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Market-Incentive Environmental Regulation and the Quality of Corporate Innovation

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Abstract: Environmental issues have received worldwide attention in recent years, and a large body of literature has focused on environmental regulations and business innovation. However, very few studies examine the effects of market-incentive-based environmental regulation policies on the quality of corporate innovation. Thus, this paper uses China's A-share listed enterprises in 2010–2020 and China's carbon trading policy (CCTP) to conduct a quasi-natural experiment. The results show that the CCTP significantly increases the quality of innovation but does not affect the quantity of firm innovation. Furthermore, according to the result of heterogeneity analysis, the effect of CCTP on high-quality innovation occurs mainly in low-financialization and non-state enterprises.

Keywords: market-incentive environmental regulation; China's carbon trading policy; corporate innovation

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1. Introduction

In recent years, massive emissions of greenhouse gases have had a serious effect on the ecosystem. The Global State of the Climate report by the World Meteorological Organization (WMO) confirms that 2015–2019 were the hottest five years in history. As the world's industries continue to grow, industrial enterprises develop and operate, consuming fossil energy, which causes a continued rise in atmospheric CO_2 [1]. In the face of rising global temperatures and environmental degradation, energy saving and emission reduction have also become a responsibility that all countries and regions in the world must undertake [2,3].

With the start of the third technological revolution and the growing prominence of environmental issues, the relationship between environmental policy and innovation has also attracted the attention of scholars around the world [4]. Some scholars have divided environmental regulation into order-controlled and market-incentive types [5,6]. Carbon trading policies (CTPs) are regarded as an effective market-incentive environmental regulation (MER) to combat climate change and control greenhouse gas emissions [7,8]. At the same time, there is an increasing trend toward differentiated innovation quality in recent years [9]. High-quality innovation can contribute to technological progress and environmental protection. However, low-quality innovation is often considered ineffective and a waste of resources [10]. In response to this phenomenon, it is important to analyze the drivers of different quality innovations. To this end, we attempt to respond to the following question: can MERs improve the quality of corporate innovation?

As a major carbon emitter and the world's largest developing country, China has taken the initiative to take responsibility and actively participate in energy-saving and emission-reduction initiatives [11,12]. At the Paris Conference in 2015, China pledged to reduce its carbon emission intensity by 60–65% by 2030 [12,13]. In the 11th Five-Year Plan, the Chinese government established the goal of energy saving and emission reduction by increasing efforts to reduce emissions and promoting energy-saving policies. Since 2013, China has launched eight pilot carbon-trading markets including Beijing, Shanghai, Shenzhen, Guangdong, Tianjin, Chongqing, Hubei, and Fujian [14,15]. With the EU's restrictions on certified emission reductions (CERs) in the international market for emerging countries such as China and the improvement of the domestic carbon trading market, Chinese companies are slowly turning to the domestic carbon trading market. By 22 December 2022, the cumulative turnover of the national carbon market exceeded RMB10 billion.

Porter (1991) pointed out that appropriate environmental regulations stimulate firms to innovate technologically, and that technological innovation leads to productivity gains that offset environmental protection costs, ultimately increasing the enterprises' competitiveness; this is the so-called "Porter Effect" [16]. However, the subsequent literature on the "Porter Effect" has not reached a uniform conclusion. Some research has respectively examined that the "Porter Effect" does exist under environmental regulation [17,18]. Lanoie et al. revealed that the Lagging effect of environmental regulation on productivity is positive [17]. Berman et al. found that US air pollution regulations can improve the productivity of refineries [18]. However, according to Dean and Brown, environmental regulations have a negative effect on technological innovation because it increases the cost of environmental management and crowds out corporate investment in R&D [19].

In response to the two contradictory views, some scholars have classified environmental regulation based on their functioning mechanisms into order-controlled and market-incentive types [5,6]. Order-controlled environmental regulation (OER) uses administrative orders to intervene directly with highly polluting enterprises to force them to meet energy efficiency and emission reduction standards [20]. It has strong administrative aspects and is classified as direct control. For example, OERs could consist of setting strict emission and technical standards and forcibly closing down highly polluting and outdated production enterprises. MERs are based on Coase's theorem, which establishes a market for emission rights by defining property rights over environmental resources [21]. Significant spatial differences exist in the policy effects of different environmental policy instruments [22]. An increasing number of studies suggest MERs have more long-term incentives than order-controlled regulations [5,23]. According to Dong and Feng [23], a flexible MER may trigger positive productivity effects in the new energy sector. Milliman and Prince point out that the impact on technological innovation is stronger under an MER than under an OER [24].

At the same time, some scholars distinguish among corporate innovation types. Some researchers have addressed the relationship between environmental regulation and low-carbon innovation. Laing et al. found that the EU Emissions Trading Scheme (EUETS) has a limited effect on low-carbon innovation [25]. Eikeland and Skjærseth pointed out that the power sector has been more proactive than the oil sector with regard to low carbon innovation in EUETS [26]. Additionally, Qi et al. found that China's carbon trading policy (CCTP) can promote corporate low-carbon innovation [27]. Some scholars have revealed the effect of environmental regulation on green innovation. For example, Zhang et al. revealed the positive impact of CCTP on the green innovation of listed companies [28]. Additionally, some of the literature wanted to find the innovation performance of environmental regulation. Jiang et al. discovered that regional environmental regulation in China promoted innovation performance [29]. Furthermore, according to Mo, the Korean Emission Trading Scheme (KETS) has a positive effect on innovation and thus reduce carbon emissions [30]. These studies have analyzed the impact of market-incentive environmental regulation policies on innovation from different perspectives. However, few studies have analyzed the heterogeneous effects of CCTP on the quality of corporate innovation.

Certainly, the above research has inspired us to analyze the heterogeneous impact of CCTP on corporate innovation with different qualities. At the same time, this analysis is necessary. The variations in the quality of innovation affect the technological variations of companies and reflect the variations in the level of environmental protection. According to Thoma, low-quality innovations are usually invalid patents filed for strategic competition and contribute little to overall corporate innovation capability [31]. These low-quality innovation patents are a waste of resources and can even lead companies to lose their market competitiveness [10]. According to Dang and Motohashi, China's innovation subsidy policies promote more low-quality innovation and have less impact on high-quality innovation [32].

