Roll with the Punches:

Climate Change Regulation and Short-term Financing

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Abstract

This paper employs China's regional Emissions Trading System (ETS) pilots as a quasi-natural experiment to examine the impact of climate change regulations on corporate short-term debt financing decisions. The empirical analysis indicates that the introduction of the ETS results in a 27.8% reduction in short-term financial leverage among regulated firms compared to their non-regulated counterparts, while keeping unchanged in their long-term debt. This effect is particularly pronounced for firms headquartered in regions with lower free quota rates, those with less government ownership, and those facing higher product market competition. The mechanism analysis suggests that the regional ETS has increased firms' environmental compliance costs and financial distress risks, prompting a reduction in short-term debt financing. These findings substantiate the argument that the ETS has inadvertently impaired manufacturing firms' access to short-term credit by elevating their distress risk. This research underscores the unintended consequences of climate policy on the maturity structure of corporate debt.

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1 Introduction

The intensifying dialogue surrounding climate change underscores its multifaceted ramifications for global economic systems, environmental sustainability, and social welfare (Stern, 2008; Howe et al., 2013; Nordhaus, 2019). Governments across the globe have implemented market-based instruments, such as carbon taxes and emission trading schemes (ETS), to curb the ever increasing greenhouse gas emission, and these regulations pose considerable policy risk to the corporate sector. While existing research has predominantly focused on the impact of climate regulations on firms' energy use, resource relocation, innovation, accounting and financial outcomes (Veith et al., 2009; Martin et al., 2014; Borghesi et al., 2015; Oestreich and Tsiakas, 2015; Brown et al., 2022; Cui et al., 2022; Bartram et al., 2022; Ivanov et al., 2023), there is a scarcity of studies examining the corporate response in capital structure, especially on short-term debt financing. This study moves forward and investigates how firms adapt their short-term financial leverage in response to tightening emission mitigation policies.

Short-term debt is an important component of firms' capital structure and is considered to be highly volatile (Buch and Lusinyan, 2003). Existing literature has underscored that short-term debt plays a significant role in resolving moral hazard problems (Dewatripont and Tirole, 1994; Zwiebel, 1996; Della Seta et al., 2020) and lowering information asymmetries (Flannery, 1986, Diamond, 1991, Goyal and Wang, 2013; Gao and Zhu, 2015). However, high shares of short-term debt may expose firms to the refinancing risk (He and Xiong, 2012; Custódio et al., 2013; Dangl and Zechner, 2021), therefore it is often used as bridge financing and refinanced with long-term debt to limit rollover risk (Kahl et al., 2015). This paper, by delving into the impact of climate policies on corporate short-term debt financing, offers a micro-level perspective within the realm of climate finance research.

By leveraging the introduction of China's regional Emissions Trading Scheme (ETS) pilots as a quasi-experiment, this study reveals a 27.8 percent decline in short-term debt financing among regulated firms compared to unregulated firms. This effect is more pronounced for firms in regional carbon markets with lower free quota rates, firms with less government ownership, and firms facing higher product market competition. Mechanism analysis indicates that the regional ETS pilots have increased environmental compliance costs and reduced cash flows for firms. Consequently, facing a heightened risk of financial distress, regulated firms have reduced their short-term financial leverage to mitigate refinancing risk.

This paper adds to a growing literature on climate finance by providing the first causal evidence that climate policy influences corporate short-term debt financing decisions. Existing research has shown that market-oriented environmental policies, particularly climate regulations, affect various aspects of firms including production efficiency, energy usage, hiring decisions, export behavior, financial performance, and and innovation activities (Veith and Zimmermann, 2009; Martin et al, 2014; Calel and Dechezlepretre, 2016; Shi and Xu, 2018; Cainelli et al., 2020; Mao et al., 2023). However, there is limited research on how firms adjust their financing decisions, especially for short-term debt, in response to climate regulatory policies. Our paper focuses on short-term financing and offers important policy implications for the government and financial intermediaries.

Our work is closely related to Dang et al. (2023), which examined the impact of the U.S. Nitrogen Oxides Budget Trading Program (NBP) of 2004 on the financial leverage of manufacturing firms. However, our research diverges from theirs in two crucial aspects. First, our focus lies on short-term financial leverage, contrasting with the broader examination of total financial leverage undertaken by Dang et al. (2023). While Dang et al. (2023) observed a reduction in total financial leverage among firms in response to emission abatement policies, our findings indicate that regulated firms in China's regional ETS pilots primarily decrease short-term debt, while keeping the long-term financial leverage unchanged. Second, the targeted firms in our study differ from those in Dang et al. (2023). Specifically, the regulated firms in our analysis are firms participating in China's regional ETS pilots, whereas the NBP scrutinized by Dang et al. (2023) pertains to a cap-and-trade program designed to mitigate nitrogen oxides emissions only for coal power generators, leading to higher electricity prices, which affected the capital structure decisions for manufacturing firms in affected regions.

Furthermore, this study provides innovative evidence on how cost shocks impact corporate capital structure. Existing research has shown that corporate capital structure is influenced by factors such as labor market friction (Agrawal and Matsa, 2013; Simintzi et al., 2015; Alimov, 2015; Woods et al., 2019), information asymmetry (Li et al., 2019), and energy prices (Fan et al., 2021). This paper explores how compliance costs for climate policy affect corporate financing decisions, thereby extending the consideration of costs into the realm of climate regulation.

The subsequent sections of this manuscript are structured as follows: Section 2 offers a comprehensive examination of the institutional backdrop, theoretical underpinnings, and the formulation of hypotheses. Section 3 delves into methodological nuances, including considerations such as sample construction and the delineation of the identification strategy. Section 4 elucidates the primary findings, supplemented by the outcomes of sensitivity analyses and cross-sectional scrutiny. Section 5 delves into an exploration of the underlying mechanisms at play. Finally, Section 6 provides the concluding remarks.

2 Institutional Background and Hypothesis Development

2.1 Institutional Background

To mitigate carbon dioxide emissions and address the threats posed by climate change, the United Nations adopted the Kyoto Protocol in 1997, which came into effect in 2005. China stands as one of the principal signatory nations to the Kyoto Protocol. In 2009, during the Copenhagen Climate Conference, China pledged to reduce its carbon dioxide emissions per unit of GDP by 40-45% by 2020 compared to 2005 levels. In pursuit of these emission reduction targets, the National Development and Reform Commission (NDRC) issued a notification in October 2011, announcing the initiation of its regional carbon market pilots in seven regions, including four municipalities (Beijing, Shanghai, Tianjin and Chongqing), two provinces (Guangdong and Hubei), and one city with independent planning (Shenzhen). These pilots were then launched in 2013 and started trading carbon allowances henceforth.

