Study on the Evaluation of ETS Abatement Effectiveness in China

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Abstract: This paper constructs the evaluation tool based on China's seven pilots ETS operation experience and DID method by setting the necessary condition, sufficient conditions and evaluation standards, and taking the actual data from Chinese pilots ETS to do the empirical analyze, as well as inspect the reliability and validity of this evaluation tool. Analyze showed that: Shenzhen, Hubei and Chongqing ETS are efficient in mitigation, Guangdong, Beijing, Tianjin ETS have malfunction in emission reduction, Shanghai ETS does not have the effectiveness of emission reduction. This research shows that there are five key elements for executing impact on emission reduction effectiveness of ETS: total amount of quotas, potential emission reduction rate, mechanism coverage scale, control group's emission reduction rate, economic growth rate.

Keywords: ETS evaluation, mitigation efficient, China

1. Introduction

Addressing climate change has being one of the top tasks for China, it is necessary to build a newly mechanism to drive GHGs mitigation and reach emission peak around 2030a. Now Chinese 7 pilots emission trade schemes (ETS) has operated twice period at least since Chinese government launch ETS pilots in 2013a. Chinese National ETS is planning to start-up based on the experience of the seven pilots ETS operation in 2017a, it is necessary to conduct a comprehensive review and evaluation of the operation of Chinese pilots ETS so as to provide a framework forecast of Chinese national carbon trading market. This paper builds an assessment method based on Difference-in-Difference(DID) model for evaluating the ETS abatement effectiveness and takes Chinese ETS pilots as cases to conduct empirical analysis and verify the evaluation method's validity and reliability.

Research shows there are three types of GHGs mitigation effectiveness from the seven pilot regions: Positive abatement effectiveness (Shenzhen, Hubei and Chongqing), failed abatement (Guangdong, Beijing and Tianjin) and ineffective abatement (Shanghai). Through indices and abatement intensity analysis of GHGs mitigation, it is found there are five key factors affecting the abatement effectiveness of ETS, they are including: ETS coverage scale, regulated entities' emission reduction potential, the allowance cap's laxity or tight, the economic growth speed. Allowance cap is not lax is the necessary condition for ETS to deliver abatement effectiveness, it plays a determinant role in influence GHGs emission reduction rate of the ETS. On the other hand, the ETS's mitigation limitation decided by the industrial sectors' GHGs emission reduction potential; when a sector has reached its abatement extreme under the best available technology, the ETS will lose its function partly as an emission reduction tool. Therefore the ETS is just as a tool option for controlling GHGs emission besides carbon emission tax, a pre-assessment of the industry's emission reduction potential should be conducted. Generally speaking, emission allowance cap, economic growth speed, emission abatement potential and ETS coverage scale are all positively correlated to the ETS emission mitigation effectiveness; under the other conditions unchanged, the tighter the allowance cap is, the more the mechanism abatement effectiveness is; the higher the economic growth rate of the ETS regulated sectors, the bigger their abatement potential is, the more the ETS's emission reduction effectiveness is. By adjusting the ETS's component factors, the ETS emission reduction effectiveness can be changed. Empirical analysis shows this evaluation method has good validity and reliability and is suitable for pre-assessing ETS's emission mitigation effect.

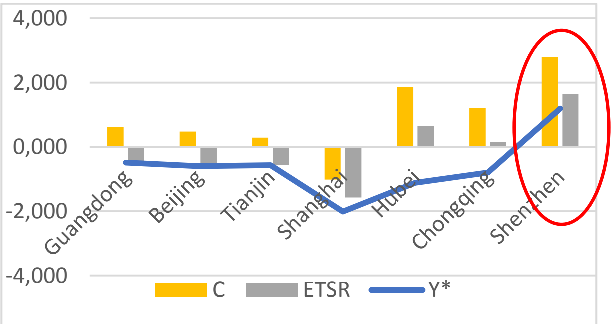

Figure 1. Calculation results of abatement effectiveness of Chinese ETS pilots

2. Features and Operation Status of Chinese Pilot ETS

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Table 1. Comparison of Management Factors among Chinese seven ETS Pilots