Previous studies focused more on the impact of environmental regulation on low-carbon innovation, green innovation, or on a single indicator of technological innovation [27–29]. At the same time, CCTP may affect innovation that is not green innovation, but this impact may be different from green innovation [33]. On the one hand, the implementation of the CCTP may increase the demand for low-carbon technologies, which in turn will boost the development of relevant technologies. On the other hand, the implementation of the CCTP may put companies under greater economic pressure to seek new production methods, products, or services to reduce carbon emissions and improve efficiency. How then can companies improve the quality of their patents while ensuring quantity? Can CCTP, which involves market-based incentives for environmental regulation, reduce low-quality innovation and increase high-quality innovation, thereby reducing resource waste? The existing literature does not provide a precise answer to this question.

To fill this gap, we used China's A-share listed enterprises in 2010–2020 and CCTP to conduct a quasi-natural experiment. Market-incentive environmental regulations can significantly increase high-quality corporate innovations and reduce corporate low-quality innovations. This result is robust after a serious robust test, such as a test on parallel trend assumption that excludes the impact of the national carbon trading market and considers Fujian's carbon emissions trading policy and substitution of dependent variables. Our heterogeneity analysis results suggest the financialization level of firms and whether they are SOEs affect the effectiveness of CCTP.

The main contributions are as follows: First, we expand the literature on the impact of CTP on enterprises. Previous studies focused on the impact of CTP on carbon emission reduction effects, low-carbon innovation, green innovation, and innovation performance. Nevertheless, we focused more on the heterogeneous impact of CTP on different qualities of corporate innovation. Second, we examined the incentives for innovation of listed corporations under environmental regulation policies. High-quality innovation is an indication of the pursuit of technological breakthroughs, while low-quality innovation may favor ineffective innovation that appeals to policy. We focus on whether CTP can increase high-quality innovation and at the same time reduce low-quality innovation. Third, we use CCTP to conduct a quasi-natural experiment to test the impact of CCTP on corporate innovation, which provides a reference to investigate the question of sustainability from emerging markets.

The rest of the paper is structured as follows: Section 2 shows the development of our hypothesis. Section 3 presents the research design of this paper, including background, key variables, data and model. Section 4 shows the main result and robust test. Section 5 details the heterogeneity analysis based on the financialization level and the nature of the enterprise. Section 7 provides the conclusions.

2. Hypothesis Development

According to Porter and Linde (1995), appropriate environmental regulations will provide an impetus for firms' innovative activities [34]. Thus, as a type of environmental regulation, the CCTP may produce a "Porter effect" and promote innovation in corporates. In the face of environmental pressure from CCTP, companies may purchase carbon emission quotas directly on the market to meet their emission reduction constraints or engage in innovative activities to save energy and reduce emissions. Different quality innovations may be produced in the process of corporate innovation because of the different motivations for innovation. Recent studies have often classified the quality of innovation according to the type of patent [35–37].

We first hypothesize that CCTP will incentivize firms to engage in high-quality innovation. As a market-incentivized environmental regulation tool in China, the CCTP aims to internalize the negative externality costs of environmental pollution through the market price mechanism. Theoretically, the carbon emission trading policy makes carbon emission rights a commodity property, i.e., the allocation of resources is achieved through the market trading behavior of carbon emission rights. In this context, high-quality innovation by companies can not only improve their technology and reduce carbon emissions but also trade their excess carbon emission rights on the market for a profit. Hence, companies have an intrinsic incentive and motivation to engage in high-quality, substantial technological innovation [38]. From the above analysis, we develop the following hypothesis.

H1. *CCTP has a positive impact on high-quality innovation in enterprises.*

Second, we further consider the impact of CCTP on low-quality innovation by corporates. According to Tong et al., strategic innovation for "other benefits" is common among Chinese enterprises [39]. The "quantity over quality" strategic innovation is a significant burden on firms' profitability, and low-quality innovation is merely a response by corporates to seek support in the face of regulatory policies, without any increase in their real innovation capacity [38]. The CCTP is an environmental regulatory policy based on market regulation to achieve its objectives, which makes it difficult for companies to benefit from low-quality innovation. At the same time, CCTP will signal to enterprises that high-quality innovation is the only way to achieve sustainable development. In turn, it reduces low-quality innovation activities of enterprises. Thus, we propose the following hypothesis:

H2. *CCTP has a negative impact on low-quality innovation in enterprises.*

3. Research Design

3.1. Background

Before 2013, Chinese companies participated in carbon trading on the international carbon trading market through the Clean Development Mechanism (CDM) of the Kyoto Protocol. Since 2013, the EU has also stopped accepting CER emission reduction targets from countries such as China and India, and thus, Chinese companies have turned to domestic CCER trading. From 2013 to 2017, China launched seven carbon emission trading pilot projects, including Fujian, Beijing, Shenzhen, Chongqing, and Hubei. Therefore, this paper takes the start time of the CCTP in each region as the quasi-natural experiment [33,40]. Using a multi-period difference-in-difference (DID) research method, we collect data on Chinese A-share listed companies to study the impact of CCTP on corporate innovation. Companies in the pilot carbon trading region are the experimental group while companies outside the pilot region are the control group.

3.2. Key Variables

3.2.1. Dependent Variables

Corporate Innovation: The existing literature on firm innovation has two directions: innovation inputs and innovation outputs. Corporate R&D expenditure is the major indicator of corporate innovation inputs [41,42]. The corporate patent acquisition is the major indicator of corporate innovation outputs [43,44]. However, the process of converting R&D into innovation involves opportunity costs and is influenced by the market environment. Therefore, this paper selects the number of patents acquired as an indicator of corporate innovation [45].

According to the China National Intellectual Property Administration (CNIPA), patents can be categorized into three types: invention, utility model, and design patents. Invention patents have a high technical content and have the most stringent examination procedure [9,46]. Therefore, invention patents are usually considered high-quality technological innovation projects [47]. Utility patents are granted for new technical solutions relating to an object's shape or structure. Design patents are granted for original designs relating to an object's shape, design, or color. Utility model and design patents have a low technical threshold and are easy to obtain, and thus, are often seen as low-quality innovations. At the same time, some scholars use design patents and utility patents to measure low-quality innovation. For example, Hou (2018) used patents for inventions that are recognized as high-quality patents, and non-invention patents, such as utility model and design patents, are recognized as low-quality patents [48]. This paper further divides the number of patents using the number of invention patents to represent high-quality innovation and the number of utility model and design patents to represent low-quality innovation.

