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Implementation and Effectiveness of ETS in Motivating Enterprises' Environmental Innovation

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Implementation and Effectiveness of ETS in Motivating Enterprises' Environmental Innovation

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Abstract: Emission trading scheme (ETS) and voluntary agreements (VAs) have been used for energy efficiency enhancement and emissions reduction in developed countries since the 1990s. This study contributes to existing research by focusing on the ETS combined with VA programs that is used for reducing energy consumption and, thereby, energy-related emissions in China. This study addresses two problems: who participate in the environmental programs and are those innovative policy instruments effective? Firstly, this study investigates the level of the participation when implementing China's ETS and energy conservation VA programs. Secondly, using multiple criteria, it evaluates the effectiveness of ETS combined with VA programs on motivating corporate green innovation in China.

Keywords: emission trading, voluntary agreements, policy mix, policy implementation, effectiveness

1 Introduction

Emission trading scheme (ETS) and voluntary agreements (VAs) are respectively the economic policy instrument and the suasive policy instrument that have been widely implemented in developed countries for emission abatement or energy efficiency, informed by a large volume of research. They are considered as new environmental policy instruments (NEPIs) that are more cost-effective and flexible than the traditional command-and-control approaches.

Research on either VAs or ETS focused on their implementation and evaluation in developed countries, particularly in European Union (EU). Evidence show that ETS or VAs has led to emission reductions or energy efficiency enhancement in developed countries. And, the experience of some countries suggest that VAs was more effective when it was combined with CO_2/energy tax or with ETS. How will these NEPIs perform in developing countries, considering the weak regulatory capacity, as in monitoring and enforcing, and the need for economic growth in developing countries?

As the second largest greenhouse gas (GHG) emitter, China has made great efforts in response to climate change in the past decade, mainly by setting ambitious policy goals. In December 2009, before the Copenhagen conference, China pledged to reduce the CO_2 emission intensity (i.e., the CO_2 emission per unit of GDP) by 40–45% by 2020 over the 2005 level. In June 2015, China submitted the report ‘‘Enhanced Actions on Climate Change: China’s Intended Nationally Determined Contributions” to the Secretariat of the United Nations Framework Convention on Climate Change and claimed to decrease CO_2 emission intensity by 60–65% by 2030 over the 2005 level (NDRC, 2015).

A set of policies and policy instruments has been undertaken to facilitate achieving the targets, including ETS. Traditional GCAC approaches are found to be unable to achieve long-term environmental targets (Q. Wang and Chen 2015). In particular, during the 12th FYP period

(2010-2015), President Xi emphasized the necessity to use economic instruments in solving environmental issues, which was also given attention in the newly released 13th FYP.

Energy efficiency has been high on China's policy agenda as well, as China seeks to reduce wasteful energy consumption, ensure energy security and reduce GHG emissions. The targets of energy efficiency enhancement in China are believed to be convertible to large amounts of carbon emission reductions. The massive attention to energy efficiency started with China's announcement of its goal of reducing energy intensity (i.e. energy consumption per unit of GDP) by 20% during China's 11th FYP period (2005-2010) (State Council Of China 2006).

To help achieve the energy conservation target of 11th FYP, in 2006, China launched a Top-1,000 Enterprises Energy Conservation Program (referred as Top-1,000 Enterprises Program hereafter). The program was modelled on VA programs in developed countries. In 2011, it was up-scaled to the Top-10,000 Energy Conservation Low-Carbon Program (referred as Top-10,000 Enterprises Program hereafter). The program covered 16,078 energy-intensive enterprises, with their total energy consumption accounting for about 60% of the national energy consumption. It turns out that some enterprises covered by the Top-10,000 Enterprises Program were later included by the ETS as well.

This study attempts to explore how to encourage industrial enterprises to undertake green innovation, which can yield long-term efficiency in energy conservation and emission reduction. So, it takes ETS as a policy case, examining its implementation, multi-criteria effectiveness, and its interactions with other policy instruments. First, this study has a brief analysis of the design of ETS, addressing its theoretical interaction with energy conservation VA program. Second, it discusses the level of participation which is the pre-condition for these policy instruments to be effective. Then, it assesses the effectiveness of the ETS-especially when combined with VA programs- on corporate green innovation from different aspects, including the economic incentives for enterprises to take low-carbon technologies, the success in enforcing compliance with emission abatement targets, the effect on building networks and knowledge, the effect on energy- and carbon-related corporate management and the cost-efficiency of the policy instrument.

This study will contribute to the existing literature by providing evidence of implementation and impact of ETS and VAs in China, deepening understanding of policy implementation and policy impact in the context of policy diffusion from developed countries to developing countries.

2 Literature review

2.1 ETS and empirical studies

ETS is known as a "cap-and-trade" approach to control pollution. The "cap" sets levels of allowed emissions or assigned amounts. These emission allowance units can be considered as the right to emit pollutants. The "trade" creates a market and allow polluters to trade the allowance units. So, the emission allowance would be a new commodity in the market.

Participation in ETS is often not completely voluntary. If an enterprise is a large emitter and belongs to the capped industrial sector, normally it is obliged to participate in the ETS. So, theoretically, the incentives for the capped enterprises to adopt low-carbon strategies include the pressure to comply and the benefits from selling excess allowances.

Empirically, can ETS effectively reduce CO_2 emissions? A group studies estimated the impact of EU ETS on CO_2 emissions at aggregate level via econometric techniques, which found that EU ETS led to emission reductions comparing with business-as-usual (BAU) scenarios. As Laing et al (2014) summarized, this literature shows that, overall, the average amount of emission reductions attributable to EU ETS was 40-80 $MtCO_2$ per year before the financial crisis in 2009. This emission reduction effect varies with industrial sectors. Ellerman and

Buchner (2008) found that EU ETS led to the largest emission reductions in power sector, in relative to other sectors, through fuel transition from coal to natural gas. However, Abrell, Zachmann and Ndoye (2011) found that non-metallic minerals (e.g. cement) and basic metal product industry achieved the largest emission reductions driven by the EU ETS, but the power sector did not achieve high emission reductions. Little evidence for other sectors have been reported (2014). Most studies on the topic covered the first four years (2005-2008) of the EU ETS. It is difficult to tease out the impact of EU ETS on emission abatement after the financial crisis bursting out in 2008, as emission abatement could also be considered as the result of the financial crisis via the depression of production activities.