ETS pilot	Launch time	Regulation standards	Regulated sectors	Allowance cap of first year and ratio	Offset rules	Compliance mechanism
Beijing	2013.11.28	Business emitters with fixed installations whose direct or indirect annual CO_2 emission between 2009 – 2011 was above 10,000 tons	415 enterprises and organizations in iron and steel, cement and petrochemical sectors	Allowance cap: about 60 million tons CO_2/year, accounting for about 40% of the city's total emissions	Offset percentage no higher than 5% of the annual allowances, and local CCER no lower than 50% of the offset amount.	Enterprise compliance rate 97.1% in 2013; 100% in 2014.
Shanghai	2013.11.26	Industrial enterprises whose annual CO_2 emission in any year from 2010 – 2011 was above 20,000 tons or non-industrial enterprises whose annual emissions have exceeded 10,000 tons during this time	191 enterprises in iron and steel, petrochemical, chemical industry, non-ferrous metals and power sectors	Allowance cap 160 million tons, accounting for about 57% of the city's total emissions	5% of emissions can use CCER for compliance	Enterprise compliance rate 100% in 2013 and 2014.
Tianjin	2013.12.26	Enterprises of key emitting sectors and civil construction sector whose CO_2 emissions since 2009 have exceeded 20,000 tons	114 enterprises in iron and steel, chemical industry, power, thermal , petrochemical, oil and gas development sectors	Allowance cap 160 million tons CO_2/year; the five regulated sectors' emissions account for 50 - 60% of the city's total	Up to 10% of participating enterprises' actual annual carbon emissions can be offset by CCER	Enterprise compliance rate 96.5% in 2013; 99.1% in 2014.
Chongqing	2014.06.19	Industrial enterprises whose annual CO_2 emissions in any year between 2008 – 2012 was above 20,000 tons CO_2 equivalent	242 enterprises in metallurgy, power, chemical industry, construction materials, mechanical and light industries.	Allowance cap 125 million tons, accounting for about 60% of the city's total emissions	Carbon offset products can only be used when regulated enterprises were short of allowances, and the offset ratio must not exceed 8% of their allocated allowances for the compliance period	Enterprise compliance rate 70% in 2014 (by 14th July 2015).
Guangdong	2013.12.19	Industrial enterprises whose annual CO_2 emissions in any year between 2010 – 2012 were above 20,000 tons (or comprehensive energy consumption was above 10,000 tons standard coal)	About 200 enterprises in power, cement, petrochemical and iron and steel sectors	Allowance cap 388 million tons, accounting for about 54% of the province's total emissions	Up to 10% of regulated enterprises' emissions can be offset by CCER	Enterprise compliance rate 98.9% in 2013; 100% in 2014.
Hubei	2014.04.02	Industrial enterprises whose annual comprehensive energy consumption in any year from 2010 – 2011 was above 60,000 tons	138 enterprises in 12 sectors including iron and steel, petrochemical and cement	Allowance cap was 324 million tons CO_2, accounting for about 35% of the province's total emissions	Up to 10% of regulated enterprises' emissions can be offset by CCER	Enterprise compliance rate 100% by July 2015, the end of the first compliance cycle in Hubei.
Shenzhen	2013.06.18	Decide the regulated sectors by cross-comparing four principles: top 800 enterprises in terms of industrial added value; top 4,000 enterprises in power consumption; major petrol consumers and enterprises using boiler.	Industrial (635) and construction enterprises (197) were included.	Allowance cap for 2013-2015 was 107 million tons, accounting for about 38% of the city's total emissions	Up to 10% of regulated enterprises' actual carbon emissions in the past year can be offset by CCER	Enterprise compliance rate 99.2% in 2013; 99.7% in 2014.

