy features of the pilot systems, including the design features of the emissions trading markets and provisions for compliance and incentives. Next, this paper will examine the pilots' market performance, and the covered firms' compliance with the programs. Finally, this paper will summarize lessons from the pilot systems for China's establishment of a nationwide carbon emissions trading program.

Table 1 provides an overview of the seven ETS pilots. The appendix summarizes the detailed design features and market performances.

II. POLICY FEATURES OF THE ETS PILOTS

Carbon emissions trading is a type of cap-and-trade system where regulators typically set the cap: a limit on the total carbon emissions during a given period for all of the firms covered by the system (ICAP 2016a). Regulators will then distribute permits, either by auction or free allocation, to the covered firms for their initially allowable emissions, which are referred to as allowances (Goulder 2013). The total amount of allowances should be equal to the cap (EDF 2016). Under the system, the covered firms are not legally allowed to release more emissions than the allowances they are holding for the given period (ICAP 2016a). Allowances can be traded in the market, so that the firms can buy or sell allowances according to their needs (ICAP 2016a). At the end of each compliance period, each firm must turn in, or "surrender," sufficient allowances to the relevant authority to cover all its emissions (European Commission 2016). In principle, firms with lower marginal abatement cost – the cost of reducing one additional unit of emissions – will choose to invest in reductions and sell their excess allowances in the market, while firms with higher marginal abatement cost will buy allowances from the market (ICAP 2016a). Following this logic, emissions trading will achieve more cost-effective emissions reductions than conventional C&C instruments (Stavins 1988).

A. Cap Setting

A typical approach to achieving a long-term emission reduction target is to set an annual cap on emissions and reduce it gradually each year until it reaches the target (C2ES 2008). In some circumstances, the cap is

Table 1: Overview of China's ETS Pilots

		Shenzhen	Beijing	Shanghai	Guangdong	Tianjin	Hubei	Chongqing
ETS Start date		June 2013	Nov. 2013	Nov. 2013	Dec. 2013	Dec. 2013	Apr. 2014	June 2014
Carbon emissions ($MtCO_2e$)	2010	83.4	110	230	541	155	306	131
	2012	153	188.1	297.7	610.5	215	463.1	243.1
Carbon intensity target* by 2015 (relative to 2010)		-21%	-18%	-19%	-19.5%	-19%	-17%	-17%
Carbon emissions covered by the ETS in its initial year ($MtCO_2e$)		32	50	160	408	160	324	125
Number of firms covered by the ETS	2013	635	415	191	184	114	N/A	N/A
	2014	634	543	191	184	112	138	242

** The carbon intensity target for each province and city was specified by China's 12th Five-Year Plan. It refers to the overall target of carbon emissions per unit of GDP by 2015 for each province and city in China, not the targets of the seven ETS pilots. Carbon emissions trading is a major instrument for meeting the carbon intensity targets, but it is not the only one.*
Source: Table created by the author using data from ICAP 2016c, IETA 2015, CDC 2015, SinoCarbon 2015a and 2015b, and World Bank 2014.

allowed to either stabilize or increase for a period of time before being reduced, since emissions released at a particular point in time do not have significant effects on the climate due to the long atmospheric lifetime of most GHGs (C2ES 2008).

Depending on the approach to setting emission limits, a cap-and-trade system can adopt an absolute or intensity-based cap. An absolute cap limits total emissions to a fixed quantity, while an intensity-based cap restricts emissions to a specified rate relative to input or output, such as emissions per unit of GDP or emissions per capita (Ellerman and Wing 2003). Intensity-based caps are less controversial in a developing economy because they are seen as more compatible with continued GDP growth (Han et al. 2012). In an ideal word where future GDP is known with certainty, the two forms of caps can be set to have identical effects on emission reductions (Ellerman and Wing 2003). However, in the real world, there is generally uncertainty about future economic performance. An intensity-based cap demonstrates more flexibility by translating economic uncertainty into environmental uncertainty, i.e. the absolute amount of emission reductions is not known in advance, but depends on actual GDP (Ellerman and Wing 2003).

As an emerging economy with rapid GDP growth, China has intensity-based carbon emissions targets set at both the national and regional levels (NDRC 2015; World Bank 2014). Despite this, six of the pilots surprisingly selected absolute caps except for Shenzhen, which set an intensity-based cap defined by tons of CO_2 equivalent (tCO_2e) for every 10,000 Chinese Yuan (CNY) ($1,600[3]) of industrial output (World Bank 2014). If the intent of allowing independent regional designs was to determine the most suitable features for adoption at a national level, the prevalence of absolute caps in the pilots might impair their learning value, given that the national cap setting has yet to be officially determined (NDRC 2014). One possible motivation for selecting absolute caps is to avoid complexity of the system and higher administrative costs (SRCUD and SEE 2015). When implementing an intensity-based cap, regulators need data on the value added of each sector to the overall GDP to disaggregate the cap for each sector (SRCUD and SEE 2015). This type of data is limited and inconsistently calculated in China, so the administrative costs of an intensity-based cap would be much larger than for an absolute cap (SRCUD and SEE 2015). Among the pilot systems with absolute caps, Beijing and Shanghai set their annual caps for the entire three year pilot period in their initial plans, while the others determine caps on a yearly basis (Beijing Government 2013; Shanghai Government 2012; Chongqing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014; Tianjin Government 2013a).

Regardless of the type of cap, a major challenge in cap setting is over-allocation. For example, if the annual emissions in 2015 were 100 $MtCO_2$, a government might set an annual absolute cap of 90 $MtCO_2$ for 2016 to encourage reductions. However, if the actual emissions were then only 80 $MtCO_2$ in 2016, the cap would be too loose to control emissions, leading to an over-supply of allowances in the market. In the case of the EU ETS, market prices of allowances declined to extremely

3 Exchange rate used in this paper is 1 Chinese Yuan=USD $0.16.

low levels due to generous caps (Goulder 2013). One can see China's ETS pilots also running the risk of over-allocation in the discussion of market performance below.

