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Does China's emissions trading system foster corporate green innovation? Evidence from regulating listed companies

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ABSTRACT

Carbon emissions trading system is expected to be both efficient and flexible in carbon reduction through green innovation. As the world's largest CO_2 emitter, China has launched the emissions trading system (CN-ETS) since 2013 in 7 pilot areas and vowed to build a nation-wide system in the second half of 2017. This study provides preliminary evidence on the impact of the CN-ETS on green innovation and the moderating role of market competition on this relationship at the firm level. Based on data of regulating listed companies in seven pilots, the results show that CN-ETS is significantly positively correlated with green innovation, and market competition weakens the positive relationship, indicating that CN-ETS is effective in the aspect of green innovation, and the effect would be better in less competitive markets.

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KEYWORDS
China's emissions trading system (CN-ETS); green innovation; CN-ETS establishment; market competition

1. Introduction

Climate change and global warming have become one of the greatest challenge the world faces (Glenn, Florescu and Millennium-Project-Team 2015). To deal with greenhouse gases emissions, the 'culprit' of climate change—carbon dioxide emissions—should be strictly controlled (González et al. 2016). In recent years, countries have strengthened control on carbon emissions (Fan et al. 2016; Martin, Muûls, and Wagner 2016). Multiple emissions reduction mechanisms have been formulated such as mandatory regulations, market-oriented regulations and voluntary regulations (Ren et al. 2018). Among them, market-oriented policies, particularly emissions trading systems (hereafter referred to as ETS) are generally considered to be efficient and flexible tools to reduce emissions at a low cost (Porter and Van der Linde 1995; Lo 2012). They have now been widely adopted in the EU, the US, Japan, China and other countries with remarkable effects (Martin, Muûls, and Wagner 2016).

The literature on the effects of environmental regulations on corporations focuses on firm competitiveness and innovation (Cohen and Tubb 2016). As to the innovation effect, there is inconsistency on the results, and relatively few studies on the boundary conditions in emerging economies (Ambec et al. 2013). Although most studies find that environmental regulations stimulate corporate innovation, some studies present contrary results (Chintrakarn 2008; Lanoie et al. 2011; Ambec et al. 2013). The mainstream studies about the impact of environmental regulation on green innovation are based on the developed countries, with inconclusive findings (Cohen and Tubb 2016; Martin, Muûls, and Wagner 2016). The relatively few studies focusing on emerging economies also draw different conclusions with positive, negative or non-significant impact of environmental regulation on green innovation (Yang, Tseng, and Chen 2012; Huang et al. 2016). An important reason for

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the inconsistency may be the neglect of the boundary conditions, especially the industry characteristics, as previous research has shown that regulation-induced corporate environmental behaviour varies by industry (Koh, Qian, and Wang 2014; Chen et al. 2017; Li and Tang 2017). Hence, it is necessary to study how market competition may modify the influence that regulations may have on green innovative activities in emerging economies. This prompts our research questions: does environmental regulation, ETS of emerging economies in particular, foster or hinder corporate green innovation? How does market competition moderate the focal relationship?

With a sample of the CN-ETS regulating listed companies in China, this study makes several important contributions. First, this research echoes whether the Porter Hypothesis stands in emerging economies, Chinese emission trading system in particular. Second, the boundary conditions of the ETS-innovation relationship, i.e. the moderating effects of market competition, are investigated, which is unexplored in previous studies.

The remainder of this paper is structured as follows: The second section contains a literature review and hypotheses; the third section describes the research design and methods; the fourth section is empirical analysis; and the final section provides research conclusions and implications.

2. Literature review and hypotheses

2.1. Carbon emissions trading system and green innovation

Environmental regulation tools refer to a series of rules and regulations which are set to solve environmental problems (Qi et al. 2010). Traditional economics holds that environmental regulations will increase costs, thereby reducing enterprises' innovation ability and competitiveness (Jaffe et al. 1995; Eiadat et al. 2008), so enterprises have no incentive to participate in carbon emissions reduction and trading (Wagner 2007; Chintrakarn 2008). However, Porter and colleagues argue that appropriate and flexible market-oriented environmental regulations do not harm corporate competitiveness, but enhance it by forming 'innovation offsets', which is known as the 'Porter Hypothesis' (Porter and Van der Linde 1995). Although a number of studies have found support for Porter Hypothesis (Borghesi, Cainelli, and Mazzanti 2015; Rubashkina, Galeotti, and Verdolini 2015; Huang et al. 2016; Van Leeuwen and Mohnen 2017), there is still controversy about the conclusions of this research (Cohen and Tubb 2016; Martin, Muûls, and Wagner 2016).