Source of data: 1. Carbon trading related policies and documents, such as the *Interim Management Measures for Carbon Emission Trading* and *Carbon Trading Implementation Scheme* issued by all pilot regions, and websites of the Development and Reform Commissions and exchanges of the pilot regions;2. Reference literature [11-22]

Geographically, Chinese ETS pilot areas scattered in the eastern, middle and western regions in China; each region has its unique situation which lead the pilot ETS construction appears various

3. Method

According to the design principles of flexible abatement mechanism in *Kyoto Protocol*, the abatement effectiveness of ETS means: other conditions unchanged, enterprises' CO_2 emission intensity decreases through implementing ETS, and the decrease level is higher than that of the unregulated enterprises; here "additional" and "policy-wise" abatements are key characteristic indicators of the abatement effectiveness of ETS. According to the definition, evaluating ETS effectiveness should meet two conditions: First, comparing to situation before, economic entities achieve higher abatement after introducing the ETS, i.e. "additional" abatement; second, the ETS provides incentive to the "additional" abatement – hence the "policy" effect of the ETS to abatement. In light of the subject of this paper, we consider whether the ETS has "policy" effect on abatement as the necessary condition in evaluating its effectiveness, and the "additional" abatement as the sufficient condition. An ETS meeting both necessary and sufficient conditions would be considered of strict abatement effectiveness while the ETS not meeting necessary and sufficient conditions at the same time will be categorized into three types: relatively effective abatement, failed abatement and negative abatement according to evaluation standards.

Literature analysis has found that the academia mainly adopt three methods to measure ETS abatement effectiveness [1-2]; (2) Use Difference-in-Difference (DID) to calculate and compare emission changes of regulated and unregulated enterprises to obtain the abatement contribution by the ETS; (3) Use CGE to evaluate the abatement result of ETS and obtain prediction of abatement contribution by ETS through designing different carbon emission cap management scenarios. Based on DID and ETS abatement principles, this paper designs the sufficient and necessary conditions for ETS to realize abatement effectiveness and on this basis, constructs the evaluation standards of ETS abatement effectiveness. Chinese pilot ETS mechanisms are used as cases for empirical analysis here to verify the validity and reliability of the evaluation tools.

3.1. *Study Hypothesis*

Hypothesis 1: Chinese EST pilot regions take industrial sectors as the only regulated sectors; and the carbon emissions from industrial sectors come only from energy consumption[4].

Hypothesis 2: Within the evaluation period, the energy conservation and emission reduction technologies remain unchanged, i.e. the ETS is the only exogenous variable causing emission reduction change in the regulated sectors.

Hypothesis 3: Only when allowance supply is lower than enterprises' emission demands will the ETS policy abatement takes effect. "Allowance cap laxity index" is used to represent ETS policy effectiveness.

Hypothesis 4: When and only when ETS produces "additional" abatement will the ETS be considered to have abatement effect, which is represented by "ETS abatement rate index".

Model construction and calculation are based on the above hypotheses.

3.2. *Model Building*

According to the definition of ETS abatement effectiveness, the evaluation method consists of three parts: (1) Building the calculation method for EST emission reduction rate based on the DID estimation principle[1]; (2) Calculating the allowance laxity index of Chinese ETS to represent the p+olicy abatement effect of ETS; (3) The ETS abatement rate and the allowance laxity index form the evaluation standard of ETS effectiveness.

3.2.1 Calculation method of EST emission reduction rate based on DID principle

The basic DID model design includes two main parts: policy variables and time variables. In this paper, the policy variable is the ETS, and study samples are classified as samples in an ETS and samples without ETS; time variables include periods before and during ETS, thus four groups of samples are obtained. Since the study subjects of this paper are industrial sectors in the seven ETS pilots only, therefore the policy variables and time variables partly overlap, producing two groups of samples: Divided by the time in 2011 when the National Development and Reform Commission issued the *Notice on Implementing Pilot Project of Carbon Emissions Right Trading*, 2005 – 2010 is set as the control period, the industrial sectors during this time are the control group; while 2010 – 2015 is the experimental period and the industrial sectors in this time are the experimental group. Traditional abatement rate calculation methods do not take much consideration on exogenous variables' disruption on calculation results, or assume exogenous conditions do not change; both might cause the results being inaccurate. This study adopts the calculation method of sector contribution rate in the *Statistical Summary of China 2010* and considers the characteristics of ETS while basing on DID principles to build united formulae with "actual relative abatement intensity index" "planned relative abatement intensity index" and other parameters, so as to minimize the impact of economic and technological development on ETS abatement evaluation.

