

# Lessons Learned from China's Regional Carbon Market Pilots

JUNJIE ZHANG,<sup>a</sup> ZHENXUAN WANG,<sup>b</sup> and XINMING DU<sup>c</sup>

---

## ABSTRACT

*This paper gives an overview of the performance of China's seven regional carbon market pilots and the range of approaches they have used. We assessed the outcomes of these pilots using publicly available secondary market trading data. The differences in market performance are explained by the design of key market elements such as emission allowances, covered sectors, allowance allocation, monitoring, reporting and verification, compliance and penalties, and offset market. The lessons learned from the regional carbon market pilots are used to provide insights that can aid in the design of the upcoming national carbon market.*

**Keywords:** Climate change, Carbon market, China

<https://doi.org/10.5547/2160-5890.6.1.jzha>

## 1. INTRODUCTION

The carbon emission trading scheme (ETS) is an important market-based instrument for China to limit its ever-increasing greenhouse gas (GHG) emissions; it also assists China in complying with its commitments under international climate agreements. Since China overtook the United States to become the world's largest GHG emitter in 2007, it has emerged as the focus of scrutiny in international climate negotiations.<sup>1</sup> Now that China has pledged to peak its carbon emissions before 2030 under the Paris Agreement, ETS is likely to be the most important policy measure for carbon emission reduction with a minimum cost of compliance.

China's efforts at climate action are also motivated by the co-benefits of climate change mitigation. The National Development and Reform Commission (NDRC 2017) has called for a synergistic approach to tackle local pollution and global climate change simultaneously.<sup>2</sup> In particular, the Thirteenth Five-Year Plan for GHG Emission Control has enhanced the coordination of climate mitigation and air quality improvement by targeting the energy mix

---

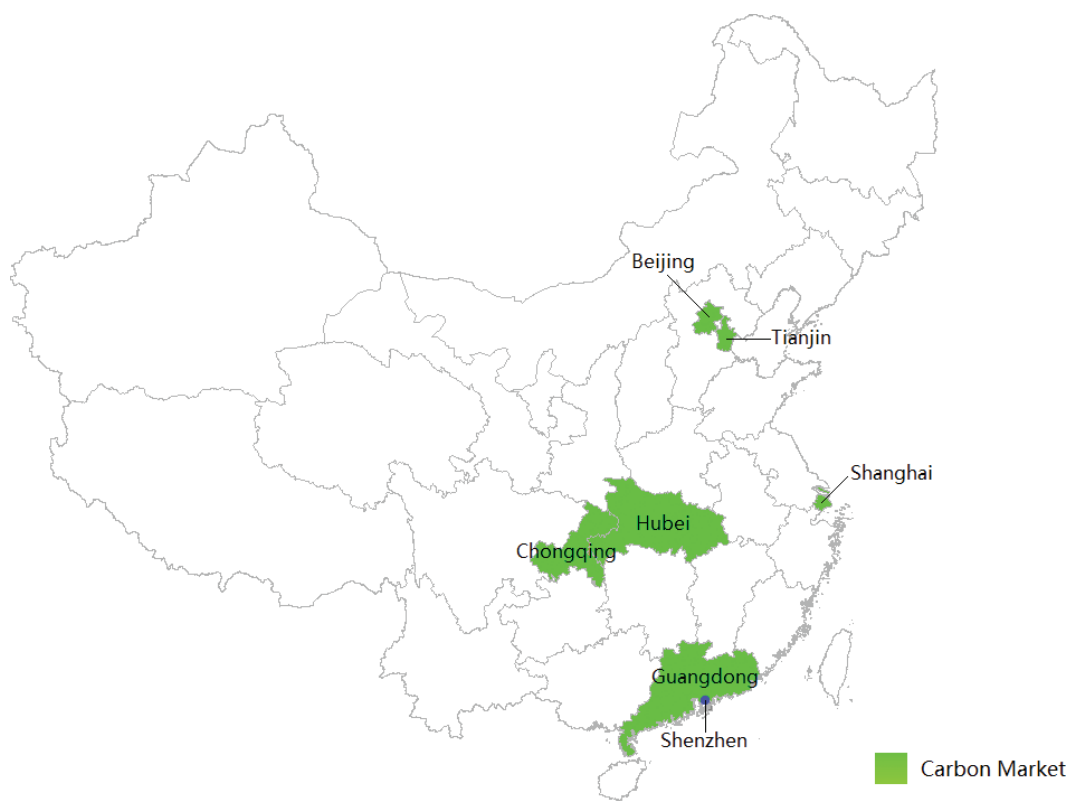
1. Source: <https://www.chinadialogue.net/article/show/single/en/5711-What-the-world-is-getting-wrong-about-China-and-climate-change> Zou Ji, What the world is getting wrong about China and climate change, China Dialogue, February 18, 2016.

2. NDRC categorizes China's climate policies into five areas: industrial structure adjustment, energy conservation and energy efficiency improvement, low-carbon power generation, increasing forest carbon sinks, and controlling non-CO<sub>2</sub> GHG emissions (NDRC 2017).

<sup>a</sup> Corresponding author. Environmental Research Center, Duke Kunshan University; Nicholas School of the Environment, Duke University. No.8 Duke Avenue, Kunshan, Jiangsu, China 215316. Tel: +86-512-3665-7068. [junjie.zhang@duke.edu](mailto:junjie.zhang@duke.edu).

<sup>b</sup> Duke Kunshan University, Kunshan, Jiangsu, China.

<sup>c</sup> Tsinghua University, Beijing Shi, China.



**FIGURE 1**  
The seven carbon market pilots

and energy efficiency.<sup>3</sup> In addition, climate mitigation contributes to development goals such as protecting public health, enhancing energy security, and increasing labor productivity. These co-benefits give provinces and municipalities incentives to engage in climate action even when their primary goal might not be about the climate.<sup>4</sup>

Under the dual incentives of climate mitigation and co-benefits, China has launched seven regional carbon market pilots since 2013. The pilots cover all four province-level municipalities (Beijing, Shanghai, Tianjin, and Chongqing), two provinces (Guangdong and Hubei), and one special economic zone (Shenzhen) (see Figure 1). The total allowances for the seven trading programs add up to 1.2 billion tons of carbon dioxide per year, about 11.4% of national emissions in 2014.

Although the seven regional pilots cover a relatively small share of China's total carbon emissions, the testing of market-based instruments in climate change mitigation represents a giant step for the world's largest emitter. In addition, the seven pilot regions are important provincial/city units in terms of their economic and political clout. The experience and lessons from these pilots will make it easier for other subnational units to join in the upcoming national ETS.

3. Source: <http://www.ccchina.gov.cn/Detail.aspx?newsId=64463&TId=60>The Thirteenth Five-Year Plan for GHG Emission Control.

4. In theory, the co-benefits can be achieved if climate policy is binding. In practice, however, the expected co-benefits may not be achieved due to lax climate regulation and more binding air pollution policies.

This paper gives an overview of the mechanisms and outcomes of China's regional carbon market pilots. In particular, we introduce the design of key market elements including selection of pilot regions; emission allowances; covered sectors; allowance allocations; monitoring, reporting and verification (MRV); compliance and penalties; and offset markets. We also assess the performance of the seven carbon markets using publicly available secondary market trading data and explain why different carbon market pilots differ significantly in market performance.

The remainder of the paper will proceed as follows. Section 2 discusses China's incentive for adopting ETS. Section 3 reviews key elements of the ETS pilots. Section 4 studies the secondary market using the online trading data. Section 5 summarizes the lessons learned from the seven regional pilots and makes policy recommendations.