ETS is an environmental regulatory tool with both flexibility and efficiency (Fan et al. 2016). The core mechanism is through emissions quotas allocated by the government. The fewer quotas an area, an industry or a firm is allowed, the more stringent the regulation is, and the more impact it has on firms' environmental behaviours (Borghesi, Cainelli, and Mazzanti 2015). As a policy tool to reduce emissions, ETS helps to realise the optimal allocation of emission reduction resources in economic systems through carbon price signals, which have cost efficiency (Porter and Van der Linde 1995; Fan et al. 2016).

Green innovation refers to innovation made in aspects such as technologies, products, services, organisational structures or management modes by enterprises to achieve sustainable development (Rennings 2000). It can effectively reduce the negative impact on the environment (Walker, Chen, and Aravind 2015). As an important market-oriented environmental regulation, ETS gives enterprises both the pressure and motivation to invest in green innovation to meet regulatory requirements and even make profits (Demirel and Kesidou 2011; He et al. 2016; Martin, Muûls, and Wagner 2016).

The ETS is exerting more and more green innovation pressure in emerging economies. As a country with the largest carbon emissions in the word, China is increasingly attaching great importance to establish an ETS to reduce emissions (Fan et al. 2016; Van Leeuwen and Mohnen 2017). In such a setting of strict carbon regulations, Chinese firms are under high environmental legitimacy pressure and have to be responsible for high carbon emissions costs, therefore, CN-ETS presses firms on promoting green innovation (Li et al. 2016).

Alongside with pressure, ETS also motivates corporate green innovation. Green innovation can help regulated firms reduce emissions, which would reduce purchase of expensive emission quotas, and even make profits from selling surplus emissions saved (Borghesi, Cainelli, and Mazzanti 2015). By adopting green technology or striving for the ISO 14001 certification (Delmas and Toffel 2004; Johnstone and Labonne 2009), enterprises can effectively enhance the resource utilisation rate and relieve the cost pressure brought about by the regulation (Lanoie et al. 2011; Ambec et al. 2013), which motivate regulated firms to adopt more green innovations.

More stringent carbon regulation, fewer carbon quotas, and higher carbon prices will prompt managers to recognise the importance of reducing emissions, and incorporate it into strategies, culture and organisation flows, adopt environmental management systems such as ISO 14001, and inspire clean low-carbon technology investment such as the research and development of carbon capture and storage (CCS) (Rogge, Schneider, and Hoffmann 2011). Also, with stricter design and implementation of CN-ETS, the Chinese government can raise more money and provide more financial support for enterprises' environmental technologies and management systems (Zhang et al. 2014; Yu et al. 2016). Thus the following hypotheses are proposed:

H1. There is a positive relationship between CN-ETS and corporate green innovation in China.

2.2. Moderating effect of market competition

If the CN-ETS can benefit corporate green innovation, the next question that should be asked is, how the effects may be limited by boundary conditions. Studies show that market competition has a sound impact on corporate environmental behaviour, influencing both the resources available and the benefits that corporations might gain from it (Zou et al. 2015). Therefore, we emphasise the role of the market competition a firm is facing in moderating the relationship between CN-ETS and corporate green innovation.

Market competition is the degree to which a firm affects others in an industry (Barnett 1997), which affects firms' strategic options (Teece, Pisano, and Shuen 1997). A high level of competition in a market makes it harder to gain and sustain a competitive advantage (Aragón-Correa and Sharma 2003). Though some research find that being green may be helpful for firms to compete (Esty and Winston 2009), we argue that market competition weakens the relationship between CN-ETS and corporate green innovation for the following reasons.

First, market competition would weaken the pressure the CN-ETS exerted on corporate green innovation. The rise of competition threatens the profit and even the survival of the focal firm, which in turn requires firms to devote more attention and resource to deal with interfirm competition. Thus, firms in more competitive markets are less able to focus their attention on CN-ETS; rather, their focus tends to be distracted instead, which results in less investments in green innovation as CN-ETS expected (Andrevski et al. 2014; Chen et al. 2017). While in less competitive markets, competitors would not be a decisive factor for firms, so they can focus on dealing with the pressures CN-ETS exerted and facilitate more green innovations.

Second, market competition would weaken corporate green innovation motivation induced by the CN-ETS. Since green innovation is featured as 'double externality', i.e. besides producing the spillover effect of typical innovations, they also produce positive externalities in reducing external environmental costs (Rennings 2000), firms are more reluctant to be compliant with carbon regulations by investing in green innovation themselves alone, especially when they are faced with intense competition since it brings about volatility and strengthens the uncertainty of the value of green innovations (Li et al. 2017). However, when the market is not so competitive, the regulated firms would live a better life and take more social responsibilities, which motivates firms to initiate more green innovation activities under CN-ETS. Accordingly, the hypothesis is proposed as follows:

H2. Market competition weakens the positive relationship between CN-ETS and green innovation in China.