Mechanism abatement rate refers to the additional abatement rate of regulated enterprises attributed to the effect of policy mechanism, excluding the influence of natural technological progress and economic fluctuation, i.e. comparing to pre-ETS period, industrial sectors under ETS produce "additional" abatement rate; when the rate is

[1] DID estimation principle: First, use virtual policy variable to classify study subjects into the experiment group which is affected by policy and the control group unaffected by policy, then use time variables to capture the subjects' changes in both groups (first difference), and finally present the trend difference of changes of both groups through second difference.

positive, the ETS is considered to generate mechanism abatement rate. Calculation of mechanism abatement rate is based on the control group's actual relative abatement intensity. If the relative abatement intensity of regulated firms set by ETS is higher than that of the control group, the difference is the "additional" abatement rate, meaning the ETS generates positive mechanism abatement rate; if the planned intensity equals to or is lower than the control group's actual intensity, the ETS mechanism abatement rate is negative.

Formula 1 indicates the difference between actual abatement rate and the control group's actual relative abatement intensity. When mechanism abatement rate is negative, the actual abatement rate can be used to judge and explain ETS abatement effectiveness. When the experimental group's relative abatement intensity index is higher than that of the control group, the actual abatement rate is positive.

Relative abatement intensity index is the basis to calculate mechanism abatement rate and actual abatement rate; it is the ratio of industrial carbon intensity reduction level to regional carbon intensity reduction level. Minimizing the influence of external factors, the index is a relatively accurate representation of the evaluation target's actual carbon intensity change: In the control period, there is an actual relative abatement intensity index Y_i ; in the experimental period, there are two relative abatement intensity indices: one is the actual relative abatement intensity index Y_j calculated from actual emission data, another is the planned relative abatement intensity index based on allowance cap. By comparing the planned relative abatement intensity index and the control group's actual relative abatement intensity index, one can judge whether "additional" abatement effect is generated by ETS; by comparing the experimental group's and the control group's actual relative abatement intensity indices, one can tell the "additional" effect of the industrial sectors under ETS.

The united formulae consist of formula 1 – 10:

Basic implications of formulae 1 – 10:

When $Y^{(*)} > 0$, it means comparing to the control group, the experimental group's planned relative abatement intensity is higher and the ETS abatement rate is positive; When $Y^{(*)} \leq 0$, ETS abatement rate is negative. When $Y' > 0$, it means comparing to the control group, the experiment group's actual relative abatement intensity is higher and the actual abatement rate is positive. By comparing actual and mechanism's abatement rates, various parameters can be analyzed; plus considering the allowance laxity index, the ETS abatement effectiveness standard can be constructed.

$\mathbf{Y}' = \mathbf{Y}_j - \boldsymbol{Y}_i$; (Formula 1) $\boldsymbol{Y}^{(*)} = \boldsymbol{Y}_j{}^{(*)} - \boldsymbol{Y}_i$ (Formula 2)

$\boldsymbol{Y}_i = \frac{\Delta e_{k_i}}{\Delta e_i}$; (Formula 3) $\boldsymbol{Y}_j = \frac{\Delta e_{k_j}}{\Delta e_j}$ (Formula 4)

$\boldsymbol{Y}_j{}^{(*)} = \frac{\Delta e_{k_j}{}^{(*)}}{\Delta e_j}$ (Formula 5) ;

$\Delta \mathbf{e}_{k_i} = \left(\frac{E_{ki(t_1)}}{GDP_{ki_1}} - \frac{E_{ki(t_0)}}{GDP_{ki_0}}\right) / \frac{E_{ki(t_0)}}{GDP_{ki_0}}$ (Formula 6)

$\Delta \mathbf{e}_{k_j} = \left(\frac{E_{kj(t_1)}}{GDP_{kj_{(t_1)}}} - \frac{E_{kj(t_0)}}{GDP_{kj_0}}\right) / \frac{E_{kj(t_0)}}{GDP_{kj_0}}$ (Formula)

$\Delta \mathbf{e}_{Li} = \left(\frac{E_{Li(t_1)}}{GDP_{Li_{(t_1)}}} - \frac{E_{Li(t_0)}}{GDP_{Li_{(t_0)}}}\right) / \frac{E_{Li(t_0)}}{GDP_{Li_{(t_0)}}}$ (Formula 8)