## 2. CHINA CHOOSES A CARBON MARKET

The reasons why China uses ETS to regulate GHG emissions include the inefficiency of command-and-control policies, long-term co-benefits, domestic politics, and the need to save the voluntary carbon market (Kong and Freeman 2013). China's ETS by design is similar to the tradable performance standard (TPS), under which the government determines a maximum emission intensity with respect to output. Firms whose emission rates are below the standard can earn tradable allowances. However, if they exceed the standard, they must submit allowances to cover excess emissions (Burtraw, Fraas, and Richardson 2012; McKibbin, Morris, and Wilcoxon 2015). Compared with the traditional standards, which are rigid and one-size-fits-all, tradable standards can result in large cost savings (Burtraw, Fraas, and Richardson 2012). In addition to the potential efficiency gain, China's preference for a carbon market is also attributed to its confidence in market-based instruments, concerns about the cost of regulating carbon emissions, and the experience gained from its participation in the global carbon market.

In the transition to market economy, China has gradually increased the use of economic incentives including tradable permits to curb pollution (Zhang 2012). In particular, China started piloting several regional sulfur dioxide (SO<sub>2</sub>) emissions trading programs in the early 1990s. The Chinese State Environmental Protection Administration (SEPA) promulgated the total emission control policy and established the national SO<sub>2</sub> emission target in the Ninth Five-Year Plan period (1996–2000). In 1994, SEPA launched air pollutant emissions trading experiments in six cities following the emissions permit pilots.<sup>5</sup> In 2002, SEPA started to roll out seven provincial pilots to facilitate a nationwide ETS. Cao, Garbaccio, and Ho (2009) shows that the SO<sub>2</sub> cap-and-trade program achieved the abatement target with considerable cost savings. China's experience in SO<sub>2</sub> ETS strengthened its confidence in using market-based instruments to address the environmental challenges.

China prefers a carbon market over other market-based instruments mainly for internal political rather than economic reasons. NDRC, a powerful cabinet member in the State Council, regulates both economic development and GHG emissions. Therefore, it is natural that NDRC dominates the climate policy process and develops its own regulatory institutions without relying on the tax agency under the Ministry of Finance. The newly passed Environ-

5. The six SO<sub>2</sub> pilot cities include Baotou, Kaiyuan, Liuzhou, Taiyuan, Pingdingshan, and Guiyang.

mental Tax Law (effective in 2018) does not include a carbon tax in its text.<sup>6</sup> However, this does not preclude the possibility in the future that China will adopt a carbon tax alongside ETS to regulate carbon emissions.<sup>7</sup>

A third reason to favor a carbon market results from China's active participation in the Clean Development Mechanism (CDM). The CDM is a project-based carbon market in the Kyoto Protocol that allows developed countries to achieve their emission targets by investing in emission reduction projects in developing countries. As of Q1 2016, China accounts for 46% of registered projects and 57% of kCERs.<sup>8</sup> The CDM helped China expand its institutional capacity for ETS and create an interest group that is now actively lobbying for a carbon market. Because China has recently been losing its dominance in the CDM system, developing a domestic ETS may rescue China's Certified Emission Reduction (CCER) program, a voluntary carbon market that evolves from the Chinese CDM market (Kong and Freeman 2013).

### ✎ 3. KEY ELEMENTS OF THE REGIONAL PILOTS ✎

#### 3.1 Pilot Regions

NDRC formally approved seven carbon market pilots in Beijing, Shanghai, Tianjin, Chongqing, Guangdong province, Hubei province, and Shenzhen in late October 2011. Shenzhen, a special economic zone close to Hong Kong, was the first one to launch the carbon ETS in June 2013, followed by Shanghai, Beijing, Guangdong, and Tianjin in the same year. The remaining two pilot schemes, Hubei and Chongqing, launched ETS in April and June in 2014, respectively.

These ETS pilot regions show wide heterogeneity in economic and energy conditions in terms of population, income, share of manufacturing, and energy consumption (see Table 1). The level of development ranges from slightly below the national average (Chongqing and Hubei) to well above the average (other regions). The low-carbon industries in most regions are growing and emission intensities are declining, which alleviates the concern that ETS would dramatically slow down economic growth. The regional heterogeneity will facilitate the study of ETS design in various regional contexts. The experience from these pilots may be applicable to the neighboring provinces and municipalities with similar regional characteristics.

Most areas are covered by air pollution control targets. In addition, most of the pilots are in the key air pollution control zones in China: Jing-Jin-Ji Area (Beijing and Tianjin), Yangtze River Delta (Shanghai), and Pearl River Delta (Guangdong province and Shenzhen). Hubei province and Chongqing also suffer from deteriorating air pollution.

The pilot regions have flexibility in determining their own market rules following some general requirements from NDRC. In principle, NDRC sets rules for allowance management,<sup>9</sup> transaction process,<sup>10</sup> emission reports, monitoring, and supervision. The pilots are responsible

6. Source: [http://www.npc.gov.cn/npc/xinwen/2016-12/25/content\\_2004993.htm](http://www.npc.gov.cn/npc/xinwen/2016-12/25/content_2004993.htm) Environmental Protection Tax Law of the People's Republic of China (Chinese), passed on December 25, 2016.

7. According to Zhaoli Jiang, deputy director general of the NDRC Climate Change Department, a CO<sub>2</sub> tax will be introduced with the CO<sub>2</sub> market in 2020. At that time, firms not covered in the carbon market will pay a CO<sub>2</sub> tax. Source: <http://gd.people.com.cn/n2/2016/0810/c123932-28809932.html>, accessed on May 28, 2017.

8. Source: <http://www.cdmpipeline.org/cdm-projects-region.htm>

9. Allowance management refers to the management of carbon emission quota and includes determining the quantity and approach of allowance allocation, choosing the covered sectors, and some other related issues.

10. Transaction process refers to the trading of carbon emission allowances. NDRC sets rules for qualified trading agencies, regulatory mechanisms, and market stability measures.

**TABLE 1**  
Basic economic and energy characteristics of the seven pilots (2014).

Region	Population (million)	GDP per capita (Yuan/person)	Secondary Industry (%)	Energy Consumption (tce/person)	Energy Intensity (tce/10 <sup>4</sup> Yuan)
Beijing	21.52	99,163	21.31	3.17	0.36
Tianjin	15.17	103,715	49.16	5.37	0.58
Shanghai	24.26	97,191	34.66	4.57	0.53
Guangdong	107.24	63,258	46.34	2.76	0.49
Shenzhen	10.78	149,564	42.57	3.44	0.23
Hubei	58.16	47,097	46.94	2.81	0.67
Chongqing	29.91	47,704	45.78	2.87	0.68
National	1,362.46	50,254	46.83	3.23	0.72

Source: China Statistical Yearbook 2014. Shenzhen is a city in Guangdong province.

for the detailed market design including scope and coverage, allowance allocation, and market stabilization. Therefore, NDRC oversees the planning and development of ETS, and most of the details are left to the regional governments. It is worth mentioning that the ETS rules in Beijing and Chongqing were enacted by the respective local People's Congress; the rules in the other five pilots were issued as local government orders. Each pilot adapts the general guidelines from NDRC to meet the specific local need. This makes each pilot a separate and unique experiment, resulting in the difficulty in market linkage because of the differing local market rules.

### 3.2 Emissions Target and Allowance

The most important component of a carbon market is an emissions cap or target China has adopted a carbon intensity target that indexes emissions with economic activities. It is hoped that intensity targets can limit emissions without capping economic activities (Newell and Pizer 2008). In the 2009 Copenhagen Accord, China pledged to a 40% to 45% reduction target in carbon intensity, defined as carbon emissions per unit of GDP, by 2020 relative to its 2005 level. The Chinese government also set intensity targets in its Twelfth Five-Year Plan (FYP 2011–2015) and Thirteenth Five-Year Plan (FYP 2016–2020). Each province is required to reduce its emission intensity by a certain level (see Table 2).