3. Research design

3.1. Settings of China's ETS pilots

China announced to establish an emissions trading scheme in 2011 and moved quickly toward seven pilot schemes in 2013 (Duan, Pang, and Zhang 2014), namely Beijing, Shanghai, Tianjin, Chongqing, Shenzhen, Guangdong, and Hubei (Feng, Shi, and Kang 2017; Yang, Wang, and Shi 2017). The seven regions for the pilot schemes spread from north to south and from east to west. Some are located in less developed inner areas, such as Hubei and Chongqing, while others are located in the coastal developed regions, each with obvious differences in natural, economic, and social conditions (as shown in Figure 1).

The pilots' geographic area accounts for 5% of China's total land mass, around 19.18% of China's population, 29.03% of China's GDP, and 17.22% of China's carbon dioxide emissions in 2010 (Zhang et al. 2013). Most of the pilots' per-capital GDP is higher than the national average (except for Hubei and Chongqing). All the pilots have a lower carbon intensity than the national average and aim to reduce their levels more than the national average of 18% in 2020 compared to 2015.

3.2. Samples and data source

Considering that China's carbon trading market is in the pilot phase, this paper selected all of the 104 listed companies (from Provincial Development and Reform Commission) which have been regulated in pilot regions during the period of 2013–2014 as initial samples. Then, these companies were screened according to the following criteria: (1) companies were excluded that went public after 2013 (7 companies); (2) companies receiving special treatment (ST) were excluded as they have exhibited continuous loss-making for over two years (2 companies); (3) backdoor listed companies which enable their assets to be listed by investing main assets into those listed companies with low market value were excluded (2 companies); (4) firms in the finance, wholesale and retail trade, and catering sectors were removed (13 companies). After screening, we got 80 regulated companies

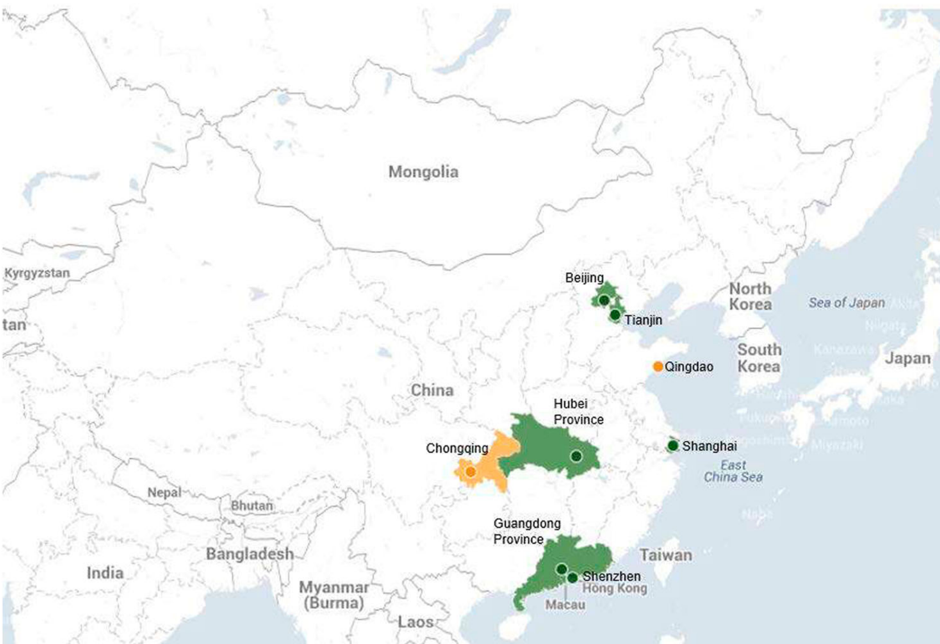

Figure 1. Seven pilot regions in China.

which have gone to public with A-shares listed on the Shanghai and Shenzhen stock exchanges with 160 observations for 2 years. Table 1 describes the regional and industrial distribution of the samples. It shows that the regulated companies are mainly from the eastern region and the manufacturing industry respectively.

The data required in this research are obtained from China National Knowledge Infrastructure, CSMAR, annual reports of listed companies, and the Baiteng patent network (http://so.5ipatent.com/).

3.3. Operational definitions of variables

The variables involved in this study are: green innovation, CN-ETS establishment, market competition and relevant control variables, such as ownership, financial leverage and so on. The operational definitions and measuring methods of these variables are described as follows.