Other studies adopted a bottom-up approach, using firm level data to estimate the policy impact. For instance, to investigate the impact of EU ETS, Abrell, Zachmann and Ndoye (2011) utilized panel data on the CO_2 emissions and performance (i.e. added value, profit margin or employment) of more than 2,000 European firms during 2005-2008. The results show that the ETS was effective in emission reductions during the beginning of Phase II. They also found that the initial allocation of permits affected the emission reductions achieved by enterprises. The stricter the initial allocation is, the more emission reductions can be achieved.

A group of studies have investigated the impact of the EU ETS on investment decisions (regarding low-carbon assets and technologies) at firm level. For instance, Martin, Muûls and Wagner (2011) interviewed managers in 800 manufacturing enterprises in six European countries in 2009 and used the collected evidence from interviews to investigate how these enterprises integrated the price signals of CO_2 emissions into their business development. They found that a large proportion of the EU ETS participants passively participated in the market and did not consider emission allowances as a type of financial asset. Most enterprises did not trade with other participants, and even the enterprises with excess allowances were not sufficiently motivated to sell the allowances until the total amount of the excess allowances was above a threshold (5,000-10,000 units).

Some evidence show that the EU ETS could bring the cost of CO_2 emissions to the boardroom of decision making (Kenber, Haugen, and Cobb 2009). However, ETS could only lead enterprises to integrate carbon prices in small-scale investment decisions with short amortization times, but not be able to affect large-scale investment decisions with long amortization times (Hoffmann 2007). Therefore, the EU ETS was moderately associated with the adoption of low-carbon measures relating to production processes (Martin, Muûls, and Wagner 2011; Anderson, Convery, and Di Maria 2010; Petsonk and Cozijnsen 2007), the cancellation of investments in energy intensive power plants in favor of cleaner ones (Hervé-Mignucci 2011), and the short-term fuel switching (Anderson, Convery, and Di Maria 2010).

A few recent studies utilized more robust econometric techniques to examine the impact of the EU ETS on technological innovation at enterprise-level when controlling for the confounding variables mentioned above. In order to get more robust results, Calel and Dechezlepretre (2012) utilized matching econometric techniques to exploit the impact of the EU ETS on technological change. They found that the scheme had increased the low-carbon innovation among regulated enterprises by about 10% without crowding out patents for other technologies, and it also affected patenting activities in non-regulated firms. In total, they concluded that the scheme caused a 1% increase of low-carbon patents in European compared to a counterfactual scenario.

The impact of ETS also varies across enterprises, technologies and the dimensions of innovation (Rogge, Schneider, and Hoffmann 2011). Based on case studies in the context of German's power sector, Rogge, Schneider and Hoffmann (2011) concluded that ETS was more likely to affect organizational innovation rather than technological innovation. In addition, they found that enterprises were less affected by ETS than by contextual factors, such as policy mix, market conditions and public acceptance. Regarding different dimensions of technological innovations, Rogge (2010) found that EU ETS led to not only incremental innovations, but also radical innovations of technologies, from the perspective of enterprise-level research, development and demonstration. In contrast, the adoption of state-of-the art technologies by enterprises depends strongly on contextual factors.

2.2 Environmental VA programs and empirical studies

VAs are tailor-made contracts between the government and industry, or "negotiated targets with commitments and time schedules on the part of all participating parties" (Bertoldi and Rezessy 2009, p.38). VAs have been used for energy efficiency and emission reduction goals in industrialized countries. Key elements of VA programs include preparation, negotiation, administration, monitoring, enforcement and evaluation, mainly involving stakeholders from governments and enterprises. VAs typically cover a long term period of five to ten years in order to promote the planning and implementation of strategic investments. Some VA programs are completely voluntary, while other VAs are implemented in combination with stricter existing/future environmental regulations.

Generally, there are three types of VA programs, categorized by Price (2005). One category refers to the programs that are completely voluntary. They use relative low-cost incentives for participants, such as government assistance and training, information provision, government/public recognition and some financial incentives in the form of low-cost energy auditing or tax exemptions for purchasing energy-efficient equipment. A second category refers to the programs that motivate participation using the threat of future regulations or energy/carbon taxes. In addition to the incentives used in completely voluntary programs, the second category of programs provides future incentives such as the promise of relief from future environmental regulations/taxes, or easier environmental permitting procedures. A third category refers to the programs that are implemented in combination with existing energy/carbon taxes or regulations. In addition to some incentives used in the other two categories of programs, the third category of programs also use for non-compliance such as the application of current energy/carbon taxes or stricter regulations. Some recent programs are combined with ETS (see Table 1), so that participants of VAs are additionally motivated by the benefits from selling excess allowances and threatened by the penalties for over emissions.

Table 1 Selected VA programs used together with ETS

Countries	Program	Duration
Canada	Large Final Emitters Program	2003-2012
Denmark	Agreements on Industrial Energy Efficiency	1993-present
Ireland	Negotiated Energy Agreements Pilot Project	2002-2003
New Zealand	Negotiated Greenhouse Agreements	2003-2012
Switzerland	CO_2 Law Voluntary Measures	2000-2012
UK	Climate Change Agreements	2001-2013

Given incentives intentionally designed by VA programs, industry participation in VA programs is motivated by various factors, such as a desire to influence or get exemptions from regulations, access to subsidies or tax rebates, improving competitiveness through building a green image as demanded by consumers or investors, possibilities to lower production costs, or a belief that non-participation is costly (Welch and Hibiki 2003). However, high administration costs or transaction costs can discourage industrial enterprises or industries from participating VA programs, despite of the incentives offered by the programs.

Evidence show that the level of industry participation varies across different types of VA programs. Price (2005) found that completely voluntary programs typically had a lower participation level with a small coverage of energy consumption or GHG emissions in industrial sector, while the other two categories of VA programs had higher participation levels.

The effectiveness of VA programs in achieving their environmental goals is also different across different types of VA programs. Many completely voluntary programs were found to be unable to reach their energy saving or emission reduction targets, or unable to determine if the targets were met due to poor monitoring and reporting (Price 2005). The VA programs that used the threat of future regulation or energy/carbon taxes, and programs that were in combination with existing regulation or energy/carbon taxes were found to be generally more successful than completely voluntary programs (Price 2005).