In the context of emission intensity target, each pilot determines the size of its own emission allowance. The seven pilots are separate experiments, and they are not linked. It is worth noting that the total emission allowance is not directly derived from the provincial intensity target. Because the regional carbon markets are basically a tradable performance standard, the allowance for each emitter is calculated by grandfathering or benchmarking. The sum of individual allowances and some allowance reserves equal the total allowance. Therefore, we cannot simply interpret the total emission allowance as the cap determined by the top-down approach.

The annual total allowance is about 1.2 billion tons per year for all pilots combined. To put it in perspective, China's total GHG emissions in 2014 amounted to 10.54 billion tons.<sup>11</sup> Based on the size of the economy and emissions, Guangdong has the largest allowance and

11. Source: CO<sub>2</sub> time series 1990–2014 per region/country." Netherlands Environmental Assessment Agency.

**TABLE 2**  
Carbon intensity reduction targets and total allowance issued.

Region	Carbon Intensity Reduction Target		Annual Allowance
	The 12th FYP	The 13th FYP	
Beijing	18%	20.50%	5.5Mt
Chongqing	17%	19.50%	131Mt (2013)
			126Mt (2014)
			121Mt (2015)
Guangdong	19.50%	20.50%	388Mt
Hubei	21%	19.50%	324Mt
Shanghai	19%	20.50%	510Mt (3 years)
Shenzhen	17%	20.50%	30Mt
Tianjin	19%	20.50%	100Mt
Nationwide	17%	18%	1.2 billion tons

Source: The State Council (2013) and The State Council (2016).

Shenzhen has the smallest. The allowance for a pilot takes the province's specific needs for economic development and intensity target into account.

### 3.3 Covered Sectors

The seven pilots cover a range of sectors with different thresholds. The sectoral coverage includes the most emission-intensive industries such as power and heating, chemical, iron and steel, and cement. Because the pilots are implemented at the regional level, each pilot regulates a different set of sectors based on its unique industrial structure and emission intensity. The covered sectors are summarized in Table 3. It is worth noting that no mobile sources are covered in those pilots except Shanghai.

The threshold for a covered entity is dependent on the type of industries, non-industries, and buildings. The threshold is usually based on the quantity of annual emissions. The only exception is Hubei, which uses energy consumption as a threshold, mainly because carbon emission data at the firm level is often not available.<sup>12</sup> Shenzhen has the lowest threshold, and thus it has the most covered entities (635 firms). The covered shares of emissions range from 33% (Hubei) to 60% (Tianjin).

### 3.4 Allowance Allocation

The seven pilots use different approaches to allocating allowances. Almost all allowances are given out for free, except that Guangdong auctions a small share of allowances. Nevertheless, allowance auctioning in Guangdong is becoming less important as the 2016 auction did not attract enough buyers. This is likely due to the fact that the GHG regulation is quite lax and allowance allocation is generous. Allowances are usually allocated on an annual basis, but Shanghai distributed all allowances for the compliance period 2013–2015 to the covered

12. The energy data are more readily available because energy consumption has been reported for a number of years under the energy conservation program. The micro-level emission data at the firm level is difficult to obtain in Hubei because of its low economic development level and weak institutional capacity. Since MRV has been implemented, it is now possible for Hubei to use emissions to determine covered firms' thresholds.

**TABLE 3**  
Covered sectors in the seven carbon market pilots.

Pilot Region	Sectors Covered	Threshold	Number of Entities	Emissions Covered
Beijing	Electricity, heating, cement, petrochemical and other industries, large public buildings including hospitals, schools and governments	>10kt	415(2013); 543(2014)	40%
Chongqing	Electricity, metallurgy, chemical industries, cement, iron and steel	>20kt	242	39.50%
Guangdong	Electricity, cement, iron and steel, petrochemical industries, public services including hotels, restaurants and business	2013: >20kt; since 2014: industries>10kt, non-industries>5kt	202(2014); 193(2015)	58%
Hubei	Electricity, heating, metallurgy, iron and steel, automobile and equipment, chemical and petrochemical industries, cement, medicine and pharmacy, food and beverage, papermaking	Energy consumption>60k tce	138	33%
Shanghai	Electricity, iron and steel, petrochemical and chemical industries, metallurgy, building materials, papermaking, textile, aviation, airports and ports, public and office buildings, railway stations	Industries>20kt, non-industries>10kt	191	57%
Shenzhen	Electricity, building, manufacturing, water supply	Industries>5kt, public buildings>20k m <sup>2</sup> , office buildings>10k m <sup>2</sup>	635	40%
Tianjin	Electricity, heating, iron and steel, chemical and petrochemical industries, oil and gas exploration	>20kt	114	60%

Information compiled from the official documents of the seven carbon market pilots: Beijing DRC (2014), Beijing Environmental Exchange (2015), General Office of the Beijing People's Government (2013), General Office of the Beijing People's Government (2014), Guangdong DRC (2013), Guangdong DRC (2014), Tianjin DRC (2013), Tianjin People's Government (2013), Chongqing DRC (2014), Shanghai DRC (2013), Shanghai People's Government (2013), Committee of the Shenzhen People's Congress (2012), Hubei People's Government (2013), and Chongqing People's Congress (2014).



**TABLE 4**  
Allowance allocation in the seven pilots.

Region	Free Allocation		Auction
	Benchmarking	Grandfathering	
Beijing	New entrants	Existing entities	
Chongqing	—	All sectors	
Guangdong	Electricity, cement, iron and steel	Other sectors	8Mt (2.06% in 2014), 2Mt (0.51% in 2015)
Hubei	—	All sectors	
Shanghai	Electricity, aviation, airports, ports	Other sectors	
Shenzhen	Electricity, heating, water supply, manufacturing	Other sectors	
Tianjin	Electricity, heating	Other sectors	

Information compiled from the official documents of the seven carbon market pilots: Beijing DRC (2014), Beijing Environmental Exchange (2014), Beijing Environmental Exchange (2015), Guangdong DRC (2013), Guangdong DRC (2014), Tianjin DRC (2013), Tianjin People's Government (2013), Chongqing DRC (2014), Shanghai DRC (2013), Shanghai People's Government (2013), Committee of the Shenzhen People's Congress (2012), Hubei People's Government (2013), Hubei DRC (2014), and Chongqing People's Congress (2014).

entities at one time. Shanghai and Shenzhen also pre-allocate allowances and may update their allowances again within the compliance period (Munnings et al. 2016).

Benchmarking and grandfathering are the two approaches used for allowance allocation. Grandfathering is based on historical emissions or intensities. Some efficiency factors, which differ across sectors, are used to adjust historical emission levels. Grandfathering is easy to implement but it creates no or only a limited incentive for technological innovation. In contrast, benchmarking rewards innovation and more efficient entities. It also provides important information about emission performance for peer comparisons.

Table 4 summarizes the allowance allocation approaches in the seven pilots. Most pilots use both approaches, except that Chongqing only uses grandfathering. Beijing uses benchmarking for new entrants and grandfathering for existing entities. The allocation in other pilots depends on the sectors covered. Benchmarking usually applies to the power sector.

### 3.5 Monitoring, Reporting and Verification

Each pilot has established a system of monitoring, reporting and verification (MRV) to assure that trading is based on credible emission reductions. The MRV protocols across the pilots are similar, with some minor technical differences (see Table 5). The threshold for reporting emissions is lower than the threshold that determines the entities to be covered in Table 3.

The accounting of firms' emissions needs to follow the uniform standards. At the national level, China's Standardization Administration has published the general guideline of GHG emissions accounting and reporting for industrial firms. In addition, the detailed protocols of accounting and reporting for the 10 key industries—including power generation, iron and steel, aviation, chemical, and cement—are also finalized.