The regional carbon market pilots encompass over 3,000 major emitters across more than 20 industries, including electricity, cement, steel, petrochemicals, construction materials, aviation, and paper production. Each pilot is afforded the flexibility to design its own market rules, including sector coverage and the threshold for firm designation. The pilots establish caps on total emission allowances, with the list of regulated firms determined based on their historical carbon emissions or energy consumption. Firms whose emissions exceed their allocated allowances must purchase additional allowances from the carbon market to ensure compliance. Noncompliance is subject to various financial and non-financial penalties (Cui et al., 2021; Cui et al., 2022).

Though China's regional carbon market pilots share similar protocol as that in the ETS of European Union, it has differentiated features on the accounting and allocation rules of emission allowances. First, the European Union employs a rate-based rule to calculate the emission allowances allocated for the regulated firms, while China's ETS pilots predominantly adopt a mass-based system, supplemented by a rate-based rule. The advantages of rate-based approach relative to mass-based approach lie in that this method establishes a benchmark for companies to reduce emissions, while also avoiding the drawback of mass-based approach which could indirectly reward companies with higher historical emissions with more quotas. This provides stronger incentives for companies to improve production efficiency and achieve energy savings and emission reductions (Lopomo et al., 2011; Tombe and Winter, 2015).

Second, the allocation rule of emission allowance diverges. Since 2013, European Union has predominantly embraced a grandfather approach, where the regulated firms acquire the allowances through auctions. Conversely, most of China's ETS pilots allocate allowances for free. Although some pilots, such as Guangdong, Shenzhen, Beijing, and Tianjin, implement auction mechanisms, but at a relatively low proportion compared to the total allowances. For instance, the pilot in Shenzhen province auctions off only 3% of its allowances.

The regional ETS pilots have been documented as effective in reducing firm emissions, resulting in a 16.7% reduction in total emissions and a 9.7% reduction in emission intensity (Cui et al., 2021). In July 2021, China launched a nationwide unified ETS, initially integrating the electricity generation sector into the national carbon market. This development has positioned China as the global leader in terms of aggregate carbon emissions coverage, surpassing the European Union. Concurrently, the seven regional ETS pilots continue to operate. Regulated firms that are not included in the national carbon market will persist in participating in the regional carbon markets.

2.2 Literature Review and Hypothesis Development

Our study connects to the ongoing literature that examines the effects of market-oriented climate regulations, which usually mandate firms to be enrolled in cap-and-trade program for greenhouse gas emission reduction. Given the critical role of climate regulations for both government and society, there has been growing interests in estimating their impacts. Previous studies reveal significant findings, indicating that stringent market-oriented climate regulations lead to reduced corporate energy use and carbon emissions (Martin et al., 2014; Cui et al., 2021), relocation of production activities (Bartram et al., 2022; Cui et al., 2022), increased R&D investment and environmental innovation (Borghesi et al., 2015; Brown et al., 2022). Concurrently, other studies have delved into corporate responses within financial outcome, including stock market performance (Veith and Zimmermann, 2009; Oestreich and Tsiakas, 2015), capital structure (Nguyen and Phan, 2020; Dang et al., 2023; Shu et al., 2023; Dang et al., 2024), and the pricing of bank loan (Ivanov et al., 2023).

To the best of our knowledge, insufficient attention has been directed towards investigating the interplay between market-oriented climate regulations and short-term debt financing. Nonetheless, this relationship carries substantial importance given the critical impact of short-term debt on tangible corporate practices, such as investment strategies and expansion opportunities (Almeida et al., 2012; Custódio et al., 2013). If the financial constraints induced by stringent climate regulations compel firms to increase their reliance on short-term debt, they will encounter more frequent renegotiation and heightened refinancing risks (He and Xiong, 2012). This, in turn, may impede their ability to invest in sustainable transitions and efforts to combat climate change. This interplay ultimately undermines the effectiveness of regulatory measures, casting uncertainties on the net societal benefits derived from the enhanced climate regulatory measures. Therefore, a comprehensive exploration of the correlation between heightened governmental interventions in climate policy and corporate short-term debt becomes imperative.

However, it remains unclear whether firms will increase or decrease their involvement in short-term debt financing. It is plausible that firms seek to spread out the maturity structure of its debt claims in response to emission-reduction regulations. The emission reduction pressure under the ETS increases the environmental compliance costs for the firms. If the compliance cost is more fixed than variable in nature, increased cost caused by the ETS would result in higher operating leverage, and in turn, raise a manufacturer's distress risk and cost of debt (Serfling, 2016; Nguyen and Phan, 2020; Dang et al., 2023; Dang et al., 2024). Aligned with trade-off theory, which posits that firms determine an optimal capital structure by weighing the benefits against the costs of debt financing (Kraus and Litzenberger, 1973; Bradley et al., 1984), as corporate distress risk rises, the affected firms are more inclined to decrease their financial leverage.

Corporate short-term debt is more sensitive to interest rate fluctuations than long-term debt. While long-term debt generally carries fixed interest rates, holders of short-term debt are more exposed to rate variability due to the typically variable structure of short-term financing. Compared to long-term debt, the risk associated with the inability to renew maturing short-term debt poses a more substantial concern for firms, particularly those facing financial constraints (Dudley and Yin, 2018). Short-term debt requires periodic refinancing or renewal, and a firm's inability to do so can lead to severe financial consequences, including default and reputational harm (He and Xiong, 2012). To mitigate refinancing risk, firms are expected to extend their debt maturity by reducing their reliance on short-term debt.

Altogether, the introduction of China's ETS pilots may provide incentives for firms to lengthen their debt maturity. As such, we proceed to evaluate our first hypothesis:

H1a: *The introduction of China's ETS pilots causes firms to use less short-term debt.*

On the contrary, insights from prior literature suggests a potential increase in short-term debt following more stringent climate regulations. To the extent that ETS heightens firms' carbon risk, it may discourage them from engaging in carbon-intensive activities while encouraging them to voluntarily switch to cleaner technologies (Nguyen and Phan, 2020; Borghesi et al., 2015; Brown et al., 2022). Accordingly, a transition from a higher to a lower carbon emission state could facilitate a firm's access to external capital markets, potentially leading to an increase in debt financing, to exploit interest tax shields (Sharfman and Fernando, 2008). Compared with long-term debt, short-term debt has a lower transaction cost, and is more favored by firms subject to greater information asymmetry (Zwiebel, 1996; Custódio et al., 2013; Kahl et al., 2015). Consequently, the regulated firms may be more likely to use more short-term debt.