3.2.2. Independent Variable

CCTP dummy variables: The data are grouped according to whether the enterprise is in a pilot region for carbon trading [49]. If the enterprise is in a region where carbon trading policy has been implemented, CCTP = 1, DID = 1; otherwise, it equals 0.

3.2.3. Control Variables

To exclude other factors that could interfere with the results, this paper controls for a set of variables that may influence firms' innovation decisions [46,50,51]. Including earnings per share (EPS), management fee (Mfee), corporate size (Size), leverage (Lev), cash flow ratio (Cashflow), stock proportion restriction (Balance), business growth (Growth), total assets turnover (ATO), corporate Tobin's Q value (TobinQ), and number of the board of directors (Board). The specific measures of all variables are shown in Table 1.

Table 1. Variable measures.

Variable	Variable Measure
Inv_all	Ln(number of patents granted +1)
Inv_high	Ln(number of invention patents granted +1)
Inv_low	Ln(number of utility model patents + design patents granted +1)
EPS	Net profit/Total number of shares
Mfee	Administrative expenses/operating income
Size	Natural logarithm of total assets at the end of the year
Lev	Total debt divided by total assets
Cashflow	Net cash flows from operating activities divided by total assets
Balance	The sum of top2-top5 shareholding divided by top1 shareholder shareholding
Growth	Operating income for the year divided by operating income for the previous year −1
ATO	Operating income divided by average total assets
TobinQ	(Market value of shares outstanding + number of non-marketable shares x net assets per share + book value of liabilities)/total assets
Board	Board size in natural logarithms

3.3. Data

This paper takes the Chinese A-share listed companies as the research object. We establish panel data of Chinese A-share listed companies from 2010–2020. The data on the characteristics of listed companies are obtained from the China Stock Market and Accounting Research Database (CSMAR) and details of corporate patents from the China Research Data Services (CNRDS). We performed the following steps to clean the data: (1) the financial sector is removed, (2) ST corporate and samples with only one period are removed, and (3) all continuous variables are winsorized at the 1–99% levels. Finally, an unbalanced panel is created through 28,269 observations of 3654 A-share listed companies. Additionally, it consists of 1523 state-owned enterprises (SOEs) and 2131 non-state-owned enterprises (N-SOEs) details of descriptive statistics are provided in Table 2).

Table 2. Statistical description.

	All Sample			Control Group			Treated Group		
Variable	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Inv_all	28,269	1.488	1.526	19,216	1.451	1.492	9053	1.567	1.592
Inv_high	28,269	0.730	1.034	19,216	0.676	0.972	9053	0.844	1.145
Inv_low	28,269	1.210	1.461	19,216	1.195	1.440	9053	1.242	1.504
EPS	28,269	0.360	0.598	19,216	0.351	0.583	9053	0.381	0.626
Mfee	28,269	0.096	0.089	19,216	0.095	0.088	9053	0.099	0.091
Size	28,269	22.17	1.305	19,216	22.10	1.252	9053	22.32	1.401
Lev	28,269	0.436	0.211	19,216	0.439	0.212	9053	0.430	0.206
ROE	28,269	0.059	0.145	19,216	0.059	0.144	9053	0.059	0.146
Cashflow	28,269	0.044	0.0720	19,216	0.044	0.072	9053	0.044	0.070
Balance	28,269	0.718	0.607	19,216	0.687	0.591	9053	0.783	0.634
Growth	28,269	0.185	0.510	19,216	0.188	0.517	9053	0.178	0.495
ATO	28,269	0.640	0.445	19,216	0.644	0.442	9053	0.630	0.452
TobinQ	28,269	2.096	1.461	19,216	2.051	1.424	9053	2.192	1.531
Board	28,269	2.132	0.199	19,216	2.141	0.194	9053	2.113	0.208

3.4. Model

3.4.1. Baseline Model

This study constructs the following DID model to test the impact of CCTP on firms' innovation:

$$Inv_{i,t} = \beta_1 + \beta_2 CCTP_{i,t} + \sum Controls_{i,t} + IndustryFE + YearFE + \varepsilon_{i,t} \tag{1}$$

where Inv is the dependent variable, which represents firm innovation in this study. CCTP is the CCTP dummy variable, which is an independent variable in this paper. The sign and significance of β_2 measure the net effect of CCTP on corporate innovation. *Control* represents the other control variables involved in this study, and finally, this paper controls for year-fixed and industry-fixed effects.

3.4.2. Model for Parallel Trend Testing

A necessary precondition for the DID model is the parallel trend assumption. That is, no significant difference in the firm's innovation level between the treated and control groups existed before the occurrence of the CCTP. Therefore, based on the previous literature, the following model is developed in this paper [52,53]:

$$Inv_{i,t} = \beta_1 + \sum_{\tau=-3}^{7} \beta_\tau CCTP_i \times I_t(t=\tau) + \sum Controls_{i,t} + IndustryFE + YearFE + \varepsilon_{i,t} \tag{2}$$

where $CCTP_i \times I_t$ is a series of dummy variables indicating the τth year of the start of the CCTP. Specifically, I_1 denotes the first year of CCTP, and we cover three years before the implementation and seven years after the start. The other variables are defined and set consistent with model (1). This paper focuses on the variable β_τ, which represents the difference in corporate innovation between the treated group and the control group in the τth year of the CCTP. We select the fourth year before the policy occurs as the base year.

4. Result

4.1. Main Result

In this section, we conduct an empirical analysis of model 1. In the analysis process, this paper sequentially adds industry-fixed and year-fixed effects to test the robustness of the results [54]. The main regression results are shown in Table 3. Columns (1)–(3) show the results with the inclusion of control variables and year-fixed effects, and columns (4)–(6) include control variables, industry-fixed and year-fixed effects. The dependent variables in columns (1) and (4) are the total number of patents obtained in the year under observation.

The results in columns (1) and (4) indicate that the CCTP does not significantly affect the total number of patents obtained by firms.

Table 3. Main results.