In terms of the effect on green innovation, some studies reported that VA programs could encourage the incremental environmental initiatives more than radical improvement (Jiménez 2007). Johannsen (2002) assessed the implementation of a Danish VA program on energy efficiency in combination with a CO_2 tax and found that the program had a high impact on administrative costs, but a low impact on innovation. However, in China, a pilot VA program targeting at energy efficiency in Shandong significantly promoted corporate technological investments and enhanced energy management (Hu 2007). Thus, we can say that the impact of VA programs on enterprise-level innovations also varies with contextual factors. One supporting condition for the success of a VA program could be the resources that the participating enterprises have. For instance, Lo, Li and Wang (2015) performed a survey of 11 enterprises through interviews with enterprise managers in order to examine the effectiveness of China's Top-1,000 Enterprises Program. They found that the effectiveness of the VA program varies by the size and ownership of the participating enterprises. Large state-owned enterprises (SOEs) had more resources and incentives to adopt substantial energy-efficient technologies and practices.

2.3 Theoretical framework

The discussions surrounding the NEPIs assume that the selection of different types of policy instruments relates to the effectiveness in achieving environmental goals. Recent studies on policy implementation also address the relation between the selection of policy tools and the implementation success. The focal idea is to see whether the policy/policy instrument is implemented as intended, relying on the tools selected for implementation. One of the major implementation concerns is that targeting participants fail to respond in ways anticipated by policy makers due to opportunity costs, inertia, low/perverse incentives, and so on (Weaver 2010).

Advocates of NEPIs, including economic instruments and suasive instruments, believed that the implementation effectiveness could be notably improved by relying on less interventionist approaches. Economic instruments, such as ETS, follow the principle of polluters pay, which requires that the polluters pay for the negative environmental impact that they incur. Theoretically, ETS is an effective policy tool with the least social cost, as a participant can adopt the most affordable pollution abatement measures. Suasive instruments, such as VAs, work in the other way, addressing the dialogue between the polluters and the regulators in order to encourage voluntary and cooperative environmental actions. Theoretically, suasive instruments improve the implementation effectiveness by leaving discretions for the participants to align their environmental commitments with the specific contexts, especially when policy makers have limited capacity to take diverse contexts at different government levels into account during policy-making process.

However, institutional contexts are also important. There is no simple causal relation between the selection of policy instruments and implementation effectiveness (Knill and Liefferink 2007). In the cases of developing countries where the monitoring and enforcement resources are limited, the success of economic or voluntary policy instruments is an empirical question. And, given the complexities of climate change issues, a well-designed policy mix would be more effective rather than using policy instrument separately.

2.4 Research question

Research question 1: Who participate in ETS? And who participate in both ETS and VA programs?

This part assesses the success of implementation by examining the level of participation.

Research question 2: Is ETS, when combined with VA instruments, effective in motivating enterprises to undertake environmental innovation?

This part assesses the policy effect from the realized incentives for adopting low-carbon technologies, the success in enforcing compliance with environmental targets, the effect on building policy networks and relevant knowledge, the effect on energy- and carbon-related corporate management and the cost-efficiency.

3 Data and method

So far, China has ETS pilots in two provinces, including Guangdong and Hubei, and five cities, including Beijing, Shanghai, Shenzhen, Tianjin and Chongqing. The energy conservation VA program, that is, the Top-10,000 Enterprises Program is at national level, with participants from different provinces or cities. Information for policy designs of the ETS pilots and the VA program were collected mainly from policy documents and literature.

China's National Development and Reform Commission (NDRC) asked each ETS pilot to make the list of capped enterprises publicly available. NDRC also publicized the list of participants in the VA program, and it annually reported state-owned enterprises' progress towards their annual energy-saving targets. These name lists of enterprises were collected from the websites of NDRC and Emission Exchanges of ETS pilots.

Regarding characteristics of the participating enterprises, the government websites of China's State Administration for Industry and Commerce (SAIC) [1] and local Administration for

[1] Enterprise-level information can be found at http://www.gsxt.gov.cn/index.html.

Industry and Commerce (AIC) provide enterprise-level information, including shareholders, registered capital, and business activities. Additional information was collected from Shenzhen Stock Exchange and corporate websites.

Evidence for ex-post evaluation of the ETS were collected from triangular sources, including direct observations, academic studies, media coverage, industrial association, enterprises' websites, corporate business reports and corporate social responsibility reports (CSR).

Basic statistical analysis is used to see the characteristics of participants, while economic reasoning is used to discuss the effects of ETS and its interactions with VA instrument.

4 Policy design and policy interaction analysis

Although ETS and VA are different types of policy instruments, they have some common policy elements. They both need to (1) set rules for recruiting potential participants, (2) assign targets to identified participants, and (3) enforce compliance using penalties or rewards. From the three aspects, Table 2 displays the design of two policy instruments that have been implemented in China.

Table 2 Policy features of ETS and energy conservation VA in China

Program (duration)	Top-10,000 Enterprises Program (2011-2015)	ETS pilots (2013-present)
Policy goal	250 million tce energy savings in 2011-2015: considering the international, domestic and sectoral best practice	Intensity-based emission reduction targets (ton CO_2e/GDP) in relative to 2010 levels: (1) BJ-18% reduction of carbon intensity; (2) SH-19% reduction; (3) SZ-21% reduction; (4) TJ-19% reduction; (5) CQ-17% reduction; (6) GD-19% reduction; (7) HB-17% reduction.
Coverage	60% of the national energy consumption in 2010	Coverage of the total emissions in the city/province: (1) BJ-40%; (2) SH-57%; (3) SZ-38%; (4) TJ-60%; (5) CQ-40%; (6) GD-55%; (7) HB-35%
Identifying potential participants	(1) industrial enterprise that each used more than 10,000 tce energy in 2010; (2) transportation enterprises that each used more than 10,000 tce energy in 2010; (3) hotels, restaurants, commercial enterprises, and schools that each used more than 5,000 tce energy per year	Enterprises are capped if they meet thresholds as follows. (1) BJ: annual emission >10,000 tons CO_2e on average during 2009-2012. (2) SH: emission >20,000 tons CO_2e in 2010 or 2011 for major industrial sectors; the threshold is >10,000 tons CO_2e for other sectors.