Building on this rationale, we anticipate that the introduction of China's ETS pilot may lead to higher short-term financial leverage. Therefore, we propose an alternative hypothesis as follows:

H1b: *The introduction of China's ETS pilot causes firms to use more short-term debt.*

3 Data and Identification Strategy

3.1 Sample

To examine the impact of the regional ETS pilots on corporate financing decisions, we conduct our analysis based on Chinese publicly-traded firms from 2010 to 2018, which includes four year before and five years after the introduction of China's ETS pilots. Financial and accounting data for the listed firms comes from the CSMAR database, which is a widely recognized data vendor for Chinese financial market. We manually compile a list of regulated firms in the regional ETS pilots and merge it with the listed firms, to identify the affected listed firms which are included in the pilots.

We screen our initial sample based on several principles. First, we restrict our sample to firms headquartered in regional ETS pilots to ensure geographical comparability between regulated and non-regulated firms. Second, firms in the financial industry are excluded due to their typically high financial leverage. Third, firm-year observations with negative net profits are excluded, as operating losses may impede a firm's capabilities for debt financing. Fourth, all continuous variables are winsorized at the 1st and 99th percentiles to mitigate the impact of outliers. This rigorous screening process ensures the quality and comparability of our sample for analysis, thereby facilitating a more precise examination of the impact of carbon markets on corporate debt financing.

3.2 Identification Strategy

Following the guidelines outlined by China's regional ETS pilots, firms with historical annual emissions or energy consumption above certain threshold are designated to be the regulated firms. This regulatory framework presents an exogenous policy shock. Following Cui et al. (2021; 2022), we employ a difference-in-difference approach to examine the impact of ETS on corporate debt financing decisions.

$$SDebt_{it} = \beta_0 + \beta_1 Regu_i \times Post_t + \beta_1 X_{it} + \gamma Z_{ct} + \kappa_i + \delta_c + \varphi_t + \varepsilon_{it} \qquad (1)$$

Where $SDebt_{it}$ is the short-term financial leverage of firm i in year t; $Regu_i$ is a dummy variable which equals one if a firm is a regulated firm under the ETS and zero otherwise; $Post_t$ is a dummy variable which equals one for observations made during 2014-2018 and zero for those during 2010-2013. X_{it} represents a set of firm-level control variables. We also include firm-fixed effect (κ_i), city-fixed effect (δ_c), and year-fixed effect (φ_t) in the regression model. ε_{it} is the error term with standard errors clustered at the firm level.

In our analysis, we employ short-term book leverage as a proxy for short-term financial leverage, following previous studies on capital structure (Agrawal and Matsa, 2013; Serfling, 2016; Dang et al., 2023). The short-term book leverage is calculated as the ratio of debt in current liabilities divided by the book value of total assets. As for the control variables, we incorporate several pivotal metrics. Following the methodologies outlined by Frank and Goyal (2009) and Heider and Ljungqvist (2015), we include firm total assets (*Size*), profitability (*ROA*), and fixed assets (*Tangibility*). Furthermore, we consider intangible assets (*Intangibles*) due to their potential as collateral for debt (Lim et al., 2020). Cash flow (*Flow*) is included to capture the debt financing motivations of cash-abundant firms (Dasgupta et al., 2011). Additionally, we control for sales growth (*Growth*) given its association with firms' debt borrowing behavior (La Rocca et al., 2011). To account for potential city-level economic and environmental factors that may influence capital structure decisions, we include city-level GDP and $PM_{2.5}$, consistent with Dang et al. (2023). For a detailed overview of our key variables, refer to Appendix A.

3.3 Summary Statistics

Table 1 presents the descriptive statistics of the key variables. Specifically, the mean and median of short-term debt stand at 0.097 and 0.056, respectively, exhibiting a close semblance to values reported in extant literature. Notably, the standard deviation of short-term debt, at 0.119, surpasses the mean, indicative of substantial heterogeneity in the short-term debt decisions across sample enterprises. Moreover, the mean value of *Regu*, at 0.123, suggests the inclusion of approximately 1194 firm-year observations within the sampled period in the regional ETS pilots. The remaining control variables align closely with existing literature and are thus not expounded upon here due to space constraints.

4 Empirical Results

4.1 Baseline results

Table 2 reports the regression results depicting the impact of the introduction of China's ETS pilots on corporate debt financing decisions. Columns (1)-(3) present the dependent variable as short-term financial leverage. In model (1), only firm, city, and year fixed effects are controlled for, without the inclusion of additional controls at the firm and city levels. Model (2) introduces firm-level control variables, while model (3) further includes city-level control variables. Across columns (1)-(3), the estimated coefficients of *Regu*×*Post* are consistently negative and statistically significant at the 1% level. To illustrate, considering the results in column (3), following the introduction of the regional ETS pilots, the regulated firms witness a decrease of 0.027 in short-term financial leverage compared to non-regulated firms. Given the mean value of short-term financial leverage in our sample is 0.097, this suggests a decline of 27.8% (=0.027/0.097) in short-term debt financing for regulated firms. Overall, the results in Table 2 indicate a pronounced decrease in short-term financial leverage for regulated firms following the implementation of the regional ETS pilots. The empirical findings lend support to hypothesis H1a.

4.2 Robustness analysis

4.2.1 Short-term debt v.s. long-term debt

Compared with short-term debt, long-term debt has a lower risk of refinancing and allows firms to undertake strategic initiatives with a longer time horizon, such as funding large capital expenditure. We also scrutinize the impact of China's ETS on firms' total debt and long-term debt. The regression results are displayed in Table 3. The dependent variable in Column (1) is long-term financial leverage, represented by the sum of corporate long-term loans, payable bonds, and non-current liabilities due within one year, divided by the book value of total assets. The dependent variable in Column (2) is total financial leverage, expressed as the sum of short-term debt and long-term debt divided by the book value of total assets. The results in Columns (1)-(2) reveal that the estimated coefficients of *Regu*×*Post* are insignificantly different from zero, indicating that the introduction of carbon emission control mechanisms has not significantly affected firms' total debt and long-term debt. In other words, the influence of carbon emission control mechanisms on firms' financing decisions primarily concentrates on short-term debt.