B. Covered Sectors

Despite their differing designs, the seven pilot systems selected covered firms from sectors with high levels of carbon emissions or energy consumption (Environomist 2015). For this reason, most of the pilots cover the electricity, steel, cement, and petrochemical sectors (Qi and Cheng 2015). However, the number of covered firms varies substantially across the pilots because of the different industrial structures in each region. For example, Guangdong and Hubei Provinces have the most industrialized economies, dominated by large-scale, carbon-intensive industries like heavy chemical firms (Qi and Cheng 2015). Because of this, the two provinces cover the two largest volumes of emissions while their numbers of covered firms are relatively small (Table 1) (Qi and Cheng 2015). On the other hand, Beijing and Shenzhen pilots cover more firms than the others though their volumes of emission coverage are the smallest (World Bank 2014). Both cities have economic systems dominated by non-industrial and service sectors, so individual firms have relatively small carbon emissions. Shenzhen's 635 covered firms include enterprises with annual emissions above 3,000 tCO_2e, while the others cover firms with annual emissions at least 10,000 tCO_2e (Environomist 2015); and the pilot in Beijing, the capital city of China, also covers many government agencies (Environomist 2015). As an industrial and financial center of China, Shanghai contains both industrial and non-industrial sectors, and thus covers a wider range of sectors in its trading system compared to the others (Environomist 2015).

In addition to mandatory covered firms, other eligible entities, such as voluntarily participating firms, investment institutions and individuals, are also allowed to participate in the markets of all the pilot systems (Environomist 2015).

C. Allowance Allocation

Free allocation and auctioning are the two best-known methods of introducing emission allowances into circulation. One prevailing economic opinion is that the choice of allocation method affects the distribution of wealth between the government and recipient firms, but not the cost-effectiveness of a cap-and-trade program (Goulder 2013). However, recent studies (Parry and Williams 2010; Goulder et al. 2010) found evidence indicating that auctioning could substantially reduce overall policy costs compared to free allocation if taking into account interactions with the fiscal system, because revenues from auctions can be recycled in the form of cuts in distortionary taxes on income, sales and payroll. Nevertheless, free allocation is still a principal approach in cap-and-trade programs because it places less cost on firms, making implementation more palatable in the initial stages (Goulder et al. 2010). All the pilot systems employ free allocation, though several are moving toward a combination of the two methods. Under free allocation, the ETS pilots allocate almost all allowances to firms at no cost. Shanghai conducted a one-off free allocation for the full pilot period (2013-2015) in 2013, while the others allocated allowances on a yearly basis (ICAP 2016c). Guangdong and Shenzhen have attempted an innovative approach by allocating a small fraction of allowances through auctioning (ICAP 2016c). Guangdong was the first ETS in China to incorporate mandatory auctioning into its design (Guangdong Government 2014a). Firms were initially required to purchase a minimum of 3 percent of their annual allocation at a reserve price of CNY60 ($9.60) per tCO_2e through auctioning before receiving the remaining 97 percent for free (Guangdong Government 2013). However, this rule was adjusted in the subsequent policy on allowance allocation. Auctioning became voluntary for covered firms and the reserve price was substantially decreased (Guangdong Government 2014b). Shenzhen auctioned 3 percent of allowances on a voluntary basis in 2014 (ICAP 2016c).

D. Monitoring, Reporting and Verification (MRV)

From cap setting to verification of compliance, a successful cap-and-trade system requires accurate emissions data. A transparent, inclusive, and credible monitoring, reporting and verification (MRV) mechanism is crucial for China's ETS pilots to be effective. Monitoring typically operates in one of two ways: carbon emissions can be monitored continuously using a real-time monitoring device, such as a continuous emissions monitoring system, or calculated using the emission factors of energy consumed and the chemical processes involved in a firm's manufacturing or production processes (ICAP 2016b). Continuous monitoring is more precise, but it often requires substantial investment in equipment and technology (Liu et al. 2014). Therefore, ETS monitoring often relies on the emission-factor approach that is applied to quantities of inputs, outputs, or both. It is the first carbon accounting approach recommended by the Intergovernmental Panel on Climate Change (IPCC), and most widely used in the world (Liu et al. 2014). Unfortunately, it has less flexibility if the chemical processes are updated frequently (Liu et al. 2014).

Under an MRV mechanism, emissions data should be reported to relevant authorities on a regular basis and verified by both government inspectors and a third party (ICAP 2016b). For example, the EU ETS has adopted a comprehensive MRV mechanism, known as the "compliance cycle" (European Commission 2016). Covered firms are required to submit an approved monitoring plan for every facility, and each facility must report its annual emissions using a standardized electronic template prepared by the European Commission (European Commission 2016). The data in the emissions report then must be verified by an accredited third party by March 31 of the following year (European Commission 2016).

In China, a pilot's Interim Measures for the Administration of Carbon Emissions Trading, or "Interim Measures," a government order setting each pilot's policies, includes general MRV requirements (Beijing Government 2014a; Chongqing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014; Shanghai Government 2013; Tianjin Government 2013a). Only three pilots, Hubei, Shanghai and Tianjin, require the submission of annual monitoring plans defining the monitoring scope, methods, frequency, and responsible person (Hubei Government 2014a; Shanghai

Government 2013; Tianjin Government 2013a). Reporting of emissions is required on an annual basis by all the pilots, and the submitted reports must be verified by an accredited third party that can be appointed by the government or contracted by the firm (Beijing Government 2014a; Chongqing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014; Shanghai Government 2013; Tianjin Government 2013a).

However, the Interim Measures is a general policy directive, and does not provide technical guidance for MRV (Beijing Government 2014a; Chongqing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014; Shanghai Government 2013; Tianjin Government 2013a). Since a national guiding document (NDRC 2013) had not been issued when the pilots were planned, the pilots issued their own regional MRV guidelines. All regional guidelines specify the methodologies of GHG emissions accounting and reporting for major covered sectors. Because of the large scope and heterogeneity of covered sectors, all the pilots obtain emissions data using the emission-factor approach. The regional guidelines also specify the emission factors that should be used for different energy sources and chemical processes (Beijing Government 2013; Chongqing Government 2014c; Guangdong Government 2014c; Hubei Government 2014b; Shanghai Government 2014; Shenzhen Government 2012; Tianjin Government 2013b).