Monitoring and reporting of emissions are self-conducted by the covered entities. The report will be sent to a third-party verifier for verification. In some regions, such as Shanghai



**TABLE 5**  
Monitoring, Reporting and Verification (MRV) of the seven pilots.

Region	Monitoring Plan Due	Emission Report Due	Threshold for Reporting	Verification Report Due	Threshold for Verification
Beijing		Feb 28	energy consumption>2k tce	Mar 27	>10kt
Chongqing		Feb 20	>20kt	Mar 13	>20kt
Guangdong		Mar 15	>10kt or energy consumption>5k tce	Apr 30	>20kt or energy consumption>10k tce
Hubei	Sep 30	Feb 28	Energy consumption>60k tce	Apr 30	Energy consumption>60k tce
Shanghai	Dec 31	Mar 31	>10kt	Apr 30	>20kt
Shenzhen		Mar 31	>1kt	Apr 30	Industries: >1kt, public buildings: >10k m <sup>2</sup>
Tianjin	Nov 30	Apr 30	>10kt	Apr 30	>20kt

Information compiled from the official documents of the seven carbon market pilots: Beijing DRC (2014), Beijing Environmental Exchange (2014), Beijing Environmental Exchange (2015), Guangdong DRC (2013), Guangdong DRC (2014), Guangdong People's Government (2014) Tianjin DRC (2013), Tianjin People's Government (2013), General Office of the Tianjin People's Government (2016), Chongqing DRC (2014), Shanghai DRC (2013), Shanghai People's Government (2013), Committee of the Shenzhen People's Congress (2012), Shenzhen Department of Housing and Urban-Rural Development (2013), Hubei People's Government (2013), Hubei DRC (2015), and Chongqing People's Congress (2014).

and Guangzhou (a city in Guangdong province), the verification report will be double-checked by a fourth party to guarantee its authenticity. The cost of verification is covered by the local government in most pilots. Only Beijing (since 2015) and Shenzhen require firms to pay. If the government pays for the verification, it will also designate the verifier.

Table 6 shows the penalties for failing to comply with the MRV protocols, including failing to report, failing to verify, and falsely reporting and verifying. All pilots but Hubei and Shenzhen implemented detailed rules for the penalties. Beijing, Shanghai, and Guangdong also use financial penalties to regulate firms' MRV process.

### 3.6 Compliance and Enforcement

All pilots have built in a variety of penalties to ensure compliance (see Table 7). The covered entities are required to surrender allowances to the local regulators before the due date. Non-compliance will incur financial and other penalties. All pilots but Tianjin have adopted financial penalties for excess emissions that are not covered by the allowance. Some pilots charge 3–5 times the market value of the excess emissions, while others charge a predetermined fine.

Besides financial penalties, Beijing, Shanghai, and Guangdong pilots deduct the excess emissions from the allocated allowances for the non-compliant entities in the following year. The deduction could be up to double the excess emissions. Other penalties include recording non-compliance in the business credit report system, annulling the qualification for government support in energy, environment and climate change, and recording non-compliance in the performance appraisal system for state-owned enterprises (SOEs).

It is obvious that financial penalties can increase compliance because of the monetary incentive. In particular, the financial penalty is based on the market value of the excess emissions,

**TABLE 6**  
Penalties for failing to comply with the MRV protocols.

Region	Financial Penalty	Order to Correct	Business Credit Report	Annual Government Support	SOE Performance Appraisal
Beijing	Certain Amount	Yes			
Shanghai	10,000-50,000 Yuan		Yes		
Tianjin		Yes	Yes	Yes	
Chongqing		Yes		Yes	Yes
Guangdong	10,000-50,000 Yuan	Yes			
Hubei					
Shenzhen					

Information compiled from the official documents of the seven carbon market pilots:

**TABLE 7**  
Penalties for non-compliance.

Region	Financial Penalty	Deduction from Allowance	Business Credit Report	Annual Government Support	SOE Performance Appraisal
Beijing	3-5 times				
Chongqing	3 times			Yes	Yes
Guangdong	50,000 yuan	double	Yes		
Hubei	3 times but <150,000 yuan	double	Yes	Yes	Yes
Shanghai	50,000-100,000 yuan		Yes	Yes	
Shenzhen	3 times	same	Yes	Yes	Yes
Tianjin				Yes	

The multiplier in the column of financial penalty is the market value of the excess emissions. Information compiled from the official documents of the seven carbon market pilots: Beijing DRC (2014), Beijing Environmental Exchange (2014), Beijing Environmental Exchange (2015), Guangdong DRC (2013), Guangdong DRC (2014), Tianjin DRC (2013), Tianjin People's Government (2013), Chongqing DRC (2014), Shanghai DRC (2013), Shanghai People's Government (2013), Shanghai Environment and Energy Exchange (2015), Shanghai Environment and Energy Exchange (2016), Committee of the Shenzhen People's Congress (2012), Hubei People's Government (2013), and Chongqing People's Congress (2014).

which increases the financial risk of non-compliance. Deduction of the excess emissions from the allowance in the next period will make future compliance more challenging. The non-monetary penalties are also important to ensure compliance. Non-compliance harms business credit ratings and increases the cost of borrowing from the financial market. Non-compliant firms are not qualified for government grants or support in the areas of energy conservation and emission reductions. In addition, SOEs are subject to periodic performance appraisals by the central government. In theory, a record of non-compliance can have negative impacts on the remuneration of SOE executives and the likelihood of promotion, although the magnitude of the effect is unknown.

The compliance rate is high across the seven pilots. For example, Beijing, Guangdong, Hubei, and Shanghai achieved perfect compliance in 2015; the compliance in Shenzhen and Tianjin was almost perfect. Only Chongqing reported above 70% of compliance. The high

**TABLE 8**  
Extension of compliance dates for the seven pilots.

Region	Due Date	Actual Due Date		
		2014	2015	2016
Beijing	Jun 15	Jun 27	Jun 30	Jun 20
Chongqing	Jun 20		Jul 23	NA
Guandong	Jun 2	Jun 20	Jun 23	Jun 20
Hubei	May 29		Jul 10	Jul 25
Shanghai	Jun 30	Jun 30	Jun 30	Jun 30
Shenzhen	Jun 2	Jun 30	Jul 1	Jun 26
Tianjin	May 31	Jul 25	Jul 10	Jun 30

Information compiled from the websites of seven carbon exchanges and related media reports.

rate of compliance is likely caused by the abundant supply of allowances in each market.<sup>13</sup> In addition, local governments also assist covered firms in compliance by offering extra allowance auctions or extending due dates.<sup>14</sup>

### 3.7 Offset Market

The seven pilots allow covered firms to use offset credits to partially meet their abatement obligations. The voluntary emission trading market, which is a project-based offset market, generates China Certified Emissions Reductions (CCERs). The CCER market follows the Clean Development Mechanism closely. NDRC plays a similar role to the CDM Executive Board in terms of methodology development and project registration.<sup>15</sup>

As of June 30, 2016, 2,191 CCER projects have been published for comment and 725 projects have been registered. In total, 162 projects have issued credits, about 37.27 million tons of carbon emissions in total. In terms of project types, CCER is dominated by wind (36%), small hydro (18%), solar photovoltaic (18%), and forest carbon sinks (10%). In terms of carbon credits issued, small hydro accounts for the largest share (32%) followed by wind (20%).<sup>16</sup>

Integrating the offset credit market into the carbon market pilots can reduce the cost of compliance; however, the flooding of offset credits is likely to crash the fragile pilot trading programs. All pilots have set constraints on the use of CCERs (see Table 9). As of June 30, 2016, 62.09 million tons of CCERs have been traded through the exchanges.<sup>17</sup> Shanghai accounts for above half of the CCER trading volume. CCER trading usually takes place on the

13. We believe that a positive allowance price under over-allocation is possible. At the sector or firm level, there may not be enough allocated allowances for some sectors or firms. In addition, some owners of extra allowances might not sell on the market due to poor carbon asset management. However, as firms learn from trading, the carbon price should approach zero under over-allocation.