4.2.2 Dynamic Effects

The cornerstone premise of the difference-in-differences model is the parallel trends assumption. Within the context of this study, the parallel trends assumption implies that, prior to the initiation of regional carbon market pilot programs, the short-term debt financing trends of both emission-controlled firms and non-emission-controlled firms exhibit a similar trajectory. This study employs the dynamic effects stemming from the implementation of regional carbon market pilots to validate this assumption. The regression equation is formulated as follows:

$$SDebt_{it} = \alpha_0 + \sum_{t=2010}^{2018} \theta_t Regu_i \times Post_t + \beta_1 X_{it} + \gamma Z_{ct} + \kappa_i + \delta_c + \varphi_t + \varepsilon_{it} \quad (2)$$

where 2013 serves as the base year for examination, $Post_t$ is a dummy variable for the year, θ_t is the parameter of our interest, with other variables maintaining their meanings as per Equation (1). The parameter θ_t delineates whether there exists a discernible discrepancy in the short-term debt financing decisions between regulated and unregulated enterprises compared to the year 2013. Statistical insignificance prior to the initiation of regional carbon market pilots implies compliance with the parallel trends assumption. Figure 1 illustrates the estimated values along with their corresponding 95% confidence intervals. It is discernible that the DID model employed in this study successfully passes the parallel trends test. Furthermore, subsequent to the commencement of regional carbon market pilots, the estimated coefficient for $Post_t$ significantly trends negatively, indicating a substantial reduction in short-term debt financing by regulated firms. This shift was not immediate in the year of policy implementation in 2014 but gradually materialized in the ensuing years.

4.2.3 PSM-DID

While the DID model employed in this study satisfies the assumption of parallel trends, it is acknowledged that systemic disparities between regulated and unregulated enterprises may potentially introduce biased estimation results. To mitigate this possibility, we employ the propensity score matched DID approach (PSM-DID) to scrutinize the robustness of our baseline results. Specifically, the methodology entails initially employing the propensity score matching algorithm to sequentially pair regulated and unregulated firms, employing the same set of control variables as delineated in Equation (1). To ensure the resilience of the outcomes, we adopt nearest-neighbor matching algorithms at ratios of 1:10, 1:15, and 1:20, respectively, to construct matched samples.

The effectiveness of the matching process is assessed through a balance test. For instance, Figure 3 illustrates the propensity score distributions for the 1:15 nearest-neighbor matching, both prior to and following the procedure. Visual inspection indicates that propensity score matching significantly reduces the bias between treatment and control groups. Additionally, Figure 4 highlights the shifts in covariates before and after matching, demonstrating that differences across all variables narrow to below 5%, thereby supporting the balance hypothesis. Similar results are observed in the 1:10 and 1:20 matching scenarios as well.

Subsequently, DID regressions are conducted utilizing the matched samples, with the results presented in Table 4. Columns (1) through (3) reveal that the coefficient for *Regu*×*Post* is positive and statistically significant at conventional levels. These regression coefficients suggest that subsequent to the initiation of regional carbon market schemes, regulated firms included in the carbon market (the treatment group) experience a significant reduction in short-term debt financing compared to their unregulated counterparts (the control group), aligning closely with the conclusions drawn from our baseline regression results presented in Table 3.

4.2.4 A permutation test

To evaluate the potential influence of unobserved firm-level variables on our study's conclusions, we conduct a placebo test, following the methodologies proposed by Chetty et al. (2009) and Mastrobuoni and Pinotti (2015). Specifically, we employ non-repeated random sampling to reassign firms into a hypothetical regulated group, generating an artificial treatment variable, *Regu_False*. We then re-estimate Equation (1) using this spurious variable. Given the random nature of the data assignment, the interaction term between the newly created treatment variable and the policy time variable, *Regu_False*×*Post*, should have no substantive impact on corporate decisions related to short-term debt financing. Consistent with the approach of Mastrobuoni and Pinotti (2015), this process is repeated 500 times to obtain 500 estimates of the regression coefficient and their associated p-values.

Figure 2 illustrates these estimation results. The hollow blue circles mark the point estimates on the *x*-axis, while the corresponding *p*-values appear on the *y*-axis, with a solid line representing the probability distribution of the point estimates. The vertical line indicates the estimated coefficient for *Regu_False×Post* from Column (3) of Table 3, and the horizontal line marks the 10% significance threshold. If the study's findings were merely artifacts driven by firm-level unobserved variables, the estimated values from random data generation would closely align with those from the actual dataset (represented by the vertical line). As shown in Figure 2, however, the estimates derived from random samples follow an approximately normal distribution centered around zero, with most *p*-values surpassing the 10% threshold. This pattern suggests that the conclusions of this study are not substantially influenced by unobserved firm-level factors.

4.3 Heterogeneous analysis

The preceding analysis substantiated the influence of ETS on corporate debt financing and we meticulously examined the robustness of the baseline regression results by employing parallel trends analysis, PSM-DID methodology, and placebo testing. To deepen our comprehension of the relationship between the implementation of ETS and corporate debt financing decisions, we conduct heterogeneous analysis based on mechanism design, corporate ownership and product market competition.

4.3.1 Allowance Allocation Rules: Free Allocation v.s. Auction

The allowance allocation method plays a pivotal role in the implementation of the ETS (Bushnell et al., 2013; Andreas et al., 2018). While free allocation based on firms' historical emissions or production is more widely accepted and requires less data, it has the drawback of rewarding carbon-intensive firms (Schmidt and Heitzig, 2014; Zhou and Wang, 2016). Auctioning, the alternative allocation method, increases government revenue and provides producers with greater incentives for green innovation (Cramton and Kerr, 2002; Liu et al., 2023), but also raises producers' environmental costs. We hypothesize that, compared to free allocation, the auction method imposes a higher financial burden on regulated firms, thereby exerting a greater influence on their debt financing decisions.

For distributing emission allowances to regulated firms, China's regional ETS pilots predominantly adopted the free allocation method, supplemented by auctions.