E. Penalty and Reward

Penalties are effective means of ensuring firms' compliance with the rules of a cap-and-trade system. Here, "non-compliance" refers to a firm's failure to surrender sufficient allowances for its emissions by the end of a compliance year, failure to submit monitoring plans or emissions reports by specified dates, or submission of falsified data and reports. The EU ETS provides an example of effective penalties. In its second trading period (2008-2012), the EU ETS increased its penalty for failure to surrender sufficient allowances from 40 euros to 100 euros per tCO_2e (European Commission 2016), a considerably higher rate than the market price of allowances (an average of 15 euros at that time) (Goulder 2013). These significantly high penalties can urge covered firms to purchase allowances from the market to meet compliance.

In China, all pilots impose non-compliance penalties, but their magnitude varies. In the Guangdong pilot, firms failing to align their carbon emissions with allowances will have double the amount of exceeding emissions deducted from their allowances allocated for the next year and will be charged a fine of CNY50,000 ($8,000) (Guangdong Government 2014a). In addition to penalties, Guangdong has adopted two rewards to encourage compliance: giving a firm priority for national low-carbon development funding and the periodic publication of their positive compliance status (Guangdong Government 2014a; Munnings et al. 2014). However, the effect of these rewards on the firms' incentive for compliance is unclear.

Shanghai charges a fine of CNY10,000-30,000 ($1,600-$4,800) to firms failing to submit emissions reports or providing falsified information during verification and CNY50,000-10,000 ($8,000-$16,000) to firms failing to surrender sufficient allowances (Shanghai Government 2013). Shanghai regulators may impose additional sanctions for serious violations, including recording unlawful acts in the credit information of the firm, publishing unlawful acts on government websites or through the media, and revoking the firm's qualification for special energy conservation and emissions reduction funding (Shanghai Government 2013).

In addition to fines for firms failing to comply with the MRV legal requirements, Shenzhen, Beijing and Hubei also fine firms for failing to surrender enough allowances based on the amount of missing allowances (Beijing Government 2014c; Hubei Government 2014a; Shenzhen Government 2014). For example, Hubei fines firms one to three times the average market price for the compliance year for each missing allowance, and will deduct double the amount of missing allowances from following year's allocation (Hubei Government 2014a).

Comparatively, penalties in Chongqing and Tianjin are less severe. In both pilots, a firm's non-compliance will be published and the firm will be disqualified for potential financial aid or grants related to climate change for three years (Chongqing Government 2014a; Tianjin Government 2013a). However, those pilots establish no specific fines (Chongqing Government 2014a; Tianjin Government 2013).

F. Carbon Offsetting

Carbon offsetting is a complementary instrument to market trading that can compensate for carbon emissions. A carbon offset is another form of allowance that can only be generated by a covered firm from emission reductions outside ordinary operations (WRI 2010). The use of carbon offsets is completely voluntary in principle (WRI 2010). In 2012, the NDRC announced a policy addressing complementary instruments for carbon emissions trading, primarily those created through the Clean Development Mechanism (CDM), a Kyoto Protocol mechanism to implement emission reduction projects in developing countries (NDRC 2012). The emission reductions achieved through CDM are verified by the NDRC, and then defined as Chinese Certified Emissions Reductions (CCERs) (NDRC 2012).

The ETS pilots are allowed to use the CCERs – rather than allowances from the ETS – for a limited number of carbon offsets (Beijing Government 2014a; Chongqing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014; Shanghai Government 2013; Tianjin Government 2013a). The covered firms in Shenzhen, Guangdong, Tianjin and Hubei are allowed to use CCERs to offset up to 10 percent of their annual allowances (1 ton of CCERs offsets 1 tCO_2e) (Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014; Tianjin Government 2013a). Chongqing allows carbon offsetting of up to 8 percent of the annual allowances, while Beijing and Shanghai allow up to 5 percent (Beijing Government 2014a; ICAP 2016c).

As within the ETS, firms decide to trade allowances based on their relative marginal abatement costs (ICAP 2016a), firms would seek offsets from external projects if the abatement cost is lower than the internal abatement cost. Thus, firms can achieve emission reductions in a more flexible and cost-effective way. In Beijing, a new policy issued in September 2014 expanded the scope of offsets (Beijing Government 2014b). The policy specifies two additional carbon offsetting instruments not available in the other pilots: Energy Conservation Project Emission Reductions and Forestry Carbon Sink Project Emission Reductions (Beijing Government 2014b). These two instruments serve the same functions as CCERs in Beijing, which can be generated from energy-saving projects and forestry projects respectively. This also means the covered firms in Beijing have more flexibility for compliance than the other six pilots because they could obtain carbon offsets using any of the three instruments mentioned above.

G. Price Management Provisions

Another significant concern for ETS is the volatility of allowance prices. In a typical cap-and-trade system, the supply of allowances is highly inelastic, so minor shifts in supply or demand can cause irregular price fluctuations (Goulder 2013). A certain level of price fluctuation encourages traders to seek arbitrage profit opportunities, but excessive volatility discourages firms' investments in emission reductions and may even lead to non-compliance (Peter Linquiti, personal communication, 2016). Therefore, price management provisions are critical for an effective carbon emissions trading market (Goulder 2013).

One effective government intervention is the incorporation of a price ceiling or price floor into the market. Price ceilings and price floors are governmental controls determining the highest and lowest prices an allowance can be traded for (Goulder 2013). In the event of price fluctuations beyond the ceiling or the floor, the government can either sell its reserve allowances or buy back allowances to stabilize the price (Goulder 2013). Shenzhen, Beijing, Guangdong, and Hubei set aside reserve allowances for this type of price stabilization (Beijing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014). The Shenzhen pilot holds 2 percent of its annual allowances in reserve and can buy back up to 10 percent of the total allowances during market fluctuations (Shenzhen Government 2014). Guangdong sets an explicit price floor for the auctions, which was initially CNY60 ($9.60) per tCO_2e and decreased to CNY40 ($6.40) after the first compliance period (ICAP 2016c). Shanghai's only price management measures are to suspend trading or impose limits on allowance holdings if prices vary more than 30 percent in a single day (ICAP 2016c).