		(3) SZ: industrial enterprises with emission>3,000 tons CO_2e per year, or public buildings with area >10,000m^2. (4): TJ: annual emission>20,000 tons CO_2e in any year since 2009. (5) CQ: annual emission >10,000 tons CO_2e in any year during 2009-2012. (6) GD: industrial enterprises with annual emission >10,000 tons CO_2e on average or any year in 2010-2012; for other sectors, enterprises with emission > 5,000 tons CO_2e. (7) HB: emission > 150,000 tons CO_2e for major regulated sectors in 2010 or 2011
Setting enterprise-level targets	Energy saving targets are decided through two-tier negotiation process, and the targets will not be negotiated again during five years: (1) First, provincial and central governments negotiated and reached agreements on targets. (2) Second, provincial governments and enterprises negotiated and reaches agreements on targets considering corporate energy saving potentials.	Intensity-based emission caps are assigned to participating enterprises through either free allocation or auctioning, and the enterprises can buy more emission allowance from the ETS market: (1) Free allocation through grandfathering approach is the prevalent allocation method across pilots; (2) Auctioning has been used as a complementary allocation method in Guangdong, Shanghai and Shenzhen to allocate a small portion of allowances.
Enforcing compliance	(1) Annual evaluation and reports of enterprises' progress towards their annual energy-saving targets. (2) For enterprises failing to meet their annual targets, mandatory energy audits and retrofits are required. (3) Additional sanctions for non-compliant SOEs: no annual awards for the leaders of non-compliant SOEs no matter how good the enterprises are in other aspects.	Except Chongqing and Tianjin, every ETS pilot has monetary penalties for non-compliance. Additionally, Shenzhen, Hubei and Guangdong have a further penalty, which is deducting the excess emissions from the following's emission allowance.

Note: "tce" denotes tons of coal equivalent. "CO_2e" denotes CO_2 equivalent. Policy data of Top-10,000 Enterprises Program is from Industrial Efficiency Policy Database and verified with Chinese policy documents. Policy data of ETS is from Swartz (2013) and verified with Chinese policy documents. Intensity based cap limit emission level to a pre-specified emission rate relative to output.

The NDRC and local DRCs play as the regulators both for the ETS pilots and for the Top-10,000 Enterprises Program. The Top-10,000 Enterprises Program covered a substantial proportion of the national energy consumption in 2011, while each ETS pilot capped a large proportion of CO_2e emissions in that pilot region. For ETS, there are four tier intensity based emission reduction targets in China: country level, provincial level, city level and enterprise level. China set an emission intensity-based target for the country in its FYPs, and provinces and cities set their targets accordingly. Thereafter, each ETS pilot set emission caps for participating enterprises.

Both the VA program and ETS have compliance enforcement mechanisms. ETS uses monetary penalties, stricter emission cap, or both to punish non-compliance. Shenzhen ETS, Hubei ETS and Guangdong ETS as well as EU ETS use both types of penalties. In Phase II (2008-2012) of EU ETS, non-compliant enterprises have to pay 100€ (about 143 $) penalty per ton of excess CO_2e emissions[2] and the over emissions would be deducted from the following compliance year's allowances. Shenzhen, Hubei and Guangdong ETS are similar to EU-ETS in using stricter emission allocation for non-compliance, but different from EU-ETS regarding the amount of monetary fines. In Shenzhen and Hubei, non-compliant enterprises should pay the penalty equal to three times the average market price for each ton of CO_2 emissions exceeding the limit, while Guangdong charges a total amount of up to 50000 RMB (about 7900 $) for non-compliance. In Beijing and Shanghai, however, there are only monetary fines on non-compliance. Chongqing and Tianjin ETS set no monetary penalties for non-compliance at all, but disqualify non-compliant entities from associated subsidies or rewards for the next three years.

For the Top-10,000 Enterprises Program, the punishment for non-compliance is "softer" without monetary fines. Non-compliant enterprises are generally faced with sanctions such as mandatory energy audits and retrofits. Non-compliant SOEs are faced with additional sanctions relating to the job promotion of corporate leaders. The introduction of ETS can give participants of the Top-10,000 Enterprises Program more incentives to comply with their energy saving targets, especially for those private enterprises. The additional incentives from ETS to VAs can be incomes from selling excess allowance or pressure to comply with ETS target.

As mentioned above, ETS pilots in China assign intensity-based caps to regulated enterprises. An enterprise regulated by ETS can meet the emission reduction target by simply increasing

[2] CO2 equivalent emissions

its economic output, without adopting any low-carbon technologies. So, the intensity-based cap setting allows the rapid economic growth to continue, and thus the total amount of emissions will increase. For an enterprise under ETS, the energy conservation VA program can give the enterprise more motivation to take actual environmental actions, because the VA program sets an absolute energy consumption limit (convertible to emission limit). In addition, knowledge gained by VA programs through benchmarking, energy audit and energy management could be valuable for reducing the implementation cost of ETS. Therefore, this theoretical analysis suggests that the combination of ETS and VAs work better together rather than using ETS or VAs separately.

5 Policy implementation analysis: who participate

5.1 Participants in ETS

Table 3 summarized the number of regulated industrial enterprises and the mainly regulated industrial sectors under ETS. The participation list reflects the economic structures of the ETS pilots. Beijing and Shenzhen have the highest number of corporate participants. Regarding the regulated industrial sectors, Beijing and Shenzhen do not cover steel sector in ETS as they have few heavy industries. Power generation sector is covered by all pilots, except Chongqing, because they rely on coal fuel and become the largest emitters for each province/city. Cement sector is often a large emitter as well, which is covered by Beijing, Chongqing, Guangdong and Hubei. Different industrial sectors have different emission reduction potentials and different emission abatement costs.