Specifically, the regional carbon markets in Shanghai, Guangdong, Tianjin, Chongqing, and Hubei opted for the free allocation method, whereas Beijing and Shenzhen employed a combination of free allocation and auctions. To validate our expectation, we categorize firms headquartered in the Beijing and Shenzhen pilots as the auction group, while the remaining are classified as the free allocation group. Columns (1) and (2) in Table 5 report the regression results for these subgroups. Column (1) presents the regression results for the free allocation group, where the coefficient of *Regu*×*Post* is negative but not statistically significant. Column (2) presents the regression results for the auction group, where the coefficient of Regu×Post is negative and statistically significant at the 1% level. These results indicate that the impact of the implementation of China's ETS on corporate short-term leverage is more pronounced in pilots that have partly adopted the auction method. The empirical findings are consistent with our expectation.

4.3.2 Government Ownership

A distinctive characteristic of the Chinese capital market lies in its substantial prevalence of government ownership, as evidenced by the substantial representation of state-owned enterprises (SOEs) among listed firms in China (Tang, 2020). SOEs, under governmental control, often exhibit a predisposition towards adhering to environmental standards even in advance of the implementation of stringent regulatory frameworks (Clò et al., 2017; Zhang and Zhao, 2022). In the context of heightened climate regulations, non-SOEs are confronted with a comparatively greater escalation in environmental compliance costs than their SOE counterparts. Consequently, non-SOEs may be incentivized to curtail their reliance on short-term debt as a means to mitigate distress risks and circumvent potential refinancing vulnerabilities. As a result, it is postulated that the impact of climate regulations on corporate short-term financing is anticipated to be more pronounced among SOEs in comparison to non-SOEs.

We categorize the firms controlled by the central and local governments as the SOEs, while other firms are classified as non-SOEs. Columns (3) to (4) of Table 5 present the regression results for the subsamples. The regression analysis reveals significant heterogeneity in policy effects between SOEs and non-SOEs. Within the SOE subsample, the coefficient for the interaction term *Regu*×*Post* is negative but not statistically significant. Conversely, in the non-SOE sample, the coefficient for the interaction term is negative and significant at the 5% level. This indicates that post the initiation of regional ETS pilots, non-SOEs experience a more significant reduction in debt financing compared to SOEs, aligning with our expectation.

4.3.3 Competitive Pressure

Firms in a more competitive product market may suffer more from climate regulation (Ni et al. 2022; Dang et al., 2023). In a competitive product market, firms are more difficult to pass regulation costs on to downstream firms or customers, and could not maintain profit margins by increasing productivity or reducing other costs, leading to deteriorating financial health status (Chava et al., 2023). Therefore, it is anticipated that following the implementation of regional ETS pilots, regulated firms in a more competitive product market experienced a more pronounced decrease in short-term debt financing compared to those facing looser constraints.

Specifically, we employ the Herfindahl-Hirschman Index (HHI) to proxy for product competition, calculated as the sum of squared market share of all firms within the focal firm's industry. Firms with a HHI higher than the sample averages during 2011-2013 are categorized as the group facing less market competition, while those with HHI above the sample averages during 2011-2013 are deemed to have to face more market competition. Columns (5) to (6) of Table 5 present the results of regression analysis in subgroups. The findings indicate that when firms face less market competition, the coefficient of the interaction term *Regu*×*Post* is negative but not statistically significant. However, when firms face more competitive competition, this coefficient is negative and significant at the 1% level. These regression results align with our expectation, indicating that the impact of the ETS on corporate short-term debt financing is more pronounced in firms facing higher product market competition.

5 Mechanism Analysis

The preceding discussion explored the heterogeneity in the impact of the climate regulations on corporate short-term debt financing. Subsequently, we examine the mechanism through which the ETS affects corporate short-term financial leverage.

In China's regional ETS pilots, firms face cost pressures resulting from carbon emissions reduction. If a firm's carbon emissions exceed the initial carbon quota, it is required to purchase additional carbon quotas in the carbon market for compliance, thereby increasing its operational costs. Such cost expenditures elevate the business pressure on firms, weaken their capacity to repay debt principal and interest, and raise the risk of financial distress. To offset losses arising from credit risk, financial institutions may demand higher risk premiums when providing debt financing to firms, consequently leading to an increase in the cost of corporate debt financing.

The capital structure trade-off theory posits that the external financing cost influences firms' debt financing decisions. When the cost of debt financing is high, firms are inclined to reduce debt financing and turn to internal financing (Kraus and Litzenberger, 1973; Fama and French, 2002). According to trade-off theory, when the cost of debt financing for firms rises, they tend to decrease their reliance on debt financing. This paper empirically examines this rationale and analyzes the underlying mechanism.

Table 6 presents the regression analysis results regarding the underlying mechanisms described above. In Column (1), the dependent variable is the cost of carbon emission reduction, computed by dividing management expenses by total assets at the end of the preceding fiscal year. According to accounting standards for carbon emissions in China, expenditures made by firms for the acquisition of carbon quotas for compliance purposes are categorized as management expenses. Additionally, expenses incurred by firms for energy-saving renovations or the procurement of clean energy equipment to reduce carbon emissions contribute to the increased production costs, which are also reflected as management expenses in the firms' income statement.[2] In Table 6, it is evident that the coefficient of *Regu*×*Pos*t is

[2] For instance, within the steel industry, the implementation of carbon emission reduction measures impacts the production costs of steel. Mainly, steelmaking facilities reliant on blast furnaces require the incorporation of equipment such as CCS (Carbon Capture and Storage) and

positive and statistically significant, indicating that the introduction of the ETS amplifies the carbon emission reduction costs for regulated firms.

Subsequently, an analysis is conducted to examine the impact of the ETS on the financial condition and debt financing costs of firms. In Column (2) of Table 6, the dependent variable is financial condition, measured using the Altman Z-score. The Altman Z-score serves as an indicator of corporate financial distress, where a lower Z-score implies a higher risk of default (Altman, 1968; Agarwal and Taffler, 2007; Almamy et al., 2016). Column (3) features the dependent variable of debt financing costs, represented by the ratio of interest expenses to total liabilities. The results from Columns (2) to (3) indicate that following the introduction of the ETS, regulated firms experience deteriorating financial conditions, consequently leading to an increase in their debt financing costs.

We also explore the effect of the introduction of China's ETS pilots on firms' research and development investment. In Column (4), the dependent variable is research and development (R&D) expenditure, calculated by dividing a firm's R&D investment by total assets at the end of the previous fiscal year. It shows that the implementation of China's ETS led to a notable escalation in R&D investment by these firms.