The Hubei pilot sets an implicit price floor through its early "price discovery." Price discovery, as defined by the Hubei Interim Measures, is a mechanism in which the local Development and Reform Commission (DRC) releases a certain number of allowances into the market in the early stages to set initial expectations about the market price for traders (Hubei Government 2014a). Hubei reserves up to 10 percent of its total annual allowances for price management, from which up to 30 percent can be used for price discovery (Hubei Government 2014a). Hubei successfully explored market prices at an early stage by implementing public auctions at a reserve price of CNY20 ($3.08) before it formally started its ETS (Qi and Cheng 2015). Covered firms and investors auctioned on allowances based on their real needs, thereby forming price expectations in the market where prices were not clear at first. In general, the price ceilings and floors achieved by allowance reserves and price discovery help the pilots manage the prices in the carbon markets within a desirable range.

Another price stabilization mechanism is "inter-temporal banking" and "inter-temporal borrowing" of allowances. Inter-temporal banking is the practice of saving current allowances for future use, while inter-temporal borrowing is the use of future allowances in the current time period (Goulder 2013). These design features make the supply of allowances more elastic, reducing price volatility (Goulder 2013). Inter-temporal banking and borrowing contributed to the success of the US Sulfur Dioxide Allowance Trading Program, a US cap-and-trade program designed to reduce the sulfur dioxide emissions that cause acid rain (Goulder 2013). The ETS pilots in China allowed banking allowances for any future period before 2015, the last year of the first pilot period (ICAP 2016c). Banking allows firms to save their excess allowances for future use for either compliance or trading, and thus prevents price slumps in the market due to oversupply of allowances during a given period. Borrowing is not explicitly authorized in any of the pilots (ICAP 2016c).

III. PERFORMANCE OF ETS PILOTS

A. Allowance Prices

Allowances cannot be traded across pilots because each is considered a separate market (NDRC 2011). As shown in Figure 1, allowance prices in most pilots appear fairly stable as of July 2015, while many of them are trending downward.

Figure 1: Historical Allowance Prices in China's ETS Pilots

Source: Figure created by the author using data provided by ChinaCarbon.info.

As the first pilot, Shenzhen experienced large price fluctuations in its early stages. Prices began at CNY30 ($4.80) per tCO_2e, and continued to increase to a peak of CNY130 ($20.80) in October 2013 (ChinaCarbon.info 2015). The price then dropped down near CNY80 ($12.80) and maintained that level for the remainder of its first year of implementation (ChinaCarbon.info 2015). Since June 2014, its allowance prices have continued to decrease, reaching CNY35 ($5.60) per tCO_2e in July 2015(ChinaCarbon.info 2015). As the first carbon market in China, Shenzhen's initial fluctuations are considered to be a result of information asymmetry (Qi and Cheng 2015), since trading participants mostly had limited understanding of ETS and carbon allowances. As with other investments, trading participants tended to reserve their allowances when seeing an upward trend in price so they could sell them for greater profits in the future, causing the initial price jumps. As the market became more mature and predictable, prices fell back to a more reasonable level (Qi and Cheng 2015).

According to Figure 1, prices in the Guangdong pilot have experienced the largest decrease since its initiation. Prices started around CNY60 ($9.60) per tCO_2e in December 2013, and continued to decrease from July 2014 onward (ChinaCarbon.info 2015). In July 2015, its allowance price reached approximately CNY15 ($2.40), a 75 percent decrease from its starting price (ChinaCarbon.info 2015). This raises the question of what triggered the July 2014 decrease. As previously mentioned, Guangdong was the first pilot to introduce auctioning in allowance allocation, where firms were required to purchase 3 to 5 percent of their annual allowances in auctions before receiving free allocation of the remainder when the pilot began in 2013 (Guangdong Government 2014a). However, after only eight months, the Guangdong government issued another policy indicating that auctioning would become voluntary in the 2014 allowance allocation (Guangdong Government 2014b). According to the policy, covered firms still obtain 95 to 97 percent of their annual allowances from free allocation, but firms can decide on their own whether to purchase the remainder in auctions or give up these allowances (Guangdong Government 2014b). The policy change might cause a minor decrease in allowance supply, but it essentially gave the market a signal that the allowances became less valuable, causing a significant decrease of the market price.

The other pilots have fewer price fluctuations. The Hubei pilot has experienced the most stable allowance prices, remaining between CNY20-30 ($3.10-$4.60) with less than a 10 percent overall change (ChinaCarbon.info 2015). Hubei's stabilization is likely attributable to its early price discovery mechanism because it helped the trading participants form price expectations before the market was formally launched. Beijing and Shanghai have also maintained relatively stable prices (ChinaCarbon.info 2015). This stability is due to these pilots determining their caps and amount of allowances to be allocated to each firm for the whole pilot period (2013-2015) at the very beginning (Beijing Government 2013; Shanghai Government 2012). This approach helped trading participants make flexible investments and form reasonable expectations (Qi and Cheng 2015).

While the seven pilots started with widely varying prices, they are gradually moving toward a smaller price range. The prices in most of the pilots dropped under CNY20 in the summer of 2015 (ChinaCarbon.info 2015). One possible reason for the consistent downward trend in the seven pilots is the uncertainty of future policy and the value of allowances after 2015. China originally planned to initiate the national ETS in 2016, but it is uncertain how these pilots would be incorporated into the national market. While more research is needed, it seems likely that trading participants, including covered firms and voluntary participants, sold off their allowance holdings as the end of the pilot phase was approaching. This would have caused an increase in supply and decrease in the market price. It is also likely that firms in the pilot regions found more cost-effective emissions reduction methods, causing a decrease in the demand of allowances and thus a decrease in the price.