14. Please note that the compliance rate is defined as the ratio of the firms that have surrendered a sufficient amount of allowances in a given compliance period. If a large enterprise fails to comply, the size of its emissions is not taken into account by our definition. However, we do not have access to the detailed compliance information to calculate a compliance rate based on emissions.

15. Source: <http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2894.pdf> Interim Measures on China's Voluntary Emissions Trading. (2012)1668.

16. Source: <http://cdm.ccchina.gov.cn/ccer.aspx>

17. The traded volume is higher than the total issued CCERs because a CCER can be traded multiple times.

**TABLE 9**  
Requirements of using offset credits in the seven pilots.

Pilot	Offset Credit	Limit	Local Source	Other Restrictions
Beijing	CCER; energy conservation and forestry offsets	< 5% of allowance	> 50% from Beijing	Offsets generated after Jan 1, 2013, excluding industry gas and hydro projects
Chongqing	CCER	< 8% of verified emissions		Offsets generated after Dec 31, 2010 (except for carbon sinks); excluding hydro projects
Guangdong	CCER	< 10% of verified emissions	> 70% from Guangdong	> 50% from CO <sub>2</sub> and CH <sub>4</sub> , excluding hydro, fossil fuel, and pre-CDM projects projects,
Hubei	CCER	< 10% of allowance	All	Only small hydro
Shanghai	CCER	< 5% of allowance	Not from covered firms	Offsets generated after Jan 1, 2013
Shenzhen	CCER	< 10% of verified emissions		Offsets from renewables, clean transport, ocean, forestry offsets, and agriculture
Tianjin	CCER	< 10% of verified emissions	Priority for Beijing, Tianjin and Hubei offsets	Excluding hydro and pre-CDM projects

Information compiled from the official documents of the seven carbon market pilots: Beijing DRC (2014), Beijing Environmental Exchange (2014), Beijing Environmental Exchange (2015), Guangdong DRC (2013), Guangdong DRC (2014), Tianjin DRC (2013), Tianjin People's Government (2013), Chongqing DRC (2014), Shanghai DRC (2013), Shanghai People's Government (2013), Shanghai Environment and Energy Exchange (2015), Shanghai Environment and Energy Exchange (2016), Committee of the Shenzhen People's Congress (2012), Hubei People's Government (2013), and Chongqing People's Congress (2014).

over-the-counter (OTC) market and it mainly attracts investors. However, the detailed CCER trading prices and volumes are not publicly reported. Carbon exchanges only report very rough information about CCER on an occasional basis. Both covered entities and investors can purchase CCERs in an exchange, so we cannot tell whether a CCER is purchased for compliance or for investment.

#### 4. THE SECONDARY MARKETS

Emission allowances and related financial instruments are traded on the secondary carbon markets. We study the outcomes of the secondary markets using the daily online trading data from the seven pilots. China's secondary market includes online and over-the-counter transactions. Both types of trading are required to clear at the carbon exchanges. We only have access to the detailed information about online trading, which accounts for 57% of total trading volume and 65.7% of total trading value between June 18, 2013 and June 20, 2016.<sup>18</sup>

The online trading data provide the spot market historical quotes, including prices (opening, high, low, and closing) and trading volumes.<sup>19</sup> The time span is from November 2013 to October 2016, varying with different pilots. This is the best available information for the ETS pilots. The data and information for the covered entities at the micro level are not publicly

18. Source: <https://www.thepmr.org/content/china-carbon-market-monitor-q2-2016> Partnership for Market Readiness. China Carbon Market Monitor: Q2 2016.

19. The data set is available at <http://k.tanjiaoyi.com/>.

accessible. Because China's ETS experiment is still at a very primitive stage and the liquidity of carbon allowances is very low, this makes the use of formal financial econometrics less meaningful. Therefore, we only report the basic graphical analyses (See Figure 2) and summary statistics.

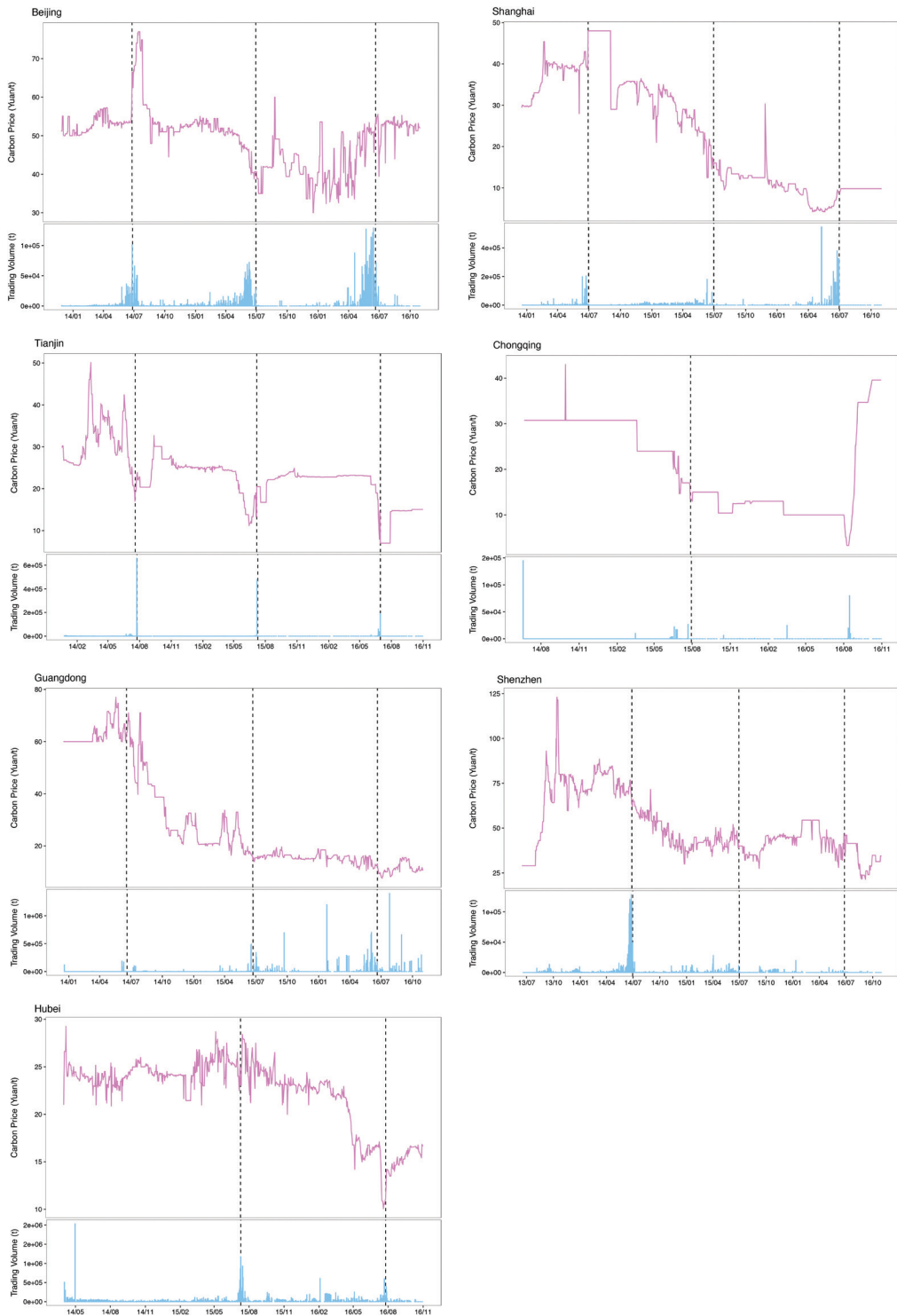
The seven pilots have traded 94 million tons of emission allowances in this period at an average price of US \$3.72/ton. The carbon prices of most markets rose during the early stage of trading and then declined gradually. It is likely that the market has realized that the allowance supply is abundant. Most transactions occur in the period that leads up to the compliance deadline. This may be for the following reasons. First, financial derivatives such as carbon futures and options are scarce. Second, in some pilots, the covered firms have no idea about their final allocations until the beginning of the third quarter or even later because of the adjustments within the compliance period. Finally, since the decision makers of the seven pilots are unfamiliar with carbon trading, they procrastinate due to lack of practice; they may also try to win additional allocations for local governments strategically. The covered entities are also learning carbon emission trading by participating in the market. As China's carbon market becomes more mature, the volatilities of carbon prices and trading volumes will improve in the future.