	(1) Inv_all	(2) Inv_high	(3) Inv_low	(4) Inv_all	(5) Inv_high	(6) Inv_low
CCTP	−0.008	0.091 ***	−0.059 ***	0.024	0.095 ***	−0.033 *
	(−0.402)	(6.299)	(−2.961)	(1.315)	(7.135)	(−1.919)
EPS	0.130 ***	0.017	0.135 ***	0.067 ***	0.012	0.068 ***
	(4.979)	(0.997)	(5.395)	(3.076)	(0.798)	(3.227)
Mfee	−0.490 ***	0.451 ***	−0.714 ***	0.049	0.560 ***	−0.189 **
	(−4.646)	(5.942)	(−7.737)	(0.534)	(8.187)	(−2.249)
Size	0.169 ***	0.204 ***	0.134 ***	0.303 ***	0.272 ***	0.249 ***
	(15.066)	(25.327)	(12.473)	(31.797)	(37.173)	(27.110)
Lev	−0.891 ***	−0.634 ***	−0.579 ***	−0.527 ***	−0.331 ***	−0.384 ***
	(−17.853)	(−19.522)	(−12.258)	(−11.977)	(−10.665)	(−9.117)
ROE	−0.113	−0.021	−0.077	0.135*	0.085	0.127*
	(−1.227)	(−0.362)	(−0.887)	(1.693)	(1.584)	(1.681)
Cashflow	0.511 ***	0.319 ***	0.357 ***	0.895 ***	0.445 ***	0.805 ***
	(4.009)	(3.938)	(2.975)	(8.356)	(5.967)	(7.822)
Balance	0.084 ***	0.043 ***	0.056 ***	−0.015	−0.013	−0.028 **
	(5.701)	(4.303)	(3.924)	(−1.220)	(−1.431)	(−2.337)
Growth	−0.119 ***	−0.057 ***	−0.115 ***	−0.123 ***	−0.070 ***	−0.115 ***
	(−7.747)	(−5.933)	(−8.147)	(−8.958)	(−7.641)	(−8.762)
ATO	0.224 ***	0.172 ***	0.183 ***	0.210 ***	0.131 ***	0.195 ***
	(9.156)	(11.207)	(8.102)	(9.764)	(8.885)	(9.416)
TobinQ	−0.019 ***	0.027 ***	−0.031 ***	−0.000	0.026 ***	−0.003
	(−2.859)	(5.690)	(−4.717)	(−0.072)	(5.952)	(−0.594)
Board	−0.074	−0.003	−0.091 **	0.171 ***	0.136 ***	0.128 ***
	(−1.511)	(−0.085)	(−1.979)	(4.196)	(4.522)	(3.287)
_cons	−1.866 ***	−3.787 ***	−1.349 ***	−5.551 ***	−5.679 ***	−4.540 ***
	(−7.558)	(−21.407)	(−5.689)	(−26.215)	(−34.833)	(−22.081)
Ind	No	No	No	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
N	28,269	28,269	28,269	28,269	28,269	28,269
r2	0.049	0.065	0.042	0.370	0.268	0.352

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level.

The dependent variables in columns (2) and (5) are the number of invention patents obtained in the year, i.e., the degree of high-quality innovation of the firm. According to the results in columns (2) and (4), CCTP positively and significantly impacts firms' high-quality innovation. Meanwhile, column (5) of Table 3 shows that enacting the CCTP will raise the number of corporate invention patents in the pilot region by 9.5%. This result is consistent with hypothesis 1.

The dependent variables in columns (3) and (6) are the total number of utility model and design patents obtained in the year, i.e., the degree of low-quality innovation generated by the firm. The results in columns (3) and (6) show that CCTP significantly reduces the number of utility model and design patents obtained by firms and that the enactment of the CCTP will result in a 3.3% decrease in the number of utility model and design patents obtained in the year. These results are consistent with hypothesis 2.

4.2. Robust Test

4.2.1. Test on Parallel Trend Assumption

The DID model must satisfy the parallel trend assumption, which ensures that the treated and control groups have the same trend before the occurrence of the carbon trading policy [55,56]. Figure 1 reports the results of model (2), where the dependent variables are, in order, the total number of patents, the number of invention patents, and the number of design and utility model patents. The figure shows that no significant difference in firm innovation between pilot and non-pilot cities could be observed before the CCTP was launched. This finding shows that the treated and control groups selected under the CCTP satisfy the parallel trend assumption.

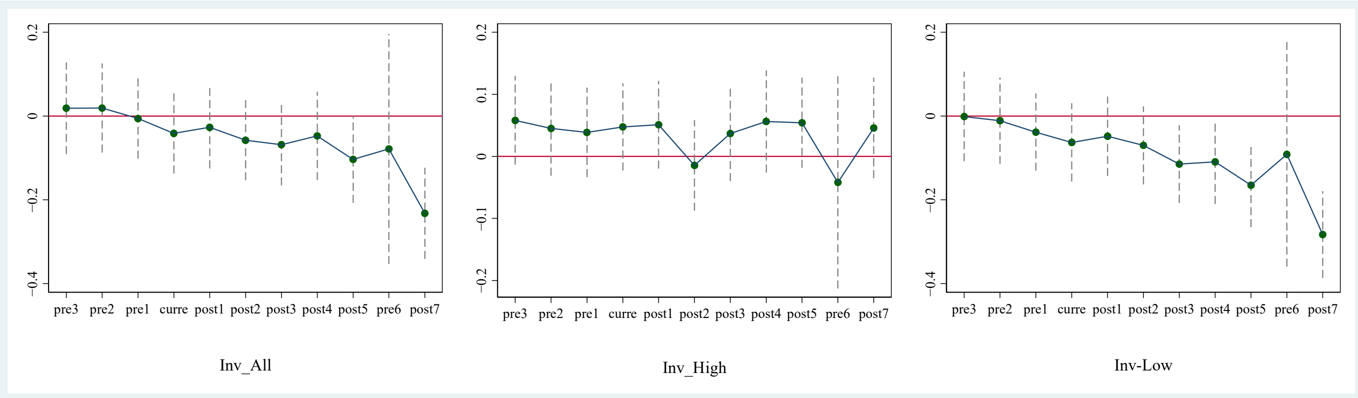

Figure 1. Parallel trend test, for each coefficient, the 95% confidence interval is reported.