B. Compliance

Compliance status is another important criterion to evaluate the ETS pilots. Covered firms are required to surrender sufficient allowances for their emissions before an annual compliance deadline (Beijing Government 2014a; Chongqing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shenzhen Government 2014; Shanghai Government 2013; Tianjin Government 2013a). As of the end of 2015, Shenzhen, Beijing, Shanghai, Guangdong, and Tianjin have completed two compliance periods, which ended in July 2014 and July 2015, while Hubei and Chongqing have completed only one compliance period because of their relatively late starting dates. Table 2 summarizes the final compliance rates for the two periods. While the first five pilots all had final compliance rates over 96 percent for the two periods, Shenzhen, Tianjin, and Beijing all delayed their initially scheduled compliance deadlines (SinoCarbon 2015a). Shanghai is the only region to achieve 100 percent compliance on time (SinoCarbon 2015a). All of the first five pilots improved in the second compliance period (SinoCarbon 2015a; SinoCarnon 2015b). While Hubei had only 112 out of 138 covered firms in compliance as of the deadline in July 2015 (SinoCarbon 2015b), all remaining firms reached compliance in August following the Hubei DRC's order (Hubei Government 2015). As the newest pilot system, Chongqing only completed 70 percent compliance out of the 242 covered firms even after a one-month delay of the deadline (TanTongBao 2015). Chongqing's lower compliance rate may relate to its relatively brief time in operation, but is also likely a result of its looser penalty provisions, as discussed in the previous section.

While the first five pilots all achieved satisfactory compliance, their historical transaction data demonstrate a common characteristic: the highest volume of allowance trading occurred right before the annual compliance deadline. Figure 2 shows the proportion of the volume traded from May to July within the total volume traded in 2014. If trading occurred evenly throughout the year, about 25 percent of the transactions would take place during any three-month period (Peter Linquiti, personal communication, January 29, 2016). The trading volume from May to July, however, is nearly

90 percent of the 2014 total in Beijing, Guangdong and Tianjin, and is over 60 percent of the 2014 total in Shenzhen and Shanghai (SinoCarbon 2015a). While it does not affect the achievement of the overall emission reduction targets, this compliance-oriented trading creates higher costs for firms to acquire the same volume of allowances as they would if trading occurred more evenly throughout the year, reducing the cost-effectiveness of the cap-and-trade system (Qi and Cheng 2015).

Since its June 2014 launch, Chongqing's market has been largely inactive. From June 2014 to May 2015, there are only two days where a small volume was traded, with the other days having zero trading volume (ChinaCarbon.info 2015). The total volume traded between June and July 2015, right before the compliance deadline, was only 99,418 tCO_2e (ChinaCarbon.info 2015). While the other pilots used the average of historical emissions to determine their annual caps, Chongqing set its cap based on the highest annual emissions from 2008-2012 (Chongqing Government 2014b). This may have caused over-allocation, leading to the extremely low trading volume.

Table 2: Compliance Rates of the ETS Pilots

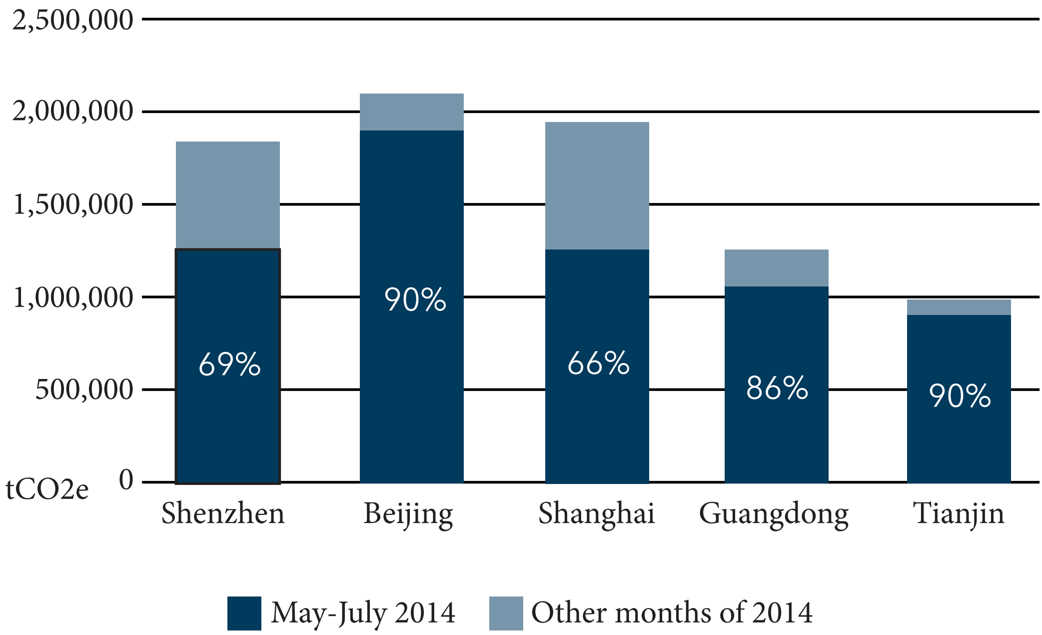
	Shenzhen	Beijing	Shanghai	Guangdong	Tianjin	Hubei	Chongqing
2013-2014: First Compliance Period							
Firms covered	635	415	191	184	114	-	-
Compliance rate	99.4%	97.1%	100%	98.9%	96.5%	-	-
2014-2015: Second Compliance Period							
Firms covered	634	543	191	184	112	138	242
Compliance rate	99.7%	100%	100%	100%	99.1%	100%	70%

Source: Table created by the author using data from Hubei Government 2015, SinoCarbon 2015a, SinoCarbon 2015b, and TanTongBao 2015.

IV. LESSONS FOR THE NATIONAL ETS

As the pilot phase ends and the national ETS implementation approaches, the lessons of the seven pilot systems should inform the design and implementation of China's national ETS program. This section first examines the existing policy regarding the establishment of the national ETS. It then discusses the lessons that can be drawn from the policy features and performance of the pilot systems.

Figure 2: 2014 Volume Traded in Five ETS Pilots



Source: figure created by the author using data from SinoCarbon 2015a.

A. Proposed National ETS

While multiple state-level policy documents (the 12th Five-Year Plan and China's INDC) have confirmed the intent to establish a national ETS, few policies have been issued concerning the system's specific design. As of the end of 2015, the Chinese government has issued only two noteworthy policy documents relevant to the national ETS (NDRC 2013; NDRC 2014).