Based on the trading data, we construct an indicator similar to the turnover rate in the stock market, which is measured by the ratio of trading volume to the total allowance (See Table 10). Among the seven pilots, Shenzhen operates the most active carbon market. The close price in the Shenzhen market ranged from 21.38 to 143.99 yuan/t, and the maximum price was the highest there among all pilots. The active transaction in the Shenzhen carbon exchange is attributed to the large number of market participants (635 firms), which is more than in any other pilot. It may be also attributed to the market openness that allows institutional, individual, and foreign investors to participate. In addition, the active carbon finance innovation in Shenzhen—including carbon bonds, carbon funds, carbon asset custody, carbon structural products, and carbon forward contracts—also facilitates market activities.

Hubei has the largest trading volume and the second highest turnover rate. The active trading may be attributed to the provision that banking between compliance periods is not allowed, which may lead to the fact that some firms will have an additional need for emissions. Its carbon price ranged from 10.07 to 29.25 yuan/t and the average price was 22.78 yuan/t. The average difference between the highest and lowest daily price was only 8 yuan/t, the lowest among the pilots. Thus, Hubei's carbon market had the lowest price volatility. This is partly due to the unique market stabilization mechanism, which set the limits for gains and losses at 10% and 1%, respectively (between July 15, 2016, and December 26, 2016).<sup>20</sup> The intervention by the Hubei government to boost the carbon market has also generated numerous critics. It is worth noting that Hubei created China's first carbon forward contract.

Beijing also runs a relatively active carbon emission trading program. It has benefited from its proximity to financial institutions, carbon fund management companies, enterprises' headquarters, and the central government. The Beijing emission allowance price ranged from 30–77 yuan/t with an average closing price at 50.6 yuan/t; the average closing price was the second highest of all pilots. Because Beijing has the earliest compliance deadline, its trading volume also has the earliest peak in each year.

20. The limits for daily gains and losses are set at  $\pm 30\%$  for Shanghai,  $\pm 20\%$  for Beijing and Chongqing, and  $\pm 10\%$  for other pilots.

**FIGURE 2**

Historical Quotes of the Seven Carbon Market Pilots. The dashed lines are the compliance due dates when the covered entities are required to surrender allowances.

**TABLE 10**  
Turnover rate of the carbon markets.

Pilot Region	Turnover Rate
Beijing	0.0296
Shanghai	0.0157
Tianjin	0.0067
Chongqing	0.0015
Hubei	0.0423
Guangdong	0.0159
Shenzhen	0.1139
Nationwide	0.0238

The turnover rate is defined by the ratio of trading volume on the secondary market to the total allowance.

The Shanghai carbon market has achieved perfect compliance three years in a row, and is the only one of the seven pilots to have done so. Its carbon price ranged from 4.2 to 48 yuan/t and the average price was 25.67 yuan/t. Shanghai is China's financial center. It has access to a large pool of institutional and human resources in finance to support the carbon market.

Guangdong has the largest carbon market in terms of the size of the emission allowance. The average carbon price was 31.72 yuan/t, with the closing price ranging from 7.57 to 77 yuan/t. Its trading volume was the second largest of all of the pilots. Guangdong is the only pilot that auctions part of the emission allowance for price discovery.

Tianjin carbon price ranged from 7 to 50.10 yuan/t, with the average price at 24.17 yuan/t. The average price was the second lowest of the pilots. Tianjin's carbon trading program is one of the least active of the seven pilots, probably because its market is composed of a small number of firms with large emissions. It covers 114 firms, the least of all pilots, but the covered emissions account for 60% of total emissions, the highest of all pilots. In addition, Tianjin has the laxest penalties for non-compliance.

Chongqing has the least active carbon market. The historical carbon price ranged from 3.28 to 43 yuan/t with the average price at 21.65 yuan/t. Both the average price and low price are the lowest of the seven pilots. Chongqing offers abundant allowances for the covered firms because these industrial sectors are instrumental for its economy.

## 5. INSIGHTS AND POLICY IMPLICATIONS

Since the creation of seven regional ETS pilots, China has become the world's second largest carbon market. This experiment will also lead to the launching of a national ETS in 2017. Based on the very limited public information, the national ETS will cover at least eight sectors including petrochemical, chemical, building materials, steel, nonferrous metals, paper, electricity, and aviation (NDRC 2016). The firms in these sectors with energy consumption higher than 10,000 tce in any year between 2013 and 2015 will be regulated by the national ETS. The allowance allocation is based mainly on the benchmarking method. NDRC is in charge of overall rule design, and local governments will be responsible for the specific allowance allocation, compliance, and supervision.<sup>21</sup> The national ETS and regional pilots are likely

21. Source: China Climate Change Info-Net, <http://www.ccchina.gov.cn>, accessed on April 15, 2017.



to coexist. The firms that are currently covered by the regional pilots but not qualified for the national ETS will remain in the regional ETS.

The rules of the national ETS have not been finalized yet. The experiment of seven regional ETS pilots can provide important insights not only for the upcoming national ETS but also for other countries that adopt carbon markets to regulate GHG emissions. It is therefore an opportune time to assess the experience of and lessons from the regional pilots and formulate policy recommendations for the upcoming national ETS.

### **5.1 Overall Performance**

The regional pilots have generated moderate emission trading activities so far. Their impacts on carbon emission reduction and cost saving might therefore be very limited. However, the primary goal of the regional ETS pilots is to test whether China can use market mechanisms to regulate carbon emissions and to prepare for the national ETS. In this context, the regional pilots have been successful in reinforcing China's capacity to develop the national and provincial institutions for climate change.

All of China's provinces are required to reduce energy and carbon intensities no matter whether they have been selected as carbon market pilots nor not. It is an empirical question whether the pilots will achieve additional emission reductions beyond the intensity targets specified in the FYPs. If the pilots do not achieve additional abatement, another empirical question is whether the carbon market will reduce the cost of compliance. Given that the covered firms are not actively engaged in emissions trading, the cost-saving effect might be very small.

In terms of the much-hoped-for co-benefits, the ETS pilots may have limited effects on improving air quality. Because the national air pollution regulation is more binding than the climate policy, the usefulness of ETS in air pollution control will be reduced. Tough air pollution control policies require firms to reduce energy consumption. The command-and-control policy reduces the demand for carbon credits and then suppresses carbon prices.