4.2.2. Excluding the Impact of the National Carbon Trading Market

In December 2017, with the consent of People's Republic of China State Council (PRCSC), the National Development and Reform Commission (NDRC) issued the national carbon emissions trading market construction program for the electricity sector [23,35]. However, the start of online trading in the national carbon emissions trading market was scheduled for 16 July 2021 [36]. Therefore, the data were not restricted to 2017 in the previous regressions. However, enacting a national carbon trading policy may impact firms' expectations and influence their innovation decisions. Therefore, in this section, we build a regression of the panel data from 2010–2017 to exclude the effect of the national carbon trading policy. According to the results in columns (1)–(3) of Table 4, the significance and sign of the regression results are consistent with Table 2 after restricting the sample period.

Table 4. Excluding the impact of the national carbon trading market and Fujian's CTP.

	(1) Inv_all	(2) Inv_high	(3) Inv_low	(4) Inv_all	(5) Inv_high	(6) Inv_low
CCTP	0.006	0.077 ***	−0.044 *	0.023	0.095 ***	−0.033 *
	(0.248)	(4.295)	(−1.955)	(1.231)	(6.926)	(−1.840)
EPS	0.084 ***	0.031	0.083 ***	0.068 ***	0.013	0.068 ***
	(2.714)	(1.430)	(2.789)	(3.000)	(0.838)	(3.104)
Mfee	0.590 ***	0.957 ***	0.202 **	0.045	0.557 ***	−0.197 **
	(5.263)	(11.029)	(2.007)	(0.482)	(7.975)	(−2.298)
Size	0.312 ***	0.260 ***	0.266 ***	0.307 ***	0.274 ***	0.254 ***
	(25.573)	(27.541)	(22.588)	(31.602)	(36.703)	(27.099)
Lev	−0.595 ***	−0.303 ***	−0.445 ***	−0.529 ***	−0.340 ***	−0.383 ***
	(−11.223)	(−7.965)	(−8.767)	(−11.829)	(−10.723)	(−8.935)
ROE	0.022	0.114	−0.027	0.137 *	0.075	0.137 *
	(0.200)	(1.525)	(−0.264)	(1.684)	(1.370)	(1.763)
Cashflow	0.770 ***	0.513 ***	0.680 ***	0.872 ***	0.421 ***	0.789 ***
	(6.074)	(5.757)	(5.590)	(7.940)	(5.510)	(7.483)
Balance	−0.029 *	−0.024 **	−0.033 **	−0.015	−0.017 *	−0.027 **
	(−1.917)	(−2.133)	(−2.230)	(−1.230)	(−1.804)	(−2.210)
Growth	−0.125 ***	−0.068 ***	−0.115 ***	−0.131 ***	−0.076 ***	−0.122 ***
	(−7.915)	(−6.365)	(−7.877)	(−9.319)	(−8.149)	(−9.076)
ATO	0.258 ***	0.164 ***	0.224 ***	0.230 ***	0.149 ***	0.210 ***
	(10.132)	(9.210)	(9.163)	(10.354)	(9.739)	(9.813)

Table 4. *Cont.*

	(1) Inv_all	(2) Inv_high	(3) Inv_low	(4) Inv_all	(5) Inv_high	(6) Inv_low
TobinQ	−0.017 **	0.007	−0.011	−0.001	0.026 ***	−0.003
	(−2.344)	(1.307)	(−1.637)	(−0.088)	(5.663)	(−0.488)
Board	0.144 ***	0.140 ***	0.078	0.158 ***	0.126 ***	0.119 ***
	(2.871)	(3.712)	(1.622)	(3.783)	(4.069)	(2.977)
_cons	−5.741 ***	−5.418 ***	−4.851 ***	−5.618 ***	−5.699 ***	−4.633 ***
	(−21.270)	(−26.064)	(−18.538)	(−25.992)	(−34.224)	(−22.079)
Ind	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
N	18,081	18,081	18,081	27,194	27,194	27,194
r2	0.385	0.284	0.361	0.372	0.271	0.354

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level.

4.2.3. Consider Fujian's CTP

The CTP in Fujian Province was officially launched on 22 December 2016, while other carbon trading pilots were launched around 2013. Thus, Fujian's CTP was implemented four years later than other regions. Compared to other pilot regions, Fujian's carbon trading market has accumulated considerable experience and involved preliminary preparations. Considering the specificity of Fujian's CTP pilot, we removed Fujian area enterprises for robustness testing. The results shown in columns (4)–(6) of Table 4 indicate that our results are robust after considering Fujian's carbon emissions trading policy.

4.2.4. Substitution of Dependent Variables

In the above analysis, we chose the number of patents granted as the dependent variable. However, some scholars point out that granting patents takes some time, and thus, using the number of patents granted as the firm's substantial innovation level in the current year may be biased [57]. Therefore, we chose the number of patent applications as the dependent variable for robustness testing. We followed Griffin et al. in order to choose the total number of patents applied by corporates as a proxy variable for innovation [58], and the number of invention patents applied by corporates in the current year as a proxy variable for high-quality innovation. We then used the sum of utility model patents and foreign design patents applied by enterprises in that year to represent low-quality innovation.

As shown in column (2) of Table 5, the CCTP has a positive effect on the application of invention patents, which passes the 10% significance test. This finding suggests that CCTP significantly improves the application of high-quality innovation patents, which is consistent with the above analysis and results. According to the results in column (3) of Table 5, the CCTP has a negative effect on the application of invention patents, and this result passes the 1% significance test. Thus, CCTP also reduces the application of low-quality patents, in line with the above research findings.

We further introduce dependent variables from the perspective of innovation inputs to boost the robustness of the results. The existing literature considers R&D expenditures an important indicator of firms' innovation input [59–61]. Therefore, we introduce three indicators of R&D investment as proxy variables for firms' innovation investment to conduct robustness tests: R&D expenditure divided by total assets (R&D_ass), R&D expenditure divided by operating revenue (R&D_ret), and R&D expenditure divided by total profit (R&D_pro). According to columns (4)–(6) of Table 5, the coefficients of CCTP are positive and pass the 5% significance test, which indicates that CCTP significantly enhances firms' innovation input.