3.3.1. Dependent variables

3.3.1.1. Green innovation. Several indicators, such as green R & D (Lee and Min 2015), eco-labelling product certification (Lin et al. 2014), green patent (Brunnermeier and Cohen 2003; Albino et al. 2014; Ardito, Messeni Petruzzelli, and Albino 2016) and so on, could be employed. But based on the consideration of being difficult to obtain the former two indicators for Chinese public companies, we chose the last one, the green patent, as a proxy of green innovation (Jaffe and Palmer 1997; Li et al. 2016). We first searched all three kinds of application patents (including patent for invention, patent of utility model and patent of appearance). Considering China's economic and social conditions, patents containing keywords such as 'low carbon', 'environmental friendly', 'green', 'emission reduction', 'energy conservation', 'clean', 'cycling', 'resource-saving', 'sustainable', 'ecological', 'environmental protection', 'environmental pollution' are green patents (Brunnermeier and Cohen 2003). We measure it by the number of green innovation lagging one year.

3.3.2. Independent variable

3.3.2.1. CN-ETS establishment. A variety of methods have been employed to measure the establishment of environmental regulations, such as pollution abatement costs and expenditures (PACE), survey-based intensity perception, international environmental treaties and so on (Brunel and Levinson 2013). However, these proxies for regulation establishment are subjective and it is difficult to figure out clear boundaries to measure carbon regulation intensity (Kozluk and Zipperer 2015). Based on the ETS establishment indicator proposed by Borghesi, Cainelli, and Mazzanti (2015), we measure CN-ETS establishment as the ratio of emissions to allocated allowances:

$$\mathrm{RE}_i = D_i/Q_i$$

Where RE_i refers to CN-ETS establishment of region i, Q_i is the total amount of quotas allocated to region i (we use regional quotas rather than firm level quotas since the data of the latter is

Table 1. Sample distribution by region and industry.

Industry	Region			Subtotal	%
	Eastern	Central	Western		
Manufacturing	51	8	4	63	78.75
Mining	3	0	0	3	3.75
Electricity, heat, gas and water production and supply	9	0	0	9	11.25
Real estate	0	2	0	2	2.5
Transportation, warehousing and postal services	3	0	0	3	3.75
Total by industry	66	10	4	80	100

not available in China), D_i is the CO_2 emission gross in region *i*, which is calculated as follows (Xu and Zhang 2016) :

$$D_i = \sum_{p=1}^{8} S_{ip} * F_{ip} * E_{ip}$$

Where *p* represents the energy types, including coal, coke, crude oil, gasoline, diesel, kerosene, fuel oil and natural gas, S_p is the factor of standard coal coefficient for every energy type *p*, F_p is the carbon emissions coefficient of energy type *p*, E_p is the consumed amount of energy type *p*.[1]

As the establishment indicator shows, the larger the CO_2 emission gross is or the fewer quotas there are, the higher the CN-ETS establishment is. When $RE_i > 1$, the permits allocated to region *i* are lower than its emissions level, suggesting that the ETS policy in the region is actually stringent. On the contrary, when $RE_i \leq 1$, the permits allocated to region *i* are higher or equal to its emissions level, indicating the ETS policy in the region is weak.

3.3.3. Moderating variable

3.3.3.1. Market competition. Market competition can be reflected by industry concentration (Chen et al. 2017) which is measured by CR4 (concentration ratio of Top 4 firms of an industry in market shares). When the industry concentration ratio is high, companies are more inclined to adopt similar business strategies, reducing the dive and complexity of a market, which indicates a less competitive market; on the contrary, when industry concentration ratio is low, companies would adopt different strategic behaviours, so that external market environment becomes complex and unpredictable, which indicates a strong competitive market (Zou et al. 2015). Herein market competition is measured by the reciprocal of CR4 in an industry (1/CR4). The closer the ratio is to 1, the more concentrated the industry is, and the less intense the market competition is.

3.3.4. Control variables

A set of control variables is incorporated in this study. First, ownership, financial leverage, independent directors ratio and leadership structure are introduced to control the impact of corporations' characteristics on green innovation. Firms in China can be divided into two categories: state-owned enterprises (SOEs) and private owned enterprises (POEs). Undertaking certain social functions, SOEs are directly supervised and regulated by government, so they are more inclined to assume social responsibility and take green measures than others. A dummy variable is thus introduced here, 1 for SOEs, 0 for others. Companies with high financial leverage face a high asset-liability ratio, and are more inclined to prove their legitimacy to creditors. High legitimacy pressure will force companies to take measures such as energy conservation and emission reduction, and green innovation to meet the requirements of stakeholders for sustainable development. Here financial leverage is measured as liabilities/total assets. The percentage of the independent directors on the board also affects corporate green innovation strategies. Independent directors tend to require managers to consider the whole firm's interest and develop long-term strategies such as reducing carbon emissions and investing in green innovation. Divide the number of independent directors by that of directors, we get the independent directors ratio (Boesso and Kumar 2007). The chairperson of the board (COB) and chief executive officer (CEO) represent the interest of the focal company and shareholders, respectively. Separation of the COB and CEO affects a firm's environmental behaviour (Wong et al. 2016). A dummy variable was introduced to measure leadership structure: 1 for a company whose CEO is not the COB, 0 otherwise.