Table 3 Number of regulated industrial enterprises under ETS

ETS pilots	Number of regulated enterprises (2013-2015)	Regulated industrial sectors
Beijing	415	Power and heat sector, and manufacturing sectors including cement, automobile manufacturing and petrochemical
Shanghai	191	Power sector, and manufactural sectors covering steel, rubber, non-ferrous metal, petrochemical, building materials, chemical, paper, textile and chemical fiber industry
Shenzhen	635	Power sector, gas sector, water sector and more than 20 manufactural sectors
Tianjin	114	Power and heat sector, civil construction, oil and gas mining and manufactural sectors covering petrochemical, chemicals, iron and steel
Chongqing	242	Manufactural sectors covering metal alloy, calcium carbide, caustic soda, cement, electro-plated aluminum, steel and iron
Guangdong	184	Power sector, and manufactural sectors covering cement, steel, ceramics, petrochemical, non-ferrous, plastics and paper
Hubei	167	Power sector, and many manufactural sectors including steel, chemical, cement, automobile manufacturing, non-ferrous metals, glass, and paper

Data source: websites of Emission Exchanges of the seven ETS pilots

Top-10,000 Enterprises Program has participants in all provinces. The program was designed at national level and implemented together with local governments. In comparison with ETS, Table 4 summarized the number of participating enterprises of the Top-10,000 Enterprises Program in Beijing, Shanghai, Shenzhen, Tianjin, Chongqing, Hubei and Guangdong. Shanghai and Beijing have the highest number of participants among the five cities. Shenzhen, on the other hand, has only 46 corporate enterprises under the Top-10,000 Enterprises Program, because it has fewer energy-intensive industries than the other four cities. Guangdong province has up to 970 participating enterprises, while Hubei province has 812 participating enterprises. In total, the national participants count up to 16078, with the energy saving target of 290 million tce, more than its initial energy saving target of 250 million tce written on the policy design document.

Table 4 Number of participating enterprises in Top-10,000 Enterprise Program

Location	Number of participating enterprises (2011-2015)	Total energy saving target (10,000 tce)
National	16078	29011
Beijing	241	224
Shanghai	269	685
Shenzhen	46	62
Tianjin	211	486
Chongqing	221	330
Guangdong	970	1430
Hubei	812	1131

Data source: the official website of NDRC. ”tce” denotes ton of coal equivalent

Some local governments also had local-level Top-10,000 Enterprise Program during 2011-2015. Take Guangdong as an example. It had a provincial level Top-10,000 Enterprises Program aiming for energy conservation and GHG emission reductions. All participants in the national-level VA program are also included in Guangdong's VA program. Guangdong referred this VA program as the Guangdong Top-10,000 Enterprises Program to differentiate it from the national program. In fact, there are less than 10,000 enterprises in Guangdong's program.

The participating enterprises in the national Top-10,000 Enterprises Program include industrial enterprises or transportation enterprises that each used more than 10,000 tce energy in 2010. For Guangdong Top-10,000 Enterprises Program, industrial enterprises that used less energy are also included. The threshold for Guangdongis 5,000 tce energy used in 2010. Under Guangdong's Top-10,000 Enterprises Program, up to 312 enterprises of Shenzhen are covered (see Table 5).

Table 5 Guangdong Top-10,000 Enterprise Program: participants and energy saving targets

No.	City	Number of participants in VA programs		Energy saving targets (tce)	
		Total	National VA program	Total	National VA program
1	Guangzhou	283	111	2329877	2103220
2	Shenzhen	312	46	971204	622081
3	Zhuhai	43	28	655194	636349
4	Shantou	17	7	322221	309317
5	Foshan	226	139	1429323	1311721
6	Shaoguan	60	28	1247798	1204632
7	Heyuan	30	14	209851	189654
8	Meizhou	42	32	508893	495919
9	Huizhou	50	26	1147833	1117110
10	Shanwei	2	2	125953	125953

11	Dongguan	165	89	1852852	1751827
12	Zhongshan	79	30	341259	278080
13	Jiangmen	103	38	595638	509433
14	Yangjiang	12	8	309870	304974
15	Zhanjiang	66	44	491105	458388
16	Maoming	30	21	852640	841097
17	Zhaoqing	81	52	462914	421540
18	Qingyuan	80	51	1032389	997857
19	Chaozhou	87	15	329917	233722
20	Jieyang	12	2	191329	167935
21	Yunfo	32	24	467201	457035
	Total	1812	807	15875261	14537844

Source: the official website of the Guangdong DRC

5.2 Participants in both ETS and VA

This section concentrates on Shenzhen's case to see who participate in both ETS and VA. Shenzhen is the first one that established ETS pilot in China, which has compiled knowledge about the design and implementation of ETS.

As aforementioned, 46 enterprises of Shenzhen have been covered by the national Top-10,000 Enterprises Program since 2011. From 2013, 22 of the 46 enterprises were included in the Shenzhen ETS (see Table 6). These 22 enterprises are energy-intensive and the focus of pollution control by the state. The national Top-10,000 Enterprises Program set a total energy saving target of 622081 tce for the 46 enterprises, while the energy saving target of the 22 enterprises is 457576 tce energy, accounting for more than 70%.

Table 6 Enterprises of Shenzhen participating in both ETS and national VA program

	Industrial sector	Number of enterprises	Energy saving targets (tce)
Manufacture sectors	Alcoholic and non-alcoholic beverages, and tea industry	1	3934
	Computer, communication equipment and other electronic equipment manufacturing	7	49033
	Electrical machinery, equipment manufacturing	2	7229
	General industrial machinery & equipment manufacturing	2	20380
	Metal products manufacturing	1	2883
	Processing of agricultural and side-line products	1	7144
	Transportation equipment manufacturing	1	4188
Production & supply of gas		1	8639
Production & supply of power and heat		6	354144
Total		22	457576

Data Source: Participants' list of ETS is from Shenzhen Emission Exchanges website. Participants' list of the national Top-10,000 Enterprises Program and their energy saving targets are from the website of the NDRC. The industrial classification that is used is the Standard Industrial Classification Code (GB/T 4754-2011) suggested by the National Bureau of Statistics of China.

With regards to the 22 enterprises regulated by both the national VA program and the local we can see that most enterprises (15) are from different manufacture sectors. Among the 15 enterprises, seven enterprises are from the industry of computer, communication equipment and other electronic equipment, one of the main industry sector in Shenzhen. Six enterprises are from the power and heat sector, and they are the large emitters. So, the emission saving target of the six enterprises is 354144 tce, about three times of the total target of all the other 16 enterprises. In addition, among the 22 enterprises, 10 enterprises are invested (partially or entirely) by foreign enterprises, while 12 enterprises do not have foreign shareholders. In terms of ownership, 11 enterprises are private enterprises, while the other half are SOEs; in terms of regulators, 9 enterprises are regulated by the central government, while the other 13 enterprises are regulated by the local government.