Overall, the mechanism analysis corroborates the anticipated transmission pathways outlined in this study. The implementation of the ETS leads to heightened carbon emission reduction costs and R&D expenditure for regulated firms. As a result, funds allocated by firms for servicing the debt principal and interest diminish, leading to an escalation in the default risk and consequently exposing firms to higher debt financing costs. This rise in debt financing costs ultimately prompts firms to passively reduce their reliance on debt financing.

6 Conclusion and Discussion

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top gas recycling units for carbon recapture. Consequently, steel enterprises are necessitated to make corresponding fixed asset investments, with this investment reflecting in the costs of steel-making. The annual depreciation expense of carbon recapture equipment is accounted for as management expenses in the firms' income statement.

The carbon ETS stands as a pivotal institutional innovation in response to climate change and serves as a crucial initiative in advancing for green development. The manner in which market-oriented environmental regulations impact the investment and financing behavior of corporations is currently garnering widespread attention from both governmental bodies and academia alike. Employing a quasi-natural experimental methodology, this paper delves into the influence of China's regional carbon market pilot program on corporate debt financing decisions, providing insights into how firms adapt to the climate transition risk by altering their capital structure.

Our paper finds that, following the introduction of the carbon ETS, the short-term debt financing of regulated firms decreased by 27.8% compared to non-regulated firms, while long-term debt financing remained materially unchanged. The effect of the carbon ETS on corporate short-term debt is more pronounced among firms located in regional carbon markets with lower free quota rates, firms with less government ownership, and firms facing higher product market competition. Mechanism analysis reveals that China's regional ETS pilots have increased environmental compliance costs, reduced cash flows, and heightened financial distress and debt financing costs, ultimately leading firms to reduce their short-term debt financing. These findings align with the trade-off theory of capital structure.

Our study offers several policy implications for policymakers and financial institutions. First, the government should foster a more favorable financing environment for firms participating in the ETS. In China's regional carbon markets, ETS firms face increased costs associated with carbon reduction, which drives them towards energy conservation and technological upgrades, thereby elevating their demand for funds. However, these increased costs also reduce the firms' cash flows, leading to a constrained ability to finance through debt. To address this issue and support green transformation, the government should implement policies that encourage financial intermediaries to enhance the financial accessibility for ETS firms, thus aiding these firms in mitigating carbon emissions.

Second, financial institutions should prioritize the long-term financing needs of ETS firms. The introduction of China's regional ETS pilots has led to a reduction in short-term debt among ETS firms, while long-term debt financing remains relatively stable. This indicates an elongation of the debt maturity structure for these firms. Given that the transition to a low-carbon economy is inherently long-term and requires sustained investments, commercial banks, as major providers of long-term funds, are well-positioned to support ETS firms through long-term loans, bonds, and asset securitization, addressing their long-term financing needs.

Third, the use of auctions in allowance allocation should be introduced and gradually expanded. Our findings suggest that a lower ratio of free quota allocation can enhance constraints on ETS firms, thereby increasing the effectiveness of climate policy and boosting government revenue. Since the initiation of China's national carbon market in 2021, the practice of fully free issuance of initial carbon quotas has persisted. Implementing reforms to allocate a portion of quotas for auction could improve the efficiency of the ETS and better align it with climate policy objectives.