### **5.2 Policy Support**

The policy support and public readiness for carbon markets vary across regions. The rules on ETS in Beijing and Chongqing were enacted by the local People's Congress; other pilots are regulated by government orders in the respective jurisdictions. NDRC promulgated a very general rule on the emission trading scheme one and half years after the carbon market was launched. Shenzhen and Hubei released regional rules on ETS pilots about one year before trading began. Beijing, Guangdong, and Shanghai published the rules and launched the markets at almost the same time. Tianjin and Chongqing did not finalize the rules until after two years of trading. Different regional regulatory rules have led to very different market outcomes. The delayed process of setting rules in Tianjin and Chongqing resulted in a lack of preparation, which partly explains their poor carbon market performance.

A fundamental flaw of the regional ETS pilots is a lack of overarching design. Although China has become more and more aggressive in climate mitigation, there is no national legislation on climate change that sets a carbon emission cap or target. The Twelfth and Thirteenth Five-Year Plans have set emission intensity targets, but they are not directly linked to the regional ETS pilots. Although FYPs play an important role in China's social and economic development, not every guideline, initiative, or strategy in the FYPs will be treated equally and

implemented faithfully. Therefore, intensity targets are not optional, but it is insufficient to merely declare them compulsory.

Without a climate law, a province has discretion to make its carbon regulations less stringent and decide for itself whether/how to comply with the national intensity targets (Zhang et al. 2014). Since most provinces are still in the process of industrialization and urbanization, they are unlikely to take climate change seriously. In addition, climate change is not an important indicator in the cadre performance evaluation system, which is powerful in shaping the career incentives of government officials. Therefore, climate change does not claim the provincial and local leaders' attention because the emission target is a "soft" constraint.

Climate legislation is the cornerstone of a healthy national ETS. Without a legally binding commitment, officials have incentive to ignore carbon emission targets to protect GDP growth, which is still the most important factor for their own careers. The regional pilots have demonstrated that legal support is instrumental for the success of an ETS. A national law on climate change, preceding the government order on the establishment of a national ETS, will ensure the sustainability and stability of the national carbon market.

### 5.3 Market Segmentation

The ETS pilots cover various regions of China that differ widely in their levels of economic development, industrial structures, institutional capacities, and carbon emissions. Each pilot is allowed to determine its own rules subject to some general requirements set by NDRC. Such heterogeneous socioeconomic conditions and diverse market designs can provide useful variations to study what key elements are important for a successful carbon market. However, this also creates a fragmented market structure, making linkages between pilots—let alone with other international markets—very difficult. A unified market design will improve the efficiency of emissions trading.

So far, the central government allows pilot regions great freedom in designing their own rules in terms of allowance allocation, MRV, compliance, and enforcement. The advantage of this approach is that it can accommodate significant regional heterogeneity in economic development, industrial structure, energy mix, and energy efficiency. The problem is that linking pilot markets is very difficult due to compatibility concerns. Without market linkage, segmented carbon markets reduce market efficiency and liquidity (Jiang et al. 2016).

Market linkage is not a good idea for regional pilots if it is impossible to impose the same MRV protocols and enforcement on all markets. The national ETS will have unified rules across regions, which will be more consistent and robust than the rules and MRV of the regional pilots. In the transition from a regional pilot to the national ETS, if allowances in a region with poor MRV are transferred to one with effective MRV, the carbon market linkage is likely to cause the leakage problem that will harm the integrity of the national ETS. In the case of inter-jurisdictional competition, it might create the problem of a "race to the bottom" in terms of MRV protocols and enforcement. Therefore, the regional pilots and the national ETS should be run independently until all firms are covered by the national ETS. In order to address the potential leakage, a generalized allowance allocation method and MRV system should be constructed to ensure a reasonable transition from a regional pilot to the national ETS.

The national ETS should also take into account different regional development levels. China's national ETS will apply the same market rules to all regions. This can create an integrated national carbon market, improve market efficiency, and avoid the potential race-to-the-bottom problem. However, China is a country with substantial regional heterogeneity. Some

regions are still in the process of rapid industrialization and urbanization; the firms in these regions might be dirtier and more vulnerable to GHG regulation. Although the ETS rules should be the same across regions, the regional equity issue can be addressed by differentiated allowance allocation.

#### **5.4 Rule Design**

Three key elements of the regional pilots—allowance allocation, compliance, and MRV system—have deficiencies that may affect the implementation of the national ETS. Allowance auctioning is a good price-discovery mechanism and should be adopted by the national ETS. In the current regional pilots, only Guangdong experimented with auctioning but failed to attract enough buyers because of the over-allocation of allowances. Different regions might auction different shares of allowances, which can address the distributional concerns across regions.

Perfect compliance is not desirable if it is achieved by manipulating the deadline. The regulators should send a clear signal that enforcement is a credible threat. The penalties for non-compliance should be set at a higher level to deter firms from deviating from their targets. The financial penalty should be determined based on the market value of the excess emissions. The market-based penalty can increase uncertainty and provide a stronger incentive for firms. The non-financial penalties are perhaps more important for SOEs, since their executives are more concerned with career advancement than with monetary remuneration.

The quality of reporting will be affected by whether it is the government or the covered firm that pays the verification fee. For example, Duflo et al. (2013) report on a field experiment in which reports were more truthful when auditors were paid by government rather than by the plant. Some regional pilots require covered firms to select verifiers and pay for verification, which might lead to the concern that the third-party verifier could become less independent. Therefore, the cost of verification should be fixed and paid by the government.

#### **5.5 Data Transparency**

Very limited data and information on regional ETS pilots are publicly accessible, because the information disclosure system has not been established and enterprises are reluctant to share their emissions data. Without further information disclosure, it is difficult for empirical researchers to evaluate the performance of the carbon market and the impact of carbon regulation on entry and exit, industrial competitiveness, R&D, and the labor market. In addition, the lack of credible information inhibits trading on the secondary market.

Basic information such as allocated allowances for each firm is difficult to find. Even the lists of the covered entities are not publicly disclosed. The best available information is the online trading data from the secondary market. However, the data are collected by third-party agencies and are not verified by the exchanges. This not only makes the empirical analysis very challenging, but also creates concerns as to whether the allocation of allowances is fair. Although some pilots have used a benchmarking approach, they do not have detailed allocation standards. As a consequence, the allocation process is not transparent enough to the public, which may lead to political intervention without public supervision. In order to ensure equity, complete and explicit criteria should be published with respect to allowance allocations. Additionally, a company's data privacy interests should also be taken into account by releasing data primarily in anonymous form.

## ✎ ACKNOWLEDGMENTS ✎

We thank Lin Zuo for excellent research assistance. We thank the editor, two anonymous reviewers, and the seminar participants at Stanford University for helpful comments and suggestions.