Table 7 Enterprises of Shenzhen participating in both ETS and provincial VA program

Industrial sector		Number of enterprises	Energy saving targets (tce)
Manufacture sectors	Alcoholic and non-alcoholic beverage, and tea industry	2	5449
	Apparel, textiles, clothing product manufacturing	1	1429
	Chemicals and chemical products manufacturing	3	3814
	Computer, communication equipment and other electronic equipment manufacturing	35	68517
	Computer, communication equipment and other electronic equipment manufacturing; automobile manufacturing	1	19184
	Electrical machinery, equipment manufacturing	7	13604
	Food and Kindred Products	1	1490
	Furniture manufacturing	1	1397
	General industrial machinery & equipment manufacturing	4	22760
	Machinery & instrument manufacturing	4	5151
	Medical and pharmaceutical products manufacturing	5	4893
	Metal products manufacturing	5	7851
	Non-metallic mineral product manufacturing	11	14350
	Papers and paper products manufacturing	2	2963
	Petroleum refining, coke making, and nuclear fuel processing	1	1084
	Plastics and Rubber Products Manufacturing	1	1138
	Print and record industry	4	4853
	Processing of agricultural and side-line products	5	12982
	Rubber and plastic products manufacturing	5	7227
	Smelting & Refining of Nonferrous Metals	2	3035
	Special industry machinery & equipment manufacturing	5	6379
	Textile industry	1	1334
	Transportation equipment manufacturing	3	7220
Production and supply of water		1	1
Production and supply of gas		1	1

Production and supply of power and heat	6	6
Total	117	582437

Data Source: Participants' list of ETS is from Shenzhen Emission Exchanges website. Participants' list of the provincial Top-10,000 Enterprises Program and their energy saving targets are from the website of the Guangdong DRC. The industrial classification that is used is the Standard Industrial Classification Code (GB/T 4754-2011) suggested by the National Bureau of Statistics of China.

Shenzhen is also part of the provincial Top-10,000 Enterprises Program of Guangdong. There are 312 enterprises in Shenzhen covered by this provincial VA program since 2011, including the 46 enterprises participating the national program. Among the 312 enterprises, 117 enterprises have joined Shenzhen ETS from 2013 (see Table 7). 95 out of the 117 enterprises participate both Shenzhen ETS and Guangdong's VA program, while the other 22 enterprises participate both Shenzhen ETS and the national VA program. And, the energy saving target of the power and heat sector account for more than 50% of the total target of the 117 enterprises.

6 Policy effectiveness analysis

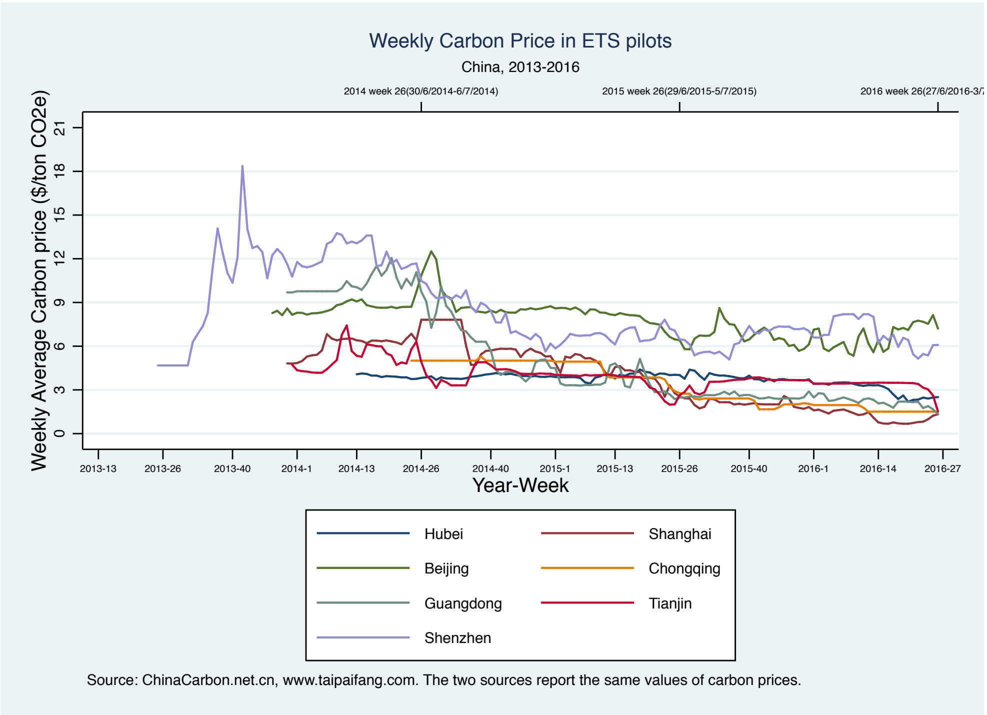
This section examines the effectiveness of ETS using multiple criteria.

6.1 Economic incentives for adopting low-carbon technologies

ETS creates a market for emission allowance. Each regulated enterprise by ETS is allocated with some emission allowances for free. If the enterprise produces more emissions than the allocated allowances, it can either buy emission allowances from the market, or reduce the emissions internally by investing in low-carbon technologies. If the carbon price (i.e. the price of emission allowance) is low, the enterprise would simply buy the allowances because it is cheaper than buying low-carbon installations. The higher the carbon price, the enterprise is more motivated to achieve actual emission abatement.

Descriptively, the carbon prices in each ETS pilot of China are far less than the ideal prices that can cause substantial low-carbon actions. According to a government official in China's NDRC, the carbon price ideally should be 30-45 \$/ton CO_2e in order to motivate enterprises to take strategic actions[3]. Based on a two-region dynamic CGE model, Wang et al (2015) also suggested that the carbon price should be about 38$ CO_2e for reaching the Copenhagen target towards 2020 in Guangdong. Among the seven ETS pilots in China, Shenzhen has the highest carbon price on average. However, even in Shenzhen, its highest carbon price was less than 20$/ton CO_2e over the history of price development (see Figure 1), far from the ideal price suggested by Wang et al (2015). For Shanghai ETS, its price once reduced to 0.68$/ton CO_2e, which provided very poor incentives for emitters to make environmental changes. In that case, even if an enterprise reduces emissions that are equivalent to 10,000 ton CO_2e emission allowance by introducing low-carbon technologies, which can be costly, the enterprise could only earn 6800$, a small number of income even for a small-to-medium enterprise. So, the enterprise would probably just buy the allowance using 6800$.