Another set of external factors of industry and region is controlled. Companies in polluting industries are under more stringent supervision of the government and are more impacted by emission control policies than those in cleaner industries (Boesso and Kumar 2007). In China, there are huge differences among eastern, central and western regions in social, economic and culture conditions. The eastern region is the most developed but polluted area, therefore, it has the capacity and motivation to exert more stringent environmental regulations (Wong et al. 2016). A dummy variable is thus introduced, 0 for the eastern region and 1 for central and western regions. Patent stock was adopted to control for a firm's technological stock, which was measured as patents in 5 years prior the observation period. In addition, dummy variable Year was introduced to test the influence of time scale. Table 2 shows the definitions of all variables.

3.4. Research models

To test the hypotheses above, the following econometric models are constructed:

Main Effect Model:

$$\begin{aligned} \mathrm{GI}_{i,t+1} = \beta_0 + \beta_1 \mathrm{RE}_{i,t} + \beta_2 \mathrm{Lev}_{i,t} + \beta_3 \mathrm{Own}_{i,t} + \beta 4 \mathrm{Reg}_{i,t} + \beta 5 \mathrm{Inde\,p}_{i,t} \\ + \beta 6 \mathrm{LS}_{i,t} + \beta 7 \mathrm{Patent}(t-5)_{i,t-5} + \beta 8 \mathrm{Com}_{i,t} + \mathrm{Year} + \varepsilon_{1i,t} \end{aligned}$$

Moderating Effect model:

$$\begin{aligned} \mathrm{GI}_{i,t+1} = \delta_0 + \delta_1 \mathrm{RE}_{i,t} + \delta_2 \mathrm{Com}_{i,t} + \delta_3 \mathrm{RE}_{i,t} \times \mathrm{Com}_{i,t} + \delta_4 \mathrm{Lev}_{i,t} + \delta_5 \mathrm{Own}_{i,t} \\ + \delta_6 \mathrm{Reg}_{i,t} + \delta_7 \mathrm{Inde\,p}_{i,t} + \delta_8 \mathrm{LS}_{i,t} + \delta 9 \mathrm{Patent}(t-5)_{i,t-5} + \mathrm{Year} + \varepsilon_{2i,t} \end{aligned}$$

$GI_{i,\ t+1}$ for green innovation lagging one year, RE_i for CN-ETS establishment, Com_i for market competition. Lev_i for financial leverage, Own_i for ownership, Ind_i for industry, Reg_i for region, $Indep_i$ for ratio of independent directors, LS_i for leadership structure in sequence, $Patent_{t-5}$ for patents in 5 years prior year *t*, Year for year fixed effects.

4. Empirical analysis

4.1. Descriptive statistical analysis

Table 3 presents the descriptive statistics and correlation analysis of all variables. The average CN-ETS establishment is 1.749, reflecting a stringent policy in the pilot regions. Maybe due to the insufficient basic data, the minimum value of CN-ETS establishment is only 0.991, which means that the government gave more quota than total CO_2 emissions. This is the same as the first stage of EU-ETS, whose allowances issued also exceeded emissions. But the post correction makes CN-ETS establishment level trend to be higher. The mean value of market competition is 6.194, the minimum value is 1.108, and the maximum value is 7.358, indicating that the intensity of market competition varies in different industries. The mean value of green innovation is 9.344, the minimum value is 0, and the maximum value is 266, which means that there is a big gap in the number of green patents in different companies. Descriptive statistics of other variables are also shown in Table 3.

Table 4 describes the total carbon emissions, quotas and the CN-ETS establishment in seven pilot areas. As shown in the table, during the period of 2013–2014, ETS in Beijing was the most stringent

Table 2. Measurements of variables used in this research.