In October 2013, the NDRC issued guidelines for GHG emissions accounting and reporting in 10 industry sectors, including electricity generation and distribution, steel production, chemical production, electrolytic aluminum production, magnesium smelting, plate glass production, cement production, ceramic production, and civil aviation (NDRC 2013). This document provides technical support for methodologies of carbon accounting, quality control, recordkeeping, and reporting in each industry (NDRC 2013). However, this document does not explicitly refer to the ETS pilots or national ETS.

The second key document is the state-level Interim Measures issued by the NDRC in December 2014, outlining an official framework for the national ETS (NDRC 2014). The framework specifies a few features of the national ETS: it confirms allowance allocation will be mainly free allocation in the initial stages, with auctioning being introduced and expanded gradually (NDRC 2014). It confirms the use of CCERs for carbon offsetting and allowance reserves for price management (NDRC 2014). In terms of MRV mechanisms, it refers to the above accounting and reporting guidelines as a major guiding policy for covered industries (NDRC 2014). However, this policy document lacks details about some key features of the national ETS, including cap setting, sector coverage, penalty, and other price-management provisions. The following section will discuss the lessons from the ETS pilots regarding these "missing" elements.

B. Lessons from the Pilots

Cap Setting

The first critical question in the design of China's national ETS is how tight the emissions cap should be. An excessively tight cap will impose undue technical and/or financial pressure on covered firms and lead to non-compliance, while an excessively loose cap will cause over-allocation of allowances, leading to inactive trading or significant price volatility. For example, in the Phase I of the EU ETS, allowance prices were around 30 euros ($33.57[4]) per tCO_2e (Goulder 2013). Due to the generous caps and the global recession, prices have dropped dramatically since 2006 (Goulder 2013). When Phase II began in 2008, prices rose to more than 20 euros ($22.38), but again fell to 13 euros ($14.55) in 2009 (Goulder 2013). The current prices are fluctuating around only 5 euros ($5.6) (EEX 2016). Such uncertain price fluctuation is certainly not desirable in China's ETS, because it would reduce investors' confidence and even undermine public support for emission trading systems.

Among China's ETS pilots, Chongqing displays signs of over-allocation. As discussed above, Chongqing has had extremely low trading volume since its beginning in 2014 (ChinaCarbon.info 2015). A likely reason is that the cap was too loose, so most covered firms had sufficient allowances for their emissions, and thus had no incentive to participate in the trading (or reduce emissions). This is evident in the method of cap setting adopted by Chongqing. Chongqing set its cap by summing up all the covered firms' highest, rather than average, annual emissions during 2008-2012, and then reducing that sum by 4.13 percent (Chongqing Government 2014b). Because firms' highest annual emissions are by definition higher than their average emissions, this design likely generated a loose cap and over-allocated allowances in the Chongqing pilot.

On the other hand, the cap setting in Beijing and Shanghai provided both stringency and flexibility. Both pilots set shrinking annual caps for the entire period at the beginning of the pilot phase (Beijing Government 2013; Shanghai Government 2012). Shanghai allocated all three years' (2013-2015) allowances to the covered firms once in 2013 based on the average level of all covered sectors' carbon emissions from 2009-2011 (Shanghai Government 2012). This approach implicitly allows inter-temporal borrowing, because it allows the firms to use or sell their future allowances in an earlier year. While Beijing allocated allowances once per year, the annual caps and the amount of allowances allocated to each firm from 2013-2015 were determined and announced in the beginning (Beijing Government 2013). This helped the firms form reasonable expectations for the market. These approaches in cap setting have played an important role in the stabilization of the markets, achieving less undesirable allowance price volatility.

4 Exchange rate used in this paper is 1 Euro=USD $1.12.

One way to determine whether a cap is efficient is to compare it with the "social cost of carbon" (SCC). The SCC is defined by the US Environmental Protection Agency (EPA) as "an estimate of the economic damages associated with a small increase in carbon dioxide (CO_2) emissions, conventionally one metric ton, in a given year" (EPA 2015). US federal agencies often use the SCC to estimate the benefits of environmental rulemaking. From an economic point of view, efficiency is maximized when the marginal cost of emission (the SCC) equals the marginal abatement cost (Goolsbee et al. 2013). If a cap-and-trade system operates properly, the market price of an allowance will reflect an equalized marginal abatement cost in the covered area (Goulder 2013). Thus, to examine whether a cap is maximizing efficiency, Chinese regulators could observe the market price for emissions allowances and gradually tighten the cap until the market price matches the SCC. However, another question is which version of the SCC estimate the price should be compared to. The US Interagency Working Group on Social Cost of Carbon's latest SCC estimate is $43 in 2020 (2007 dollars) at a 3 percent discount rate, revising their earlier estimate of $26 (IAWG 2013). Nevertheless, due to the complexity and uncertainty of inputs and discount rates used in the estimation, calculations of the SCC range widely, from as little as $10 to as much as $200 per tCO_2e (Pindyck 2013). The Chinese government rarely discusses the SCC in its policy documents about the ETS; in fact, this author could find no reference to the SCC in these documents. However, the SCC could be introduced as a potential instrument for evaluating the cap by comparing the observed market price for allowances to the SCC.

Sectoral Coverage

The sectoral coverage among the seven ETS pilots is very diverse, but all the pilots started with firms that have large amount of carbon emissions or energy consumption (Environomist 2015). This should be a feature of the national ETS as well. Covering large emitters is likely essential to achieving emissions targets because of their large contribution to the national emissions. Furthermore, if the government's administrative costs of enforcing and supervising the policy are roughly the same for each firm, covering large firms will require lower administrative costs per ton of emissions than covering many small firms.

One point worth considering in selecting covered firms is whether the firm has the capacity to participate in and comply with the system. A survey of the reasons for non-compliance in the pilots shows firms failing to surrender sufficient allowances mostly lack knowledge of emission trading and its procedures (Environomist 2015). These firms were primarily small firms with insufficient human resources or firms without extra funding to invest in emission reduction measures or to purchase allowances (Environomist 2015). If the national ETS covers these types of firms, additional technical support may be required to ensure compliance among these firms.