## References

- Beijing DRC. 2014. "Guidance on Accounting and Reporting of Carbon Emissions in Beijing." Available at <http://www.iso50001.com.cn/uploadfile/2014/1120/20141120032649307.pdf>.
- Beijing Environmental Exchange. 2014. "Annual Report on Carbon Market in Beijing 2014." Available at [http://www.cbeex.com.cn/images2016/bjtsc\\_2014.pdf](http://www.cbeex.com.cn/images2016/bjtsc_2014.pdf).
- . 2015. "Annual Report on Carbon Market in Beijing 2015." Available at [http://www.cbeex.com.cn/images2016/xz\\_1.pdf](http://www.cbeex.com.cn/images2016/xz_1.pdf).
- Burtraw, D., A.G. Fraas, and N.D. Richardson. 2012. "Tradable Standards for Clean Air Act Carbon Policy." Working paper, Resources for the Future.
- Cao, J., R. Garbaccio, and M.S. Ho. 2009. "China's 11th Five-year Plan and the Environment: Reducing SO<sub>2</sub> Emissions." *Review of Environmental Economics and Policy* 3:231–250. <https://doi.org/10.1093/reep/rep006>.
- Chongqing DRC. 2014. "Guidance on Accounting and Reporting of Carbon Emissions in Chongqing." Available at <http://www.cqdp.gov.cn/article-1-20503.aspx>.
- Chongqing People's Congress. 2014. "Interim Measures on Carbon Emissions Management in Chongqing." Available at <http://www.cq.gov.cn/publicinfo/web/views/Show!detail.action?sid=3874934>. Committee of the Shenzhen People's Congress. 2012. "Rules on Carbon Emissions Trading Management in Shenzhen." Available at [http://www.sz.gov.cn/zfgb/2013/gb817/201301/t20130110\\_2099860.htm](http://www.sz.gov.cn/zfgb/2013/gb817/201301/t20130110_2099860.htm).
- Duflo, E., M. Greenstone, R. Pande, and N. Ryan. 2013. "Truth-telling by Third-party Auditors and the Response of Polluting Firms: Experimental Evidence from India." *The Quarterly Journal of Economics* 128(4):1499–1545. <https://doi.org/10.1093/qje/qjt024>.
- General Office of the Beijing People's Government. 2013. "Decisions on Carrying Out Carbon Emissions Trading Schemes in Beijing under the Control of Total Emissions." Available at [http://www.bjrd.gov.cn/zdgg/zyfb/jyjd/201312/t20131230\\_124249.html](http://www.bjrd.gov.cn/zdgg/zyfb/jyjd/201312/t20131230_124249.html).
- . 2014. "Management Methods on Carbon Emissions Trading in Beijing." Available at <http://zhengwu.beijing.gov.cn/gzdt/gggs/t1359070.htm>.
- General Office of the Tianjin People's Government. 2016. "Interim Measures on Carbon Emissions Management in Tianjin." Available at <http://www.tjzb.gov.cn/2016/system/2016/03/30/010001088.shtml>. Guangdong DRC. 2013. "Allocation Plan on Carbon Allowances in Guangdong." Available at <http://www.cnemission.cn/article/zcfg/gdszcwj/201401/20140100000640.shtml>.
- . 2014. "Guidance on Reporting of Carbon Emissions in Guangdong." Available at <http://www.carbon-manager.net/media/carbonbutler/images/guangdong03.pdf>.
- Guangdong People's Government. 2014. "Interim Measures on Carbon Emissions Management in Guangdong." Available at [http://zwgk.gd.gov.cn/006939748/201401/t20140117\\_462131.html](http://zwgk.gd.gov.cn/006939748/201401/t20140117_462131.html).
- Hubei DRC. 2014. "Allocation Plan on Carbon Allowances in Hubei." Available at <http://www.hbets.cn/dffg-Zcfg/1166.htm>.
- . 2015. "Guidance on Reporting of Carbon Emissions in Hubei." Available at <http://www.hbets.cn/res/www/upload/201501/21111655cu8p.pdf>.
- Hubei People's Government. 2013. "Implementation Plan pilot carbon trading schemes in Hubei." Available at [http://gkml.hubei.gov.cn/auto5472/auto5473/201302/t20130227\\_435678.html](http://gkml.hubei.gov.cn/auto5472/auto5473/201302/t20130227_435678.html).
- Jiang, J., D. Xie, B. Ye, B. Shen, and Z. Chen. 2016. "Research on China's Cap-and-Trade Carbon Emission Trading Scheme: Overview and Outlook." *Applied Energy* 178:902–917. <https://doi.org/10.1016/j.apenergy.2016.06.100>.
- Kong, B., and C. Freeman. 2013. "Making Sense of Carbon Market Development in China." *Carbon & Climate Law Review* 3:194–212.

- McKibbin, W.J., A.C. Morris, and P.J. Wilcoxon. 2015. "Controlling Carbon Emissions from US Power Plants: How a Tradable Performance Standard Compares to a Carbon Tax." Working paper, Social Science Research Network.
- Munnings, C., R.D. Morgenstern, Z. Wang, and X. Liu. 2016. "Assessing the Design of Three Carbon Trading Pilot Programs in China." *Energy Policy* 96:688–699. <https://doi.org/10.1016/j.enpol.2016.06.015>.
- NDRC. 2016. "The Key Steps to Launch the National ETS." Available at [http://www.sdpc.gov.cn/gzdt/t20160122\\_772150.html](http://www.sdpc.gov.cn/gzdt/t20160122_772150.html).
- . 2017. "The People's Republic of China First Biennial Update Report on Climate Change." Available at <http://www.ccchina.gov.cn/archiver/ccchinacn/UpFile/Files/Default/20170124155928346053.pdf>.
- Newell, R.G., and W.A. Pizer. 2008. "Indexed Regulation." *Journal of Environmental Economics and management* 56:221–233. <https://doi.org/10.1016/j.jeem.2008.07.001>.
- Shanghai DRC. 2013. "Guidance on Accounting and Reporting of Carbon Emissions in Shanghai."
- Shanghai Environment and Energy Exchange. 2015. "Annual Report on Carbon Market in Shanghai 2013–2014." Available at [http://www.cneeex.com/hjs\\_admin/upload/myupload\\_637.pdf](http://www.cneeex.com/hjs_admin/upload/myupload_637.pdf).
- . 2016. "Annual Report on Carbon Market in Shanghai 2015." Available at [http://www.cneeex.com/xz.jsp?link=myupload\\_854.pdf](http://www.cneeex.com/xz.jsp?link=myupload_854.pdf).
- Shanghai People's Government. 2013. "Trial Measures on Carbon Emissions Trading Management in Shanghai." Available at [http://qhs.ndrc.gov.cn/qjfbjz/201312/t20131231\\_697049.html](http://qhs.ndrc.gov.cn/qjfbjz/201312/t20131231_697049.html).
- Shenzhen Department of Housing and Urban-Rural Development. 2013. "Guidance on Accounting and Reporting of Carbon Emissions in Shenzhen." Available at [http://www.szjs.gov.cn/csml/bgs/xxgk/tzgg\\_1/201304/t20130423\\_2130581.htm](http://www.szjs.gov.cn/csml/bgs/xxgk/tzgg_1/201304/t20130423_2130581.htm).
- The State Council. 2013. "The Twelfth Five-Year Plan for Energy Conservation and Emission Reduction." Available at [http://www.gov.cn/xxgk/pub/govpublic/mrlm/201208/t20120821\\_65505.html](http://www.gov.cn/xxgk/pub/govpublic/mrlm/201208/t20120821_65505.html).
- . 2016. "Work Program on Controlling Carbon Emissions during the Thirteenth Five-Year Period." Available at [http://www.gov.cn/zhengce/content/2016-11/04/content\\_5128619.htm](http://www.gov.cn/zhengce/content/2016-11/04/content_5128619.htm).
- Tianjin DRC. 2013. "List of Enterprises in Carbon Emissions Trading Pilots in Tianjin." Available at [http://www.chinatcx.com.cn/tcxweb/pages/news/news\\_info.jsp?article\\_id=2125](http://www.chinatcx.com.cn/tcxweb/pages/news/news_info.jsp?article_id=2125).
- Tianjin People's Government. 2013. "Guidance on Reporting of Carbon Emissions in Tianjin." Available at <http://www.carbonmanager.net/media/carbonbutler/images/tianjin04.pdf>.
- Zhang, D., V.J. Karplus, C. Cassisa, and X. Zhang. 2014. "Emissions Trading in China: Progress and Prospects." *Energy Policy* 75:9–16. <https://doi.org/10.1016/j.enpol.2014.01.022>.
- Zhang, J. 2012. "Delivering Environmentally Sustainable Economic Growth: the Case of China." Asian Society Report, Available at <http://asiasociety.org/policy-institute/delivering-environmentally-sustainable-economic-growth-case-china>