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Figures and Tables

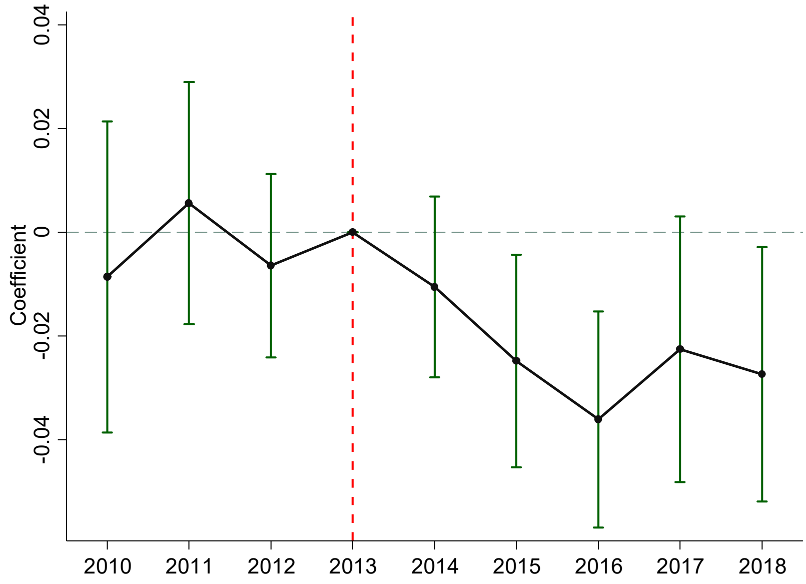

Figure 1 Dynamic Effects

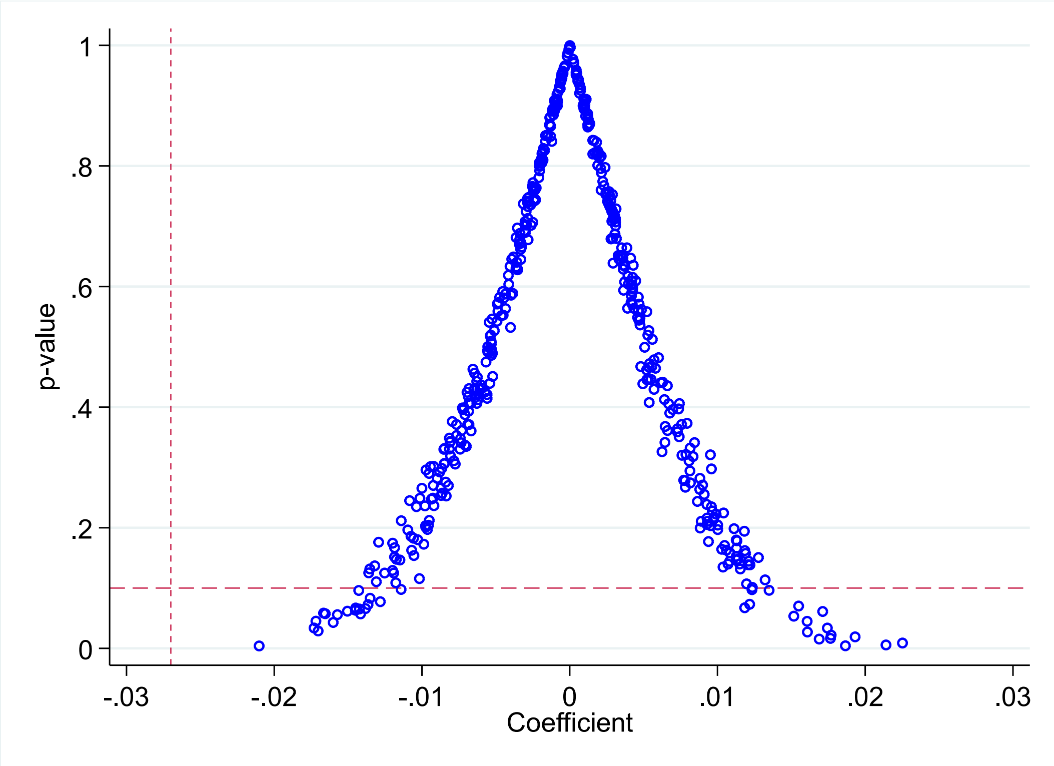

Figure 2 Permutation Test

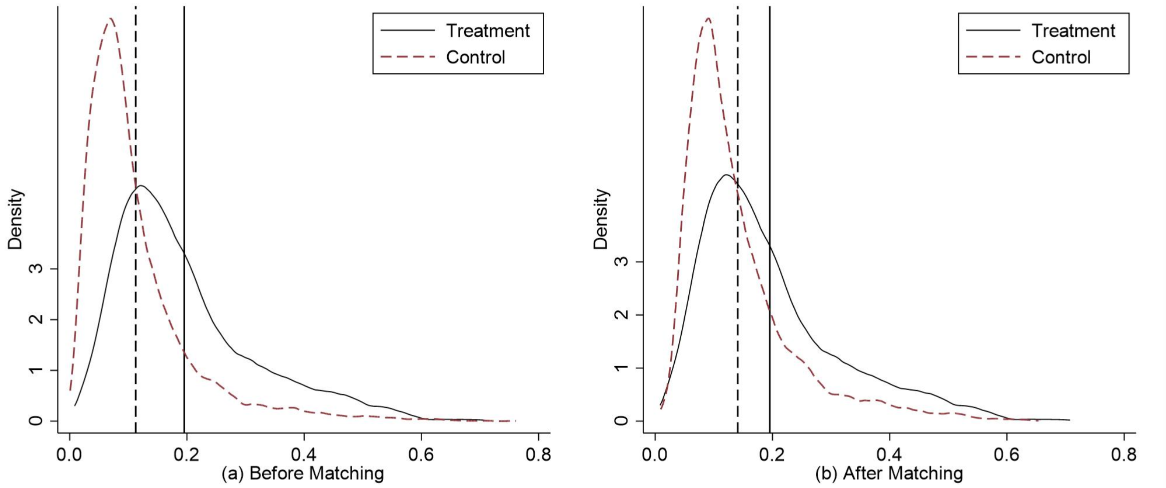

Figure 3: The Distribution of Propensity Score before and after Matching

Note: The left-hand figure illustrates the distribution of propensity scores before matching, while the right-hand figure displays the distribution after the matching process. In both figures, the horizontal axis represents the propensity scores, and the vertical axis shows the kernel density. The solid vertical line denotes the mean propensity score for the treatment group, and the dashed vertical line signifies the mean score for the control group.

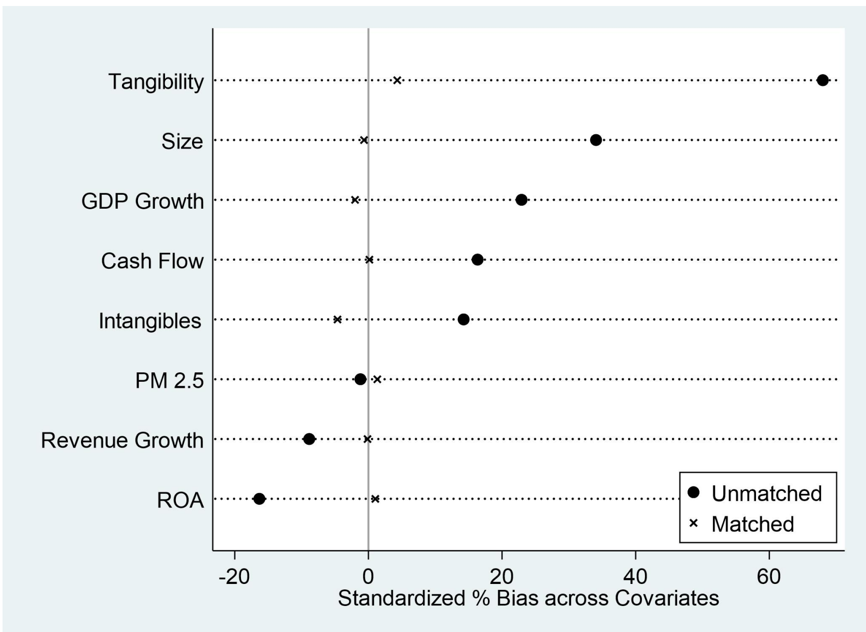

Figure 4: Comparison of Standardized Difference between Unmatched and Matched Covariates

Table 1 Summary Statistics

Variables	N	Mean	S.D.	75th	Median	25th
SDebt	9707	0.097	0.119	0	0.056	0.154
Regu	9707	0.123	0.328	0	0	0
ROA	9707	6.470	3.955	0	8.307	9.110
Tangibility	9707	0.071	0.054	0.031	0.058	0.097
Intangibles	9707	0.177	0.145	0.063	0.144	0.255
Cash_Flow	9707	0.041	0.041	0.013	0.03	0.056
Revenue_Growth	9707	0.06	0.079	0.012	0.054	0.103
GDP_Growth	9707	0.204	0.276	0.039	0.157	0.309
PM2.5	9707	0.109	0.040	0.085	0.104	0.123
LDebt	9707	3.758	0.304	3.526	3.722	3.983
TDebt	9707	0.170	0.191	0.007	0.117	0.274

Note: This table displays the number of observations, mean, standard deviation, median of the key variables, as well as the 75 percentile and the 25 percentile of its distribution. See Appendix A for the definitions of the key variables.