Table 5. Robust test with Substitution of dependent variables.

	(1) Inv_all_a	(2) Inv_high_a	(3) Inv_low_a	(4) R&D_ass	(5) R&D_re	(6) R&D_pro
CCTP	−0.003	0.031 *	−0.051 ***	0.003 ***	0.048 **	0.501 ***
	(−0.173)	(1.847)	(−2.810)	(11.427)	(2.492)	(9.152)
EPS	0.107 ***	0.069 ***	0.089 ***	0.001 ***	−0.349 ***	0.024
	(4.375)	(3.424)	(4.023)	(3.049)	(−23.295)	(0.331)
Mfee	−0.011	0.453 ***	−0.310 ***	0.047 ***	1.036 ***	25.601 ***
	(−0.102)	(5.201)	(−3.590)	(17.236)	(5.942)	(28.593)
Size	0.313 ***	0.317 ***	0.245 ***	−0.000 ***	0.003	0.201 ***
	(29.785)	(34.960)	(25.749)	(−3.300)	(0.290)	(7.078)
Lev	−0.613 ***	−0.404 ***	−0.421 ***	−0.007 ***	0.494 ***	−2.928 ***
	(−12.432)	(−9.982)	(−9.615)	(−10.989)	(9.349)	(−16.733)
ROE	0.363 ***	0.361 ***	0.231 ***	0.004 ***	1.636 ***	0.558
	(4.124)	(5.162)	(2.968)	(2.666)	(27.511)	(1.574)
Cashflow	0.986 ***	0.687 ***	0.890 ***	0.021 ***	−0.821 ***	1.546 ***
	(8.183)	(6.954)	(8.307)	(12.330)	(−6.397)	(3.694)
Balance	−0.003	0.009	−0.029 **	0.001 ***	−0.010	0.302 ***
	(−0.219)	(0.749)	(−2.327)	(5.809)	(−0.766)	(7.166)
Growth	−0.143 ***	−0.102 ***	−0.125 ***	−0.001 ***	−0.111 ***	−0.015
	(−9.085)	(−8.143)	(−9.045)	(−2.929)	(−6.636)	(−0.280)
ATO	0.243 ***	0.198 ***	0.201 ***	0.013 ***	0.153 ***	−0.752 ***
	(10.230)	(10.231)	(9.365)	(32.091)	(6.433)	(−10.607)
TobinQ	−0.005	0.023 ***	−0.004	0.001 ***	−0.039 ***	0.197 ***
	(−0.672)	(4.013)	(−0.652)	(8.854)	(−5.993)	(6.322)
Board	0.220 ***	0.190 ***	0.157 ***	0.001 **	0.010	0.013
	(4.849)	(4.933)	(3.858)	(2.265)	(0.224)	(0.097)
_cons	−5.670 ***	−6.383 ***	−4.437 ***	0.013 ***	0.291	−1.492 **
	(−24.130)	(−31.415)	(−20.817)	(4.490)	(1.346)	(−2.245)
Ind	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
N	28,269	28,269	28,269	22,957	22,957	18,981
r2	0.364	0.312	0.355	0.432	0.090	0.536

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level.

5. Heterogeneity Analysis

In our previous analysis, we examined the role of CCTP in promoting firms' high-quality innovation. At the same time, CCTP can significantly reduce low-quality innovation. However, certain differences, such as individual firms, may affect the incentive effect of CCTP on high-quality innovation. Therefore, this paper performs subgroup regression analysis according to the differences in the degree of financialization and the nature of corporate ownership.

5.1. Heterogeneity of Financialization

We first analyze the impact of carbon emissions trading policies on firm innovation from a firm financialization perspective. According to Su and Liu, whether or not a corporate is in financialization affects a corporate's current innovation decisions [62]. Hence, to verify whether corporate financialization has a heterogeneous impact on corporate innovation, we divide the corporates into two groups according to the proportion of financial assets they hold. Firms are in the High-Fin group if the degree of financialization is greater than or equal to the medium value; otherwise, they are in the Low-Fin group.

Columns (1) and (2) of Table 6 show that the coefficient of DID in column (1) is positive but not significant, while the coefficient of DID in column (2) is positive and passes the 1% significance test.

Table 6. Heterogeneity analysis with Financialization.

	(1) High-Fin	(2) Low-Fin	(3) High-Fin	(4) Low-Fin	(5) Diff	(6) High-Fin	(7) Low-Fin
	Inv_all		Inv_high			Inv_low	
CCTP	0.003 (0.133)	0.073 *** (2.599)	0.075 *** (4.368)	0.135 *** (6.362)	0.138 *** (6.633)	−0.046 ** (−2.040)	−0.000 (−0.009)
CCTP*Fin					−0.047 * (−1.834)		
Fin					−0.002 (−0.165)		
EPS	−0.004 (−0.130)	0.153 *** (4.519)	−0.036 * (−1.688)	0.072 *** (3.097)	0.001 (0.126)	0.017 (0.615)	0.117 *** (3.573)
Mfee	0.002 (0.016)	0.184 (1.238)	0.542 *** (6.440)	0.633 *** (5.462)	0.013 (1.347)	−0.214 ** (−1.986)	−0.107 (−0.786)
Size	0.318 *** (25.048)	0.293 *** (19.809)	0.291 *** (29.771)	0.256 *** (22.936)	0.280 *** (36.825)	0.262 *** (21.436)	0.237 *** (16.527)
Lev	−0.423 *** (−6.768)	−0.592 *** (−9.241)	−0.299 *** (−6.813)	−0.358 *** (−7.948)	−0.377 *** (−12.222)	−0.278 *** (−4.654)	−0.445 *** (−7.207)
ROE	0.325 *** (2.865)	−0.080 (−0.712)	0.212 *** (2.831)	−0.069 (−0.898)	−0.002 (−0.533)	0.284*** (2.626)	−0.023 (−0.212)
Cashflow	1.281 *** (8.822)	0.416 *** (2.599)	0.646 *** (6.342)	0.204 * (1.847)	0.410 *** (5.877)	1.144 *** (8.232)	0.392 ** (2.533)
Balance	0.011 (0.664)	−0.050 *** (−2.825)	0.006 (0.440)	−0.036 *** (−2.708)	−0.011 (−1.176)	−0.012 (−0.739)	−0.051 *** (−2.936)
Growth	−0.088 *** (−4.721)	−0.171 *** (−8.556)	−0.055 *** (−4.409)	−0.092 *** (−6.850)	0.000 (0.369)	−0.088 *** (−4.803)	−0.150 *** (−8.003)
ATO	0.179 *** (6.585)	0.258 *** (7.470)	0.129 *** (6.978)	0.133 *** (5.553)	0.044 *** (4.436)	0.166 *** (6.340)	0.246 *** (7.314)
TobinQ	0.031 *** (3.673)	−0.035 *** (−3.964)	0.044 *** (6.888)	0.007 (1.178)	0.011 *** (4.430)	0.024 *** (3.038)	−0.035 *** (−4.037)
Board	0.167 *** (2.964)	0.215 *** (3.618)	0.109 *** (2.639)	0.196 *** (4.420)	0.160 *** (4.911)	0.129 ** (2.407)	0.168 *** (2.906)
_cons	−6.109 *** (−21.289)	−5.194 *** (−16.115)	−6.174 *** (−27.934)	−5.307 *** (−21.708)	−5.745 *** (−34.198)	−5.033 *** (−17.982)	−4.158 *** (−13.321)
Ind	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES
N	14,860	13,407	14,860	13,407	28,269	14,860	13,407
r2	0.411	0.325	0.313	0.226	0.272	0.384	0.320