$\Delta \mathbf{e}_j = \left(\frac{E_{Lj(t_1)}}{GDP_{Lj_{(t_1)}}} - \frac{E_{j(t_0)}}{GDP_{j_{(t_0)}}}\right) / \frac{E_{j(t_0)}}{GDP_{j_{(t_0)}}}$ (Formula 9)

$\Delta e_{k_j}{}^{(*)} = \left(\frac{CAP}{GDP_{kj_{(t_1)}}} - \frac{E_{kj(t_0)}}{GDP_{kj_{(t_0)}}}\right) / \frac{E_{kj(t_0)}}{GDP_{kj_{(t_0)}}}$ (Formula 10)

In formula 1~10, parameter Y refers to emission rate, superscripts (') and (*) refer to actual rate and ETS-planned rate respectively, subscripts i and j represent data of the control period (2005~2010a) and experimental period (2010~2015a) respectively; t refers to the time, t_1 and t_0 are the beginning and end of the period, Δe_{k_i} refers to the change of energy consumption intensity while subscripts (K) and (L) are industry's change value and regional change value. Table 2 explains the meaning of parameters.

Basic implications of formulae 1 – 10:

When $Y^{(*)} > 0$, it means comparing to the control group, the experimental group's planned relative abatement intensity is higher and the ETS abatement rate is positive; When $Y^{(*)} \leq 0$, ETS abatement rate is negative. When $Y' > 0$, it means comparing to the control group, the experiment group's actual relative abatement intensity is higher and the actual abatement rate is positive. By comparing actual and mechanism's abatement rates, various parameters can be analyzed; plus considering the allowance laxity index, the ETS abatement effectiveness standard can be constructed.

Table 2. Parameter Description

para	**meaning**	**para**	**meaning**
$\boldsymbol{Y}^{(*)}$	Mechanism abatement rate	GDP	GDP of comparable regions in 2005, GDP_K refers to industrial added value
$\mathbf{Y}'$	Actual abatement rate	CAP	Energy consumption volume converted from allowance cap
$\boldsymbol{Y}_i$	Control group's actual relative abatement intensity index	Subscript K	Industrial sectors
$\boldsymbol{Y}_j$	Experimental group's actual relative abatement	Subscript L	Refers to the whole region's value

	intensity index		
$\boldsymbol{Y_j}^{(*)}$	Experimental group's planned relative abatement intensity index	t_0 ; t_1	At the beginning of period; at the end of period
$\boldsymbol{\Delta e_{k_i}}$	Control group's industrial energy consumption intensity change value	E	Energy consumption volume
$\boldsymbol{\Delta e_{Li}}$	Regional energy consumption intensity average change level in the control period	Δe_{k_j}	Experimental group's industrial energy consumption intensity change value
$\boldsymbol{\Delta e_{Lj}}$	Regional energy consumption intensity average change level in the experimental period	$\Delta e_{k_j}{}^{(*)}$	Experimental group's industrial energy consumption intensity change value as planned per allowance
D	ETS emission reduction contribution rate	C	Allowance laxity

a. Evaluation Standard for ETS Mitigation effectiveness

ETS allowance cap laxity and mechanism abatement rate are affected by two common

factors: $\Delta e_{k_j}$and$\Delta e_{k_j}{}^{(*)}$; combining with other factors, they will finally affect the abatement effectiveness of ETS. E.g. the allowance cap laxity is related to the carbon intensity change of industrial sectors; when allowance cap laxity index is larger than 1, the planned carbon intensity reduction is higher than the actual level and the planned relative abatement intensity index is larger than the actual index. The mechanism abatement rate is calculated from the relative abatement intensity index; when the mechanism abatement rate is above 0, the planned relative abatement intensity index is larger than the actual relative abatement intensity index of the same period. Through the relative abatement intensity index, the allowance cap laxity and mechanism abatement rate are related and form the basis of the evaluation standard for ETS abatement effectiveness. When: Both the experimental group's planned and actual relative abatement intensity indices are smaller than the control group's, it means according to the rule of the diminishing marginal utility of abatement, the abatement potential of ETS shrinks; calculation of mechanism abatement rate is based on the control group's actual relative abatement intensity. D refers to the judgment on abatement effectiveness and ETSR refers to the ETS abatement contribution rate.