Table 2 Baseline Results

Variables	SDebt		
	(1)	(2)	(3)
Regu × *Post*	-0.026***	-0.026***	-0.027***
	(0.009)	(0.008)	(0.008)
Size		-0.005***	-0.005***
		(0.001)	(0.001)
ROA		-0.207***	-0.206***
		(0.043)	(0.043)
Tangibility		-0.005	-0.005
		(0.020)	(0.020)
Intangibles		0.133***	0.132**
		(0.051)	(0.051)
Cash_Flow		-0.205***	-0.205***
		(0.018)	(0.018)
Revenue_Growth		0.049***	0.048***
		(0.005)	(0.005)
GDP_Growth			0.066
			(0.048)
PM 2.5			-0.013
			(0.009)
Constant	0.099***	0.145***	0.188***
	(0.001)	(0.008)	(0.034)
Firm-fixed	Yes	Yes	Yes
City-fixed	Yes	Yes	Yes
Year-fixed	Yes	Yes	Yes
N	9,707	9,707	9,707
R^2	0.633	0.656	0.657

Note: The dependent variable is *SDebt*, measured as the debt in current liabilities divided by the book value of total assets. *Regu* is an indicator that equals to one if a firm is a regulated firm in China's regional ETS pilots. *Post* is an indicator that equals zero in 2010-2013 and one in 2014-2018. All standard errors in parentheses are clustered at the firm level. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3 Impact on Long-term Financing Leverage

Variables	LDebt	TDebt
	(1)	(2)
Regu × *Post*	0.002	-0.024***
	(0.006)	(0.008)
Controls	Yes	Yes
Firm-fixed	Yes	Yes
City-fixed	Yes	Yes
Year-fixed	Yes	Yes
N	9,568	9,568
R^2	0.681	0.688

Note: This table reports the results for the impact of China's regional ETS pilots on corporate long-term financial leverage. In column (1), the dependent variable is *LDebt*, calculated as the the book value of long-term debt divided by the book value of total assets. In column (2), the dependent variable is *TDebt*, calculated as the book value of long-term debt plus debt in current liabilities divided by the book value of total assets. *Regu* is an indicator that equals to one if a firm is a regulated firm in China's regional ETS pilots. *Post* is an indicator that equals zero in 2010-2013 and one in 2014-2018. All standard errors in parentheses are clustered at the firm level. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4 Results from a matched difference-in-differences model

Variables	SDebt		
	(1)	(2)	(3)
Regu × *Post*	-0.021**	-0.024***	-0.026***
	(0.009)	(0.009)	(0.009)
Controls	Yes	Yes	Yes
Firm-fixed	Yes	Yes	Yes
City-fixed	Yes	Yes	Yes
Year-fixed	Yes	Yes	Yes
N	5,816	6,652	7,188
R^2	0.674	0.670	0.670

Note: This table reports the regression results for propensity score matched difference-in-differences model. Column (1) - (3) use nearest-neighbor matching algorithms at ratios of 1:10, 1:15, and 1:20, respectively. The dependent variable is *SDebt*, measured as the debt in current liabilities divided by the book value of total assets. *Regu* is an indicator that equals to one if a firm is a regulated firm in China's regional ETS pilots. *Post* is an indicator that equals zero in 2010-2013 and one in 2014-2018. All standard errors in parentheses are clustered at the firm level. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 5 Heterogeneous Impacts

	Panel A: Free Quota		Panel B: Government Ownership		Panel C: Competitive Pressure	
	Yes	No	SOE	Non-SOE	Low	High
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Regu × *Post*	0.003	-0.034***	-0.019	-0.041***	-0.016	-0.037***
	(0.013)	(0.010)	(0.015)	(0.010)	(0.011)	(0.012)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	982	7,188	5,445	4,262	4,239	5,468
R^2	0.687	0.649	0.649	0.673	0.669	0.640

Notes: The dependent variable is *SDebt*, measured as the debt in current liabilities divided by the book value of total assets. *Regu* is an indicator that equals to one if a firm is a regulated firm in China's regional ETS pilots. *Post* is an indicator that equals zero in 2010-2013 and one in 2014-2018. In Panel A, a firm is classified into the free quota group if its headquartered in Shanghai, Chongqing, Fujian or Hubei, and a firm is classified into the non-free quota group if its headquartered in Guangdong, Shenzhen, Beijing, or Tianjin. In Panel B, we divide the full sample into two subsamples, namely, an SOE subsample and a non-SOE subsample. In Panel C, we use the Herfindahl-Hirschman Index (HHI) to proxy for product competition, calcualted as the sum of squared market share of all firms within the focal firm's industry. A firms with a HHI higher (lower) than the sample averages during 2011-2013 is included in the high (low) competitive group. All standard errors in parentheses are clustered at the firm level. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 6 Mechanism Analysis

	Emission Reduction Cost	R&D	Default	Debt Financing Cost
Variables	(1)	(2)	(3)	(4)
Regu × *Post*	0.006***	0.005***	0.047**	0.015**
	(0.002)	(0.001)	(0.020)	(0.006)
Controls	Yes	Yes	Yes	Yes
Firm Fixed	Yes	Yes	Yes	Yes
City Fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
N	9,513	8,057	9,707	7,109
R^2	0.761	0.827	0.669	0.572

Notes: In column (1), the dependent variable is *Emission Reduction Cost*, which is proxied by the administrative expense divided by lagged assets. In column (2), the dependent variable is *R&D*, which is measured by R&D expenditure divided by lagged assets. In column (3), the dependent variable is Altman *Z-scor*e, in which a lower *Z-score* implies a higher risk of default. In column (4), the dependent variable is *Debt Financing Cost*, calculated by the ratio of interest expenses divided by total liabilities. Standard errors in parentheses are clustered at the firm level. *, ** and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Appendix A: Description and definition of key variables

SDebt = the debt in current liabilities divided by the book value of total assets.

LDebt = the book value of long-term debt divided by the book value of total assets.

TDebt = the book value of long-term debt plus debt in current liabilities divided by the book value of total assets.

Size = logarithm of firm's total asset.

ROA = ratio of net profits over total assets.

Tangibility = fixed assets divided by total assets

Intangibles = intangible asset divided by total assets

Cash Flow = operating cash flow divided by total assets

Revenue Growth = growth rate of sales revenue

GDP Growth = city-level GDP growth

$PM_{2.5}$ = the concentration of $PM_{2.5}$ on the city level

Emission Reduction Cost = management expenses divided by lagged assets

R&D Investment = expenditure in research and development divided by lagged assets.

Z-score = the Altman Z-score, where a lower Z-score implies a higher risk of default.

Debt Financing Costs = the ratio of interest expenses divided by total liabilities.