Penalty

Penalties are an essential element for enforcing regulations (Goulder 2013). However, insignificant penalties may impede firms' incentives for compliance because firms would rather pay for the penalties than purchasing allowances at a higher cost. Chongqing had a particularly low compliance rate compared to the other pilots (SinoCarbon 2015b). This may be because it has been operational for the shortest time, and thus lacks experience carrying out a carbon market. However, the Hubei pilot started only two months before Chongqing, and had a much higher compliance rate (Chongqing Government 2014a; Hubei Government 2015). Therefore, Chongqing's low compliance might stem from its "loose" penalty policies.

As discussed in Section II, most of the pilots adopted strict non-compliance penalties, including fines and deductions of future allowances. Chongqing has the least stringent penalties, as it lacks any economic punishment (Chongqing Government 2014a). According to its Interim Measures, Chongqing punishes firms' non-compliance by disqualifying them from climate change-related government grants and publishing details of their violation (Chongqing Government 2014a). These penalties hardly provide firms with incentives to actively participate in the trading system, particularly when the market price is high.

Regulators can establish significant penalties by setting the non-compliance fine significantly higher than the market price. While fixed-amount penalties for one-time non-compliance prevail in China's ETS pilots, in the EU, penalties are calculated per unit of emissions (Goulder 2013). These penalties have contributed to the high compliance rates for the EU ETS (Goulder 2013). Thus, in China, a more effective penalty could be calculated per unit of emissions.

Price Management Provisions

As discussed above, the ETS pilots have adopted a set of price-management provisions to control undesirable price volatility in the markets. Allowance reserves have been incorporated into all the pilots and are expected to be included in the national ETS (NDRC 2014). While not confirmed, inter-temporal banking should be considered for price management in the national ETS, given its demonstrated effectiveness in theory and in practice (Goulder 2013). In addition, an innovative approach adopted by the Hubei pilot should draw particular attention: price discovery.

Hubei has maintained stable market prices, while the other pilots experienced price fluctuations (ChinaCarbon.info 2015). Hubei's success in stabilizing market prices is likely a result of its unique price discovery mechanism. To discover the price in the new carbon market, Hubei publicly auctioned approximately 2 $MtCO_2e$ from its allowance reserves with a reserve price of CNY20 ($3.08) before officially launching its ETS (Qi and Cheng 2015). The auction allowed trading participants to form an initial expectation for the allowance price, so they were more confidence in participating and investing in the market after the pilot started. With Hubei's successful experience, the national ETS could also attempt early price discovery to achieve a stable launch.

V. CONCLUSION

Instead of examining whether an ETS is an effective way to reduce carbon emissions in China, this paper focused on examining the policy features and performance of China's ETS pilot programs. Lessons learned from the seven ETS pilots are particularly relevant for China's upcoming national ETS. This paper analyzed the seven pilots primarily through a literature review, examining a comprehensive set of policy features and system performance, including market prices and firms' compliance with the programs. In the end, it described lessons to be drawn from the pilots, particularly as they relate to key elements that have not been clearly defined in proposals for the national ETS: cap setting, sectoral coverage, penalty, and price management provisions. In general, the Chongqing pilot had the least satisfying performance due to its "loose" cap and insignificant non-compliance penalty. Beijing and Shanghai were successful in cap setting and allowance allocation that effectively avoided uncertain price volatility, and Hubei was innovative in its price discovery mechanism to realize stable allowance market prices.

However, due to China's unique regulatory and institutional structure, many questions about the pilots' effectiveness remain unanswered. Further research should be conducted on the following questions. First, how can the national ETS incorporate and balance different needs and circumstances in different regions? The seven pilot systems were created with different policy features based on their regional economic and social circumstances, and it is unclear how the national ETS will employ unified policy features across the country while taking local circumstances into account. Second, how will China's "socialist market economy" with heavy government intervention in its economic structure affect the operation of the ETS? Many potential covered sectors, such as the steel and electricity sectors, are owned by the government, and it is unclear whether this will ease or impede the implementation of the national ETS. Third, how will China address the technical constraints in MRV for covered firms, especially for mid-sized and small firms? Most mid-sized and small firms have limited expertise with MRV procedures as well as limited funding. It is crucial to address these constraints since MRV provides the foundation for the entire system. The effectiveness of China's national ETS, the presumably largest carbon market in the world, will largely depend on the answers to these questions.

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ZHOUDAN XIE is a second-year Master of Public Policy candidate specializing in international environmental policy and quantitative policy analysis. She graduated from Keio University in Japan with a Master's degree in environmental governance and completed her undergraduate study in Japanese and international trade in China. While attending the Trachtenberg School, Zhoudan has interned with the United Nations Environment Programme, Vital Voices Global Partnership, and International Fund for China's Environment. She currently works as a graduate research assistant at the GW Regulatory Studies Center.

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Appendix: Key Features of China's ETS Pilots

		Shenzhen	Beijing	Shanghai	Guangdong	Tianjin	Hubei	Chongqing
ETS start date		June 2013	November 2013	November 2013	December 2013	December 2013	April 2014	June 2014
Carbon emissions (MtCO2e)	2010	83.4	110	230	541	155	306	131
	2012	153	188.1	297.7	610.5	215	463.1	243.1
Overall carbon intensity target[1] by 2015 relative to 2010 level		-21%	-18%	-19%	-19.50%	-19%	-17%	-17%
Carbon emissions covered by the ETS (initial-year allowances in MtCO2e)		32	50	160	408	160	324	125
Type of cap		Intensity-based cap (per CNY10,000 of industrial output)	Absolute cap	Absolute cap	Absolute cap	Absolute cap	Absolute cap	Absolute cap
Number of firms covered by the ETS	2013	635	415	191	184	114	N/A	N/A
	2014	634	543	191	184	112	138	242
	2015	635	551	191	217	*No data*	138	*No data*
Sectors covered by the ETS		Power, water supply, manufacturing sector, and buildings	Electricity, heating, cement, petrochemicals, other industrial enterprises and manufacturers, service sector, and transport sector	Airports, aviation, chemical fiber, chemicals, commercial, electricity, financial, hotels, iron and steel, petrochemicals, ports, non-ferrous metals, building materials, paper, railways, rubber, and textiles	Energy, iron and steel, cement, and petrochemicals	Heat and electricity production, iron and steel, petrochemicals, chemicals, and exploration for oil and gas	Power and heat supply, iron and steel, chemicals, petrochemicals, cement, automobile manufacturing, ferrous metals, glass, pulp and paper, and food and beverage.	Power, electrolytic aluminum, ferroalloys, calcium carbide, cement, caustic soda, and iron and steel.
Criteria for determining firms covered by the ETS		Annual emissions > 3 thousand tCO2e	Domestic firms and annual emissions > 10 thousand tCO2e	For power and industrial sectors: annual emissions > 20 thousand tCO2e; For non-industrial sectors: annual emissions > 10 thousand tCO2e	Annual emissions > 20 thousand tCO2e or annual energy consumption > 10 thousand tons of standard coal	Annual emissions > 20 thousand tCO2e	Annual energy consumption > 60 thousand tons coal equivalent	Annual emissions > 20 thousand tCO2e