When D>0, it means the ETS has strict abatement effectiveness as both essential and necessary conditions are met; when only necessary condition is met, the ETS is relatively effective in abatement. When D<0, it means the ETS generates negative abatement effect. When D=0, the ETS fails in emissions abatement.

According to the definition, when D>0, Er=$Y^{(*)} = Y_j{}^{(*)}\_Y_j \geq 0$, when D$\leq 0$, Er= $Y_j{}^{(*)}\_Y_j < 0$, meaning the ETS is ineffective in abatement.

Specifically:

① When $C \geq 1 \Leftrightarrow Y^{(*)} > 0$, then D>0; Conclusion: emission reduction is strictly effective

② When $C < 1$, $Y^{(*)} \leq Y'$, $Y_j{}^{(*)} < Y_i < Y_j$; then $D = 0$; Conclusion: emission reduction fails

③ When $C \geq 1$, $Y^{(*)} \leq Y'$; $Y_i < Y_j{}^{(*)} < Y_j$; then $D < 0$; Conclusion: emission reduction ineffective

④ When ≥ 1, $Y^{(*)} \leq Y'$, $Y_j < Y_j{}^{(*)} < Y_i$; then $D > 0$; Conclusion: emission reduction is relatively effective

⑤ When $C < 1$, $Y^{(*)} \leq Y'$, $Y_j{}^{(*)} \leq Y_j \leq Y_i$; then $D < 0$; Conclusion: emission reduction ineffective

4 Empirical Analysis and Method Verification: Evaluation of Mitigation Effectiveness of ETS in China

The study team then calculated the allowance laxity indices, ETS abatement rates, actual abatement rates and abatement contribution ratios of each pilot ETS according to formulae 1~13 (Figure 1), and analyzed the ETS abatement effectiveness using the evaluation standards. Calculation results show that the ETS in Shenzhen, Hubei and Chongqing are effective in emission reduction. As seen from Figure 1, values of both columns and the line of Shenzhen ETS are larger than 1, meeting the efficient and necessary conditions for abatement effectiveness, indicating the ETS produces obvious abatement effective and has strict abatement effectiveness; ETS in Hubei and Chongqing also meet the efficient condition, their ETS is relatively effective in emission reduction; While in Guangdong, Tianjin and Beijing, their allowance laxity indices and emission reduction rates are both lower than effective values, indicating the ETS fail to deliver abatement function. In Shanghai's case, values of both columns and the line are smaller than 0, meaning its emission reduction is ineffective. Table 2 lists the calculation results of main indices and key parameters; data in blue grids meet the respective efficient or necessary condition, ETS in yellow grids deliver abatement effectiveness and are with positive abatement contribution rates. Specification on the calculation results of key indices is as follows

Table 3. Summary of Results of Mitigation Effectiveness and Contribution Rates of Chinese ETS Pilots

	GD	BJ	TJ	SH	HB	CQ	SZ
Δe	25.20	38.92	22.86	24.48	54.23	36.04	17.73
Δe	34.94	45.98	42.10	18.75	16.47	34.75	18.29
Δe	21.98	21.80	12.13	4.29	30.60	41.62	51.17
Δe	16.42	26.59	21.00	20.00	21.67	20.95	13.05
Δe	20.98	25.08	23.43	24	22	45.16	20.07
Y_i	1.53	1.46	1.08	1.22	2.50	1.72	1.35
Y_j	1.66	1.83	1.79	0.78	0.75	0.77	0.91
$Y_j^{(}$	1.05	0.87	0.52	0.18	1.39	0.92	2.55
Y'	0.13	0.37	0.71	0.44	1.75	0.95	0.45
$Y^{(*}$	0.48	0.59	0.57	2.01	1.11	0.79	1.19
C	0.63	0.47	0.29	-0.23	1.86	1.97	2.79
D	0	0	0	< 0	> 0	> 0	> 0
Er	0.62	0.96	1.28	1.58	0.64	0.15	1.64

Note: red number means negative number.

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