Variables	Symbols	Measurement
Green Innovation	GI	green innovation lagging one year; 1 for firms having green patents, otherwise 0
CN-ETS establishment	RE_i	the CO_2 emission gross in region *i* (D_i)/the total amount of quotas in region *i* (Q_i)
Market Competition	Com	total sales of the industry/total sales of top four companies in market shares
Ownership	Own	dummy variable, 1 for state-owned enterprise (SOEs), 0 for others
Financial Leverage	Lev	total liabilities/total assets × 100%
Independent Directors Ratio	Indep	the number of independent directors/that of directors
Leadership Structure	LS	dummy variable, 1 for firms whose CEO and chairman is the same person, otherwise 0
Region	Reg	dummy variable, 1 for central and western regions,0 for the eastern region
Patent stock	$Patent_{t-5}$	patents in 5 years prior year *t*

Table 3. Descriptive statistics and correlation analysis.

		1	2	3	4	5	6	7	8	9
1	Reg	1								
2	Lev	0.249*	1							
3	Own	0.043	0.350*	1						
4	Indep	−0.038	−0.166†	−0.320*	1					
5	LS	−0.098	−0.096	−0.385*	0.326*	1				
6	$Patent_{t-5}$	−0.067	0.191†	−0.086	0.001	−0.060	1			
7	Com	0.084	−0.181†	−0.375*	0.246*	0.218*	0.020	1		
8	RE	−0.893*	−0.265*	−0.103	0.102	0.088	0.090	0.034	1	
9	GI_{t+1}	−0.089	0.035	0.140	0.016	−0.023	0.326*	−0.324*	0.158†	1
	Min	0	0.066	0	0.25	0	0	1.108	0.991	0
	Max	1	0.877	1	0.6	1	6327.0	7.358	2.039	266.0
	Mean	0.175	0.486	0.525	0.382	0.31	139.956	6.194	1.749	9.344
	SD	0.381	0.203	0.501	0.064	0.465	652.042	2.199	0.345	32.349

Notes: †$p < 0.1$, *$p < 0.05$, **$p < 0.01$. Two-tailed.

with the value of 1.97 and 2.04 respectively, while Shenzhen came in second. In 2014, the values of CN-ETS establishment in all regions were larger than 1, and that most ETS establishment has intensified from 2013 to 2014.

4.2. Regression results and analysis

As dependent variable (green innovation) is a count and over dispersed variable, we apply the Negative Binomial Panel Data regression approach to test the hypotheses (Hilbe 2011; Ardito et al. 2018). Green innovation is introduced as the dependent variable, ETS establishment as an independent variable, and ownership, financial leverage, independent directors ratio, leadership structure region, Year and $Patent_{t-5}$ as control variables.

As shown in Table 5, Model 1 is regression models of control variables on the dependent variable. The independent variable is drawn into Model 2 based on Model 1 to test the relationship between the dependent variable and independent variables. The results of Model 2 show a significant positive correlation between CN-ETS establishment and green innovation ($\beta = 7.039$, $p < 0.01$). So H1 is supported.

The interaction term of the independent variable and the moderating variable is drawn into Model 4 on the basis of Model 3. The results show that the moderating effect of market competition on the relationship between CN-ETS establishment and innovation is negatively significant ($\beta = -0.840$, $p < 0.05$). Thus, H2 is also supported.

In order to demonstrate the moderating effects of CN-ETS establishment and market competition, we plotted the relationships at two levels of the moderator (i.e. above and below one standard deviation from mean, representing high and low levels, respectively) (Li and Tang 2010). Figure 2

Table 4. CN-ETS establishment level of 7 pilot areas.

Year:	2013			2014		
Pilot Area	CO_2 emission gross (million tons)	Total quotas (million tons)	CN-ETS establishment	CO_2 emission gross (million tons)	Total quotas (million tons)	CN-ETS establishment
Beijing	118.1213	60	1.97	122.34	60	2.04
Tianjin	201.9492	160	1.26	194.8108	160	1.22
Shanghai	271.0197	160	1.69	246.8947	149	1.66
Hubei	321.1787	324	0.99	326.6205	324	1.01
Guangdong	588.405	388	1.52	584.908	408	1.43
Chongqing	150.8303	125	1.21	158.1955	116	1.36
Shenzhen	62.061	33	1.88	65.4474	33	1.98
Total	1713.5652	1250	1.37	1699.2169	1250	1.36

Table 5. Results of regression tests.