Appendix: Key Features of China's ETS Pilots (Continued)

		Shenzhen	Beijing	Shanghai	Guangdong	Tianjin	Hubei	Chongqing
Allowance Allocation	2013	Free allocation	Free allocation	One-time free allocation in 2013 to cover 2013-2015	3-5% mandatory auctioning and 95-97% free allocation	Free allocation	N/A	N/A
	2014	3% voluntary auctioning and 97% free allocation			3-5% voluntary auctioning and 95-97% free allocation	Free allocation	Free allocation	Free allocation
Monitoring, reporting and verification (MRV) regulations/Guidelines		Regulations and Guidelines on Institution GHG Emissions Quantifying and Reporting issued in November 2012	Allowance Verification Methods for Beijing Carbon Emissions Trading Pilot issued in November 2013	Implementation Regulations on Shanghai Carbon Emissions Verification issued in March 2014	Detailed Regulations on Guangdong Enterprises Carbon Information Reporting and Verification Enforcement issued in March 2014	Notification on Implementing Carbon Emissions Trading Pilot issued in December 2013	Guidelines on Hubei Industrial Enterprises GHG Emissions Monitoring, Quantifying and Reporting, and Guideline on Hubei GHG Emissions Verification issued in July 2014	Detailed Regulations on Chongqing Industrial Enterprises Emissions Accounting, Reporting and Verification issued in May 2014
Penalties to firms failing to comply with MRV legal requirements		A fine of 3 times the average market price of the previous 6 months for each misreported allowance if the firm reports falsified emission data	A fine of CNY30,000-50,000	A fine of CNY10,000-30,000	A fine of CNY10,000-50,000	Disqualification from certain financing services and national grants related to energy saving and climate change for 3 years	A fine of CNY10,000-30,000 if the firm fails to submit monitoring report or emission report; half the amount of current year's allowances deducted from future allocation for if the firm does not accept verifications	Publication of non-compliance, and disqualification from financial support and grants related to energy saving and climate change
Penalties to firms failing to surrender sufficient allowances in the end of a compliance year		A fine of 3 times the annual average market price for each missing allowance, and the amount of missing allowances deducted from future allocation	A fine of 3-5 times the annual average market price for each missing allowance	A fine of CNY50,000-100,000	A fine of CNY50,000, and double the amount of missing allowances deducted from future allocation	Same as above	A fine of 1-3 times the annual average market price for each missing allowance (maximum CNY150,000), and double the amount of missing allowances deducted from future allocation	Same as above

Appendix: Key Features of China's ETS Pilots (Continued)

		Shenzhen	Beijing	Shanghai	Guangdong	Tianjin	Hubei	Chongqing
Carbon offsetting using Chinese Certified Emissions Reductions (CCERs) or other certified reductions		Offsets using CCERs allowed for up to 10% of annual allowable emissions	Offsets using CCERs and verified emission reductions from energy saving projects and forest carbon sink projects allowed for up to 5% of annual allowable emissions	Offsets using CCERs allowed for up to 5% of annual allowable emissions	Offsets using CCERs allowed for up to 10% of annual allowable emissions	Offsets using CCERs allowed for up to 10% of annual allowable emissions	Offsets using CCERs allowed for up to 10% of annual allowable emissions	Offsets using CCERs allowed for up to 8% of annual allowable emissions
Price Management Provisions	Allowance reserves	2% of total annual allowances	5% of total annual allowances	None	Yes, amount not specified	None	10% of total annual allowances	None
	Intertemporal banking and borrowing	Banking	Banking	Banking	Banking	Banking	Banking	Banking
Average annual allowance prices (CNY/allowance)	2013	74.28	51.65	29.25	60.02	27.74	N/A	N/A
2014	62.93	54.74	36.50	50.34	28.61	24.02	30.74	
2015 (Jan-July)	39.92	48.40	24.91	21.22	21.54	25.00	24.87	
Compliance rate (percentage of firms that surrendered sufficient allowances)	2013	99.4%	97.1%	100%	98.9%	96.5%	N/A	N/A
2014	99.7%	100%	100%	100%	99.1%	100%	70%	

Source: table created by the author using data from the Interim Measures of the ETS pilots (Beijing Government 2014a; Chongqing Government 2014a; Guangdong Government 2014a; Hubei Government 2014a; Shanghai Government 2013; Shenzhen Government 2014; Tianjin Government 2013a), the MRV guidelines of the ETS pilots (Beijing Government 2013; Chongqing Government 2014c; Guangdong Government 2014c; Hubei Government 2014b; Shanghai Government 2014; Shenzhen Government 2012; Tianjin Government 2013b), Beijing Government 2014c, ICAP 2016c, IETA 2015, CDC 2015, ChinaCarbon.info 2015, Environomist 2015, SinoCarbon 2015a, SinoCarbon 2015b, and TanTongBao 2015.

(Footnotes)

1 The carbon intensity target for each province and city was specified by China's 12th Five-Year Plan. It refers to the overall target of carbon emissions per unit of GDP by 2015 for each province and city in China, not the targets of the seven ETS pilots. Carbon emissions trading is a major instrument for meeting carbon intensity targets, but it is not the only one.