Figure 1 Weekly average carbon price in seven ETS pilots, China (2013-2016)



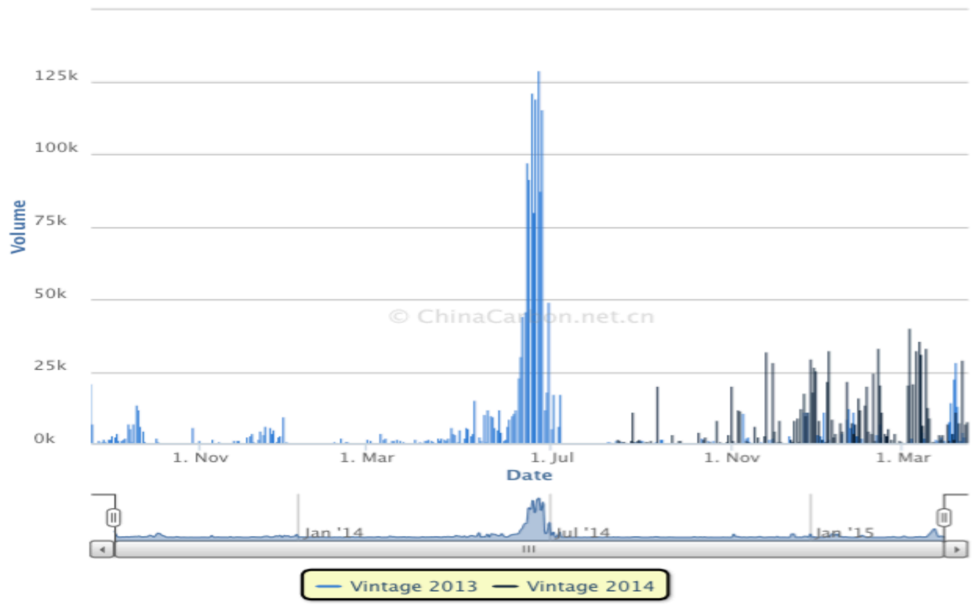
As a comparison, the price of carbon futures in EU ETS during Phase II (2008-2012) was about 23.64 $/ton CO_2e on average (Daskalakis 2013). And in particular, the carbon futures price was

[3] More information can be found at http://www.tanpaifang.com/tanjiaoyi/2016/0620/53811.html

25.49 \$/ton CO_2e in December 2009, 23.04 \$/ton CO_2e in December 2010, 23.43 \$/ton CO_2e in December 2011 and 22.57 \$/ton CO_2e in December 2012 (Daskalakis 2013). Nonetheless, the carbon price of EU ETS decreases to a low level in Phase III (2013-2020). According to World Bank (2015; 2016), the carbon price in EU ETS was about 8\$/ton CO_2e in April 2015, and 6\$/ton CO_2e in April 2016, which were similar to the carbon prices of Shenzhen ETS at that time.

Given the low carbon prices in China, there is no active carbon trading activities on average. Take Shenzhen ETS as an example. As shown in Figure 2, the market was built in June 2013, but it was pretty quiet until May 2014, with only a few days having the trading volume larger than 10000 RMB (about 1610 US\$). This was because both the demand and supply of emission allowance were at a low level at that time. Since the system was newly established, enterprises that felt challenging to achieve their emission reduction targets were waiting to see the determination of the government in enforcing the scheme. On the other hand, enterprises with excess allowances tended to keep the allowances for future use considering the regulatory risk.

Figure 2. Shenzhen spot trading volumes from June 2013 to April 2015



Source: chinacarbon.net.cn. Unit, RMB.

During June 2014 - the early July 2014, the daily trading volume suddenly increased. That was when the regulated enterprises had to submit their valid emission allowance. So, enterprises participated in trading actively to get enough allowance for compliance. After this "compliance break", the market was back to be quite as before. But from November 2014 to present, the daily carbon trading volume become more stable. This may be a sign that the market is moving toward maturity.

The passivity of the regulated enterprises in trading has been observed in EU ETS as well. For instance, Martin, Muûls and Wagner (2011) found that, during Phase I (2005-2008) of EU EST, a large proportion of the participants passively participated in the trading and did not consider emission allowances as a type of financial asset. Most enterprises did not trade with other participants, and even the enterprises with excess allowances were not sufficiently motivated to sell the allowances until the amount of the excess allowances was above a threshold (5,000-10,000 units).

Due to poor data accessibility, it is hard to know whether those enterprises under both ETS and VAs are more active in the market. There are also limited available data to examine how the participants manage to comply with their emission abatement targets. By investing in low-carbon technologies or simply increasing output? It is hard to answer with insufficient data so far. But, the analysis above at least suggests that the ETS pilots are providing poor economic incentives for participants to make large-scale investments in adopting low-carbon technologies.

However, a long-term perspective, ETS gives enterprises a price signal that emissions are with costs, urging enterprises to shift their investment decisions in future towards low-carbon technologies. This is especially true with energy intensive industries, the power and heat sectors for instance, who have higher share of technologies not aligning with the ETS policy. VA program, on the other hand, is more proper for achieving short-term environmental goals. What happened in China before was that the participant of VA programs shut down their production activities for a few days to meet the energy saving targets. Relatively, the introduction of ETS help with reaching long-term goals, and works for all industrial sectors as emission allowance can be traded between sectors.

6.2 Success in enforcing compliance

The first compliance period was 2013-2015, and one calendar year is a compliance year. According to the data published by the Emission Exchanges, all ETS pilots had high compliane rates. For instance, the compliance rates of year 2013 were all higher than 95% in Beijing, Shanghai, Shenzhen, Tianjin and Guangzhou. So, we can see that ETS pilots in China are successful in enforcing compliance.

However, the high compliance accomplishment rates are not quite equal to quantity based emission reductions, since China uses intensity-based targets. And, some pilots have post-allocations. At the beginning of a compliance year T, enterprises get their initial emission allowances from regulators. Post-allocation means, when the emissions of an enterprise in the compliance year T are reported in year T+1, the regulator can adjust the allowances allocated to the enterprise for year T according to its economic output. If the enterprise had large amount of economic output in the compliance year T, it can get more post-allocated allowances. Given the mechanism, the quantity of emissions may increase even though the intensity based target is reached. Because enterprise-level emission data is not publicly available, it is hard to find out whether their quantity-based emissions decrease.