	Dependent Variable: GI_{t+1}			
	Model 1	Model 2	Model 3	Model 4
Constant	−1.077 (1.709)	−15.546** (3.547)	−13.970** (2.825)	−3.098* (1.288)
Lev	0.237 (1.214)	1.34 (1.304)	2.022† (1.228)	2.329* (1.127)
Own	1.489** (0.521)	1.433** (0.455)	1.048** (0.398)	0.670† (0.406)
Reg	−0.692 (0.502)	5.450** (1.382)	5.160** (1.191)	4.146** (1.224)
Indep	3.073 (3.553)	4.223 (3.51)	4.778 (2.993)	4.368 (2.784)
LS	0.41 (0.446)	0.769† (0.408)	0.725* (0.358)	0.523 (0.349)
$Patent_{t-5}$	0.002† (0.001)	0.002 (0.001)	0.001† (0.001)	0.001* (0.001)
RE		7.039** (1.553)	6.646** (1.294)	6.127** (1.209)
Com			−0.185* (0.086)	−0.103 (0.108)
RE*Com				−0.840* (0.435)
Year	√	√	√	√
Wald chi-square	33.18**	71.23**	91.03**	108.98**
Log-likelihood	−339.023	−330.990	−329.090	−325.784

Notes: Standard error in parentheses †$p < 0.1$, *$p < 0.05$, **$p < 0.01$. Two-tailed.

indicates that the slope is much steeper when market competition is low. In other words, as CN-ETS establishment increases from one standard deviation below the mean to one standard deviation above, green innovation increase significantly faster in low market competition.

4.3. Robustness tests

In order to ensure the reliability of the results, a supplemental analysis was conducted. We used another measurement of market competition for robustness test, i.e. '1-HHI'. HHI is a well-accepted measurement of industrial competition and is calculated as the sum of the squared market share of each firm competing in an industry (Zou et al. 2015). Since HHI is inverse indicators of the level of market competition, we used 1-HHI to measure market competition. And we also added the number of green patents lagging two years to measure green innovation. We reran the regressions to demonstrate possible long-run effects. The results of the robustness test are exhibited in Table 6. As shown in Model 5, Model 6, Model 7 and Model 8, the results are similar to our previous ones, indicating that the results are robust.

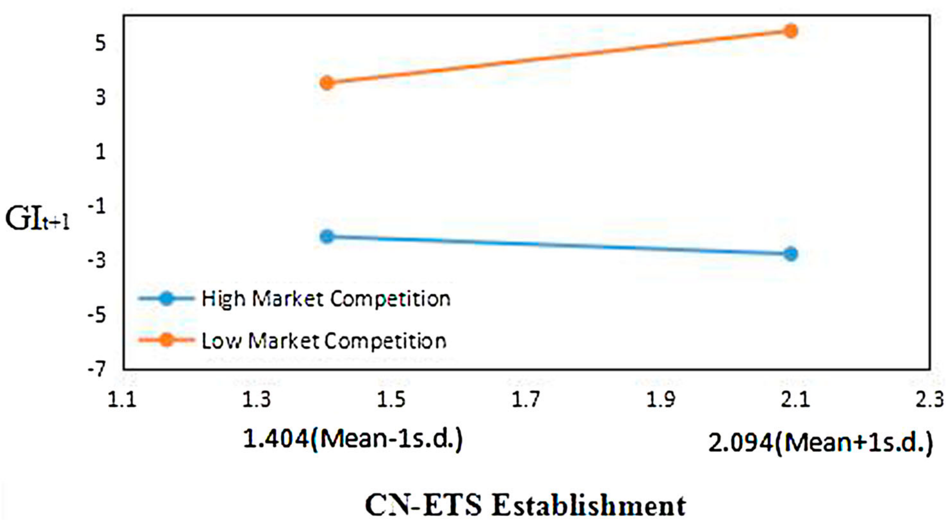

Figure 2. Moderating effect of market competition on RE-GI relationship.

Table 6. Robustness tests.

	Dependent Variable: GI_{t+2}			
	Model 5	Model 6	Model 7	Model 8
Constant	−0.721 (1.541)	−11.754** (2.861)	−2.541 (3.499)	−1.754 (1.081)
Lev	−0.189 (1.291)	0.761 (1.243)	1.167 (1.044)	1.232 (0.993)
Own	2.007** (0.469)	2.038** (0.404)	1.466** (0.381)	1.365** (0.376)
Reg	−0.728 (0.582)	4.129** (1.183)	3.347** (1.168)	1.823† (1.097)
Indep	3.714 (3.09)	4.173 (2.806)	3.552 (2.367)	3.026 (2.373)
LS	−0.051 (0.372)	0.192 (0.347)	0.453 (0.34)	0.398 (0.354)
$Patent_{t-5}$	0.002 (0.001)	0.001 (0.001)	0.001* (0.0002)	0.001* (0.0002)
RE		5.454** (1.261)	4.118** (1.181)	4.262** (1.009)
1-HHI			−6.812** (2.098)	15.705* (6.251)
RE*(1-HHI)				−95.977** (26.742)
Year	√	√	√	√
Wald chi-square	41.54**	61.16**	90.76**	108.04**
Log-likelihood	−365.590	−359.422	−354.804	−349.902

Notes: standard error in parentheses $^{\dagger}p < 0.1$, $*p < 0.05$, $**p < 0.01$. Two-tailed.