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level.

The coefficients of DID in columns (3) and (4) of Table 6 are positive and pass the 1% significance test, suggesting that CCTP increases the number of invention patents for high-financialized and low-financialized firms. Considering that the coefficient differences in columns (3) and (4) cannot be compared directly, we follow Qi et al. to build a triple difference model based on the financialization of the corporate for analysis [49]. We first generate dummy variables for the financialization of the firm, i.e., if the degree of financialization is greater than or equal to the medium value Fin = 1, otherwise Fin = 0. Then, we further analyze the interaction term of CCTP and Fin.

The result in column (5) of Table 6 reported that the coefficient on CCTP*Fin is negative and passes the 10% significance test, thereby suggesting that increased financialization of firms can decrease the incentive effect of CCTP on invention patents.

In columns (6) and (7) of Table 6, we further analyze the heterogeneous impact of corporate financialization on low-quality innovation. For the more financialized corporates, the coefficient of DID is negative and passes the 5% significance test. However, for less financialized corporates, the coefficient of CCTP is almost equal to zero and insignificant.

5.2. Heterogeneity of Corporate Ownership

In China, SOEs play a leading position in the economy, while N-SOEs also hold a highly significant status [63]. Corporate innovation activities have technology spillover effects and strong externalities [64]. At the same time, technological innovation in firms requires long-term and continuous capital investment and involves relatively high risks [65]. Due to the differences in business objectives and corporate governance between SOEs and N-SOEs, the environmental objectives and innovation decisions of enterprises with different corporate ownerships also differ significantly [66]. According to Laffont and Tirole, technological innovation activities often conflict with the goal of profit maximization for non-SOEs [67]. As a market-incentive environmental regulation policy, carbon trading can convert the external effects of technological innovation activities into internal benefits for enterprises, which may affect the decision-making of both SOEs and non-SOEs regarding technological innovation activities. This section provides an empirical test of this issue.

We first investigate the impact of CCTP on the total innovation of SOEs and non-SOEs. As reported in columns (1) and (2) of Table 7, the coefficient of CCTP in SOE is negative and statistically significant at the 1% level. In contrast, the coefficient of CCTP in N-SOE is positive and statistically significant at the 1% level. As a result, CCTP significantly reduced the total amount of technological innovation in SOEs and increased the total amount of technological innovation in non-SOEs.

Table 7. Heterogeneity analysis with corporate ownership.

	(1) SOE	**(2) N-SOE**	**(3) SOE**	**(4) N-SOE**	**(5) SOE**	**(6) N-SOE**
	Inv_all		**Inv_high**		**Inv_low**	
CCTP	−0.206 ***	0.139 ***	−0.022	0.149 ***	−0.244 ***	0.071 ***
	(−6.483)	(6.474)	(−0.918)	(9.288)	(−8.005)	(3.350)
EPS	−0.004	0.123 ***	−0.020	0.052 ***	−0.004	0.119 ***
	(−0.094)	(4.714)	(−0.730)	(2.805)	(−0.116)	(4.696)
Mfee	−0.107	0.215 *	0.344 ***	0.657 ***	−0.346 **	−0.025
	(−0.668)	(1.897)	(2.850)	(7.805)	(−2.272)	(−0.239)
Size	0.357 ***	0.289 ***	0.292 ***	0.252 ***	0.305 ***	0.234 ***
	(23.116)	(23.029)	(25.210)	(25.436)	(20.529)	(19.371)
Lev	−0.675 ***	−0.416 ***	−0.496 ***	−0.227 ***	−0.597 ***	−0.255 ***
	(−8.951)	(−7.540)	(−9.111)	(−5.899)	(−8.252)	(−4.827)
ROE	−0.126	0.213 **	−0.033	0.100	−0.070	0.191* *
	(−0.909)	(2.234)	(−0.348)	(1.567)	(−0.516)	(2.119)
Cashflow	0.518 ***	1.069 ***	0.342 ***	0.540 ***	0.431 **	0.966 ***
	(2.844)	(8.156)	(2.653)	(5.930)	(2.473)	(7.657)
Balance	−0.068 ***	−0.014	−0.046 **	0.001	−0.069 ***	−0.027 *
	(−2.711)	(−0.996)	(−2.554)	(0.091)	(−2.847)	(−1.937)
Growth	−0.109 ***	−0.136 ***	−0.070 ***	−0.071 ***	−0.104 ***	−0.124 ***
	(−4.594)	(−7.918)	(−4.399)	(−6.299)	(−4.615)	(−7.550)
ATO	0.128 ***	0.238 ***	0.063 ***	0.144 ***	0.112 ***	0.225 ***
	(4.275)	(8.054)	(2.817)	(7.361)	(3.879)	(7.938)
TobinQ	0.020	−0.011	0.022 **	0.022 ***	0.024 *	−0.017 **
	(1.568)	(−1.622)	(2.446)	(4.094)	(1.930)	(−2.485)
Board	0.252 ***	0.138 ***	0.145 ***	0.112 ***	0.219 ***	0.088 *
	(3.510)	(2.766)	(2.735)	(3.018)	(3.239)	(1.823)
_cons	−7.030 ***	−5.092 ***	−6.083 ***	−5.190 ***	−6.018 ***	−4.085 ***
	(−19.376)	(−18.595)	(−22.491)	(−23.760)	(−17.185)	(−15.379)
Ind	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
N	10,272	17,997	10,272	17,997	10,272	17,997
r2	0.440	0.346	0.365	0.224	0.408	0.343

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the firm level.