Table 8 Compliance rate of the compliance year 2013

ETS pilot	Due date for submitting valid allowance	Compliance rate (%)	Publication of the compliance rate
Beijing	15 June, 2014 (extended to 27 June)	97.1 (403/415)	September, 2014
Shanghai	30 June, 2014	100 (191/191)	30 June, 2014
Shenzhen	30 June, 2014 (extended to 10 July)	99.4 (631/635)	3 July, 2014
Tianjin	25 July, 2014	96.5 (110/114)	28 July, 2014
Guangdong	15 July, 2014	98.9 (182/184)	15 July, 2014

Note: information is collected from websites of Emission Exchanges of the ETS pilots. For Hubei and Chongqing, their first compliance year was 2014, and the due for submitting valid allowance of 2014 was 2015.

Some evidence show that the implementation of ETS possibly contributed to the compliance of the national VA program. The national Top-10,000 Enterprises Program evaluates enterprises' progress towards their annual energy-saving targets. Shenzhen, for instance, had some enterprises under the national VA program that were non-compliant the annual energy-saving targets before 2013, but all enterprises in Shenzhen were able to comply with their annual targets after 2013, the year when ETS was established. As a matter of fact, Chinese ETS itself included a voluntary tool, CCER (Chinese Certified Emission Reduction) mechanism. Project developers can voluntarily invest in low-carbon projects to get CCER units and then emission-intensive enterprises can buy the CCER units to offset their emissions. This mechanism encourages players uncapped by ETS to join the market.

However, the ETS and the national energy conservation VA program are not deliberately designed to support each other. It may be better if they are designed together as a package. For instance, Denmark uses a policy package including CO_2 taxes, subsidies, and VAs aiming at energy efficiency (2006). Under the policy package, enterprises that manage to comply with the VA targets can get a CO_2 tax rebate, which builds a good inter-link between policy instruments.

6.3 Effect on networking and knowledge

Although there was no active trading between regulated enterprises (Figure 2), ETS attracted many intermediaries and even unregulated enterprises to join the business. To satisfy the demand, most ETS pilots, such as Guangdong and Beijing, have been conducting trainings for different groups of actors, including regulated enterprises, unregulated enterprises and intermediaries, which can be seen from the websites of Emission Exchanges. As Shen (2014) summarized, the major incentives for intermediaries are new profit-making opportunities. In 2000s, China built many Clean Development Mechanism (CDM) projects under Kyoto Protocol, being motivated by the benefits from selling the projects to industrialized countries who had compulsory emission reduction obligations. Since ETS has been introduced to China, those CDM project developers are eager to make profits with their carbon related expertise. Many technology providers, energy service companies, research institutes and consultancies are also mobilized to the carbon-related consultancy and carbon asset management. So, ETS brings regulated enterprises and those intermediaries together.

For unregulated enterprises, they are also incentivized to join the market with voluntary emission reduction projects, because they want to be prepared for the upcoming nationwide ETS and deal with the peer pressures from the regulated enterprises who may have more competitive advantage in the nationwide ETS market (Shen 2014).

To facilitate the implementation of ETS, local governments and Emission Exchanges of the ETS pilots have been providing relevant information, assistance and trainings. This can improve corporate awareness and knowledge about climate change and low-carbon strategies, which will prepare China better in the long-term battle against climate change.

6.4 Effect on encouraging carbon-related corporate management

One evidence is that some large-scale regulated enterprises have built their own carbon asset management subsidiaries. For instance, four out of the five largest state-owned electric utility enterprises in China all have their own carbon asset management subsidiaries to provide carbon-related services as well as energy related services. Besides the power sector, ETS covered most emission-intensive industries in each pilot, leading to an increased distribution of carbon-related expertise across sectors.

6.5 Cost-effectiveness

Some studies reveal that applying ETS can save economic costs for carbon emission mitigation in the society. For instance, Cui et al. (2014) establish an inter-provincial emissions trading model of China and modeled the economic performance of carbon emission trading scenarios in China. They conclude that the carbon emission abatement cost may be reduced by 23.67%

with a national emission trading scheme in relative to the no ETS scenario. Based on CGE model analysis, Wang et al (2015) also claimed that ETS could significantly reduce the GHG emission abatement costs for the whole economy. Although ETS is believed to be cost-effective (Grubb et al. 2011), it is criticized for its uncertainty. In practice, carbon prices are often low and with high volatility (Figure 1). In those cases, industrial participants have little incentives to reduce internal emissions and have to adapt to the volatile market costly.

There was some concern about the negative impact of ETS on economic development. However, there is no sign that the implementation of the ETS depressed economic development in China. As it used intensity-based targets, ETS allows the economic output to grow. For an enterprise with increasing emissions during the compliance period, it still can achieve its emission abatement targets if its economic output grows faster than its emissions.

7 Discussion

This study examines the policy design, participants and effectiveness of ETS, addressing its interaction with VA programs in China. In fact, the two policy instruments are only part of the policy mix. Table 9 listed the major policy instruments, besides ETS and VAs, that relate to energy efficiency and energy-related emission abatement.

Table 9 The current use of ETS and other major policy instruments in China

Category		Industry sector
Economic instrument	Taxes	(1) Pollution charges for SO_2 and NOx (2) differential electricity price (3) tax reduction and exemption for energy conservation projects (4) tax credit for capital expenditure on energy conservation equipment
	Tradable allowances	(1) ETS (2) Emission credits under CDM (3) Tradable energy use permits, piloting
	subsidies	(1) Financial subsidies for promotion of energy efficient products; (2) Financial subsidies for corporate energy conservation projects
Suasive instrument	Information measures	(1) Energy audits (2) Labelling (3) Industrial energy performance standards
	VAs	Voluntary agreements (VAs) between government and enterprises
Government command-and-control		Forced closure

Source: Chinese policy documents

Many other instruments, such as the differential electricity price, can facilitate VAs in a way that participants get additional incentives to comply with their energy saving targets. Considering that ETS provides limited economic incentives for corporate environmental actions, some policy instruments, such as financial subsidies for corporate energy conservation projects, can lead to more substantial technological change by compensating enterprises' costs. But, one concern is that this kind of policy instruments may reduce the demand for emission allowances and drag down the carbon price. Further research should be conducted to evaluate the policy mix and policy interactions more comprehensively.

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