5. Conclusions and implications

5.1. Research conclusions

This study analysed the impact of CN-ETS on green innovation by considering the moderating role of market competition. Using a sample of 160 observations obtained from the regulating listed companies in seven pilot provinces and cities of China from 2013–2014, we found that CN-ETS was significantly positively correlated with green innovation, and market competition weakens the positive relationship.

First, CN-ETS has a positive impact on corporate green innovation, which is in accordance with Rennings et al. (2006) and Marin (2014). Rennings et al. (2006) point out that under the pressure of stringent environmental regulation, companies increasingly prioritise their green innovation. Marin (2014) shows that, as carbon regulation intensity increases, decreased emission quotas will lead to increasing carbon emissions costs, which subsequently will force enterprises to make more substantial efforts, such as the research and development of low carbon innovation to improve energy efficiency and reduce carbon emissions.

Second, market competition weakens the positive impact of CN-ETS on green innovation. The result means that, in a more competitive market, companies are likely not to invest in green innovation under the pressure of CN-ETS since they have to spend more resources to deal with their competitors for more business profits. While in a less competitive market, companies tend to invest more in green innovation with their abundant resources and favourable environment.

5.2. Theoretical contributions

By exploring whether and when CN-ETS foster corporate green innovation, this research makes several theoretical contributions. First, this study examines and extends Porter Hypothesis within the setting of CN-ETS. The results demonstrate that ETS fosters rather than hinders corporate green innovation in China. Thus this study clarifies the debate on whether Porter Hypothesis stands by investigating the market-oriented environmental regulation in the Chinese-like emerging economies. Also, to our knowledge, this is the first empirical research in exploring the impact of ETS on innovation in the Chinese context, which is an important complement to current studies that focus on developed countries (Han and Li 2015).

Second, this paper contributes to enriching the theory of environmental regulation and Porter hypothesis by exploring the boundary conditions of market competition in the ETS-innovation relationship (Li et al. 2017). The results show that, market competition weakens the green innovation effect of CN-ETS. And this may, in some way, explain the inconsistency in the impact of ETS on green innovation.

5.3 Policy implications

The findings above have several policy implications. First, policy makers should scientifically design and implement CN-ETS since it fosters corporate green innovation. It is necessary to vigorously build a nationwide carbon market based on the experiences of pilot regions as soon as possible (Fan et al. 2016). Governments should continue the pressure and motivation for firms to initiate green innovation activities. As to the pressure, policy makers should avoid the common problems of 'strong legislation, weak enforcement' in China, and fully and strictly implement the proposed nationwide ETS (Li, Ren, and Chen 2015). As to the motivation, policy makers should understand the 'double externality' nature of green innovation and design more incentives in the ETS to make firms to be more willing to invest in green innovations. Policy tools may include training assistance, tax refund, environmental subsidies, low interest loans, among others.

Second, to help foster green innovation through CN-ETS, policy makers should be aware of market competition. Intense market competition forces firms to devote more resources to survive but not to take on environmental responsibility. Thus, optimising the market competition mechanism, guiding the enterprises to internalise the environmental responsibility into the self-conscious pursuit and enhancing the initiative for firms to obtain differentiated competitive advantage by green innovation, are necessary to mitigate this negative impact. The government should provide more financial support for companies' green innovation. what's more, measures, such as improving the industry concentration ratio appropriately to keep interfirm competition at an optimal level and announcing policies on carbon trading system explicitly and regularly should be taken to help enterprises actively respond to the sustainable development trend.

5.4. Limitations and future research opportunities

This study has several limitations that future research can help to clarify. First, since the implementation of CN-ETS was started in 2013, only data during the period of 2013–2014 were available to the study, hence the effects of dynamism are hard to be reflected so that we don't take the other factor into consideration in the analysis. In addition, data in a short period may not reveal the development tendency. Future studies should adopt longer-period data to conduct further study. Second, corporate green innovation is the result of multiple factors, such as environmental legitimacy, market atmosphere, and the dynamic capability of senior executives. This study only focused on CN-ETS and market competition. Future research should consider multiple factors to have a comprehensive study. Third, we only focused on the China's carbon emissions trading market, which limits the generalisability of our results. Future research should establish a comparison with the findings of the ETS in developed and other developing countries.

Note

1. Data on standard coal coefficients and total energy consumption are collected from the China Energy Statistical Yearbook. Carbon emission coefficients are extracted from the average number from the National Energy Research Institute, the Japan's Institute of Energy Economics and the US Energy Information Administration published.

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