Columns (3) and (4) of Table 7 present the results of the heterogeneous impact of CCTP on firms' high-quality innovation. We can observe that the coefficient of CCTP in N-SOE is positive and statistically significant at the 1% level, whereas the coefficient in SOE is not significant.

Finally, we compare the impact of CCTP on low-quality innovation in SOEs and non-SOEs. According to the result of columns (5) and (6) of Table 7, the coefficient of CCTP in SOE is negative and statistically significant at the 1% level. In contrast, the coefficient of CCTP in N-SOE is positive and statistically significant at the 1% level. Thus, our results show that the CCTP significantly increased the technological innovation activities of non-state enterprises while reducing the low-quality technological innovation behavior of SOEs.

6. Discussion

According to the results in Table 3, the CCTP has a positive impact on corporate high-quality innovation and this result is consistent with H1. This may be because the CCTP imposes higher technological requirements on enterprises, making them seek more innovative and advanced technologies to reduce carbon emissions. This finding validates Porter's hypothesis [16,34]. It is also consistent with the conclusions of the literature on CTP and corporate innovation [33,38]. We further find that CCTP has a negative impact on corporate low-quality innovation. In the process of improving energy efficiency and reducing carbon emissions, corporate may facilitate the transformation from low-quality innovation to high-quality innovation.

Columns (1) and (2) of Table 6 indicate that the CCTP significantly increases the total number of patents of low-financialized firms and has no effect on high-financialized firms. Column (5) of Table 6 reveals that increased financialization of firms can decrease the incentive effect of CCTP on invention patents. The main reason is that a high level of corporate financialization may lead companies to focus more on return on investment rather than environmental benefits. CCTP aims to reduce carbon emissions through price incentives, but if companies are more concerned with return on investment, they may see carbon trading as an investment and thus focus more on its return rather than its environmental result when buying carbon emission quotas. Thus, higher financialization of corporations may diminish the incentives of CCTP for high-quality innovation.

As is revealed in Columns (3) and (4) of Table 7, the impact of CCTP on high-quality corporate innovation occurs mainly in non-SOEs. This may be because SOEs hold a critical position in the Chinese economy and often receive policy assistance and other favorable policies [63]. These policies may mitigate the impact of CCTP on their business behavior. In contrast, non-SOEs tend to face more competition and market risks and, as a result, need to pay more attention to carbon emissions [66]; therefore, they need to be more sensitive to carbon emission issues. Furthermore, according to the results of Columns (5) and (6) of Table 7, CCTP significantly reduces low-quality innovation in SOEs and increases low-quality innovation in non-SOEs. This may result from the fact that for SOEs, their propensity for low-quality innovation may be relatively low due to the preferential treatment and greater resource support they enjoy in terms of policy. For non-SOEs, on the other hand, their propensity to engage in low-quality innovation may be greater due to their lack of resources and policy support.

7. Conclusions

7.1. Findings

China's national carbon trading market was launched in 2021. While innovation-driven development is a matter of sustainable economic development, the impact of carbon emissions trading policies on innovation is worth exploring. The quality of a firm's innovation not only affects its technology but is also related to the performance of its environment. However, the literature analyzing the impact of CCTP on the quality of corporate innovation is scarce. Hence, this paper used China's A-share listed enterprises in

2010–2020 and CCTP to conduct a quasi-natural experiment. The relevant conclusions are as follows:

First, CCTP significantly improved the quality of innovation, increasing the granting of patents for high-quality innovations while reducing the granting of patents for low-quality innovations.

Second, the level of corporate financialization affects the effectiveness of CCTP. When firms are highly financialized, it can suppress the positive impact of corporate CCTP on high-quality innovation. At the same time, highly financialized firms can enhance the negative impact of CCTP on low-quality innovation.

Finally, the CCTP has different impacts based on the various natures of enterprises. The positive impact of CCTP on high-quality innovation occurs mainly among N-SOEs. In contrast, the negative impact of CCTP on low-quality innovation occurs mainly among N-SOEs.

7.2. Policy Recommendations

Based on the findings of this paper, we offer the following policy recommendations:

First, China should continue to promote the development of a national carbon emissions trading market. Currently, China's national carbon trading only covers the power sector, which has been an important part of the regional carbon trading market. As an energy conversion sector, improvements in the power sector can effectively reduce the proportion of primary energy consumed by coal and promote technological innovation in other energy-intensive enterprises.

Second, focus should also be given to the development of the real economy. According to the empirical results in Section 5, corporate innovation behavior is limited by corporate financialization. Hence, it is necessary to perfect the financial market system to provide financial support to real enterprises in technology innovation.

Finally, the supervision of innovation investment in SOEs should be strengthened and these enterprises should be guided toward improving innovation quality. In China, SOEs play a leading position in the economy. Hence, the improved innovation quality of SOEs would be of real significance for the sustainable development of China's economy.

7.3. Research Limitations

First, we have considered all the pilot region enterprises to be affected by the CCTP. This may not be consistent with the facts. In the next study, we will further match the specific list of firms in the CCTP to more accurately measure the policy effects of the CCTP.

Second, we have only examined the heterogeneous impact of CCTP on corporate innovation and have not investigated its specific transmission mechanisms in depth. In our future work, we will continue to deeply explore the internal motivations of corporate innovation and the internal mechanisms of CCTP that influence innovation.

Finally, while we have excluded the effect of a national carbon trading market from our robustness tests, we did not develop an analysis of the effect of a national carbon trading market in the electricity sector. This issue will be an important topic as the national carbon trading market develops.

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