Carbon liability risk, corporate governance, and corporate green policies: Evidence from China's National ETS program

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Abstract

We investigate whether firms with larger exposure to carbon liability risk adjust their green policies regarding investment and financing. We exploit the launch of China's national carbon trading market in 2017 as an exogenous shock to carbon liability risk and employ the difference-in-differences (DiD) design. Following an increase in carbon liability risk, firms in *ex ante* highly carbon-emission intensive industries engage in more green innovations and are more likely to issue green bonds. Such responses appear to be primarily motivated by corporate governance schemes in that these policies could be value-enhancing. Overall, our results suggest that carbon liability risk is critical in corporate decision-making.

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1 Introduction

Human emissions of heat-trapping greenhouse gases are causing climate change, contributing to the global burden of diseases and premature deaths. International cooperation is essential to combating climate change, and governments and regional alliances have put forth a series of environmental regulations and will continue to do so. For instance, in 2005, the European Union implemented the EU Emissions Trading System (EU ETS) to regulate carbon emissions in a variety of industries. To demonstrate their commitment to reducing carbon emissions, 196 Parties adopted the Paris Agreement at COP 21 in 2015. Tightening regulations to control carbon emissions are likely to impose substantial compliance costs and other payments on firms (Böhringer, Koschel, and Moslener, 2008), increasing the risk associated with carbon liability. Researchers have studied the physical risk of climate change, such as hurricanes (Dessaint and Matray, 2017; Massa and Zhang, 2021), and the policy risk of pollution or climate change (Nguyen and Phan, 2020; Bartram, Hou, and Kim, 2021; Dang, Gao, and Yu, 2022; Seltzer, Starks, and Zhu, 2022) on corporate capital structure and general financing decisions. In this paper, we focus on the carbon liability risk and examine how firms adjust their green policies in terms of investment and financing choices in response to the risk exposure to carbon liability.

It is empirically challenging to establish the causal relationship between business risk and firm behavior since there are issues of simultaneity and reverse causality. As argued by Gormley and Matsa (2011), the setting examining the real effects of business risk should serve as an exogenous shock to firms' expected future cash outflows but have a minimal impact on firms' current resources. In this paper, we use China's recent national ETS program as an exogenous shock to corporate carbon liability risk. In December 2017, the national ETS was announced, and its preparation took three years before it went into effect. This program presents a unique carbon liability risk. Specifically, prospective trading firms in the national ETS will pay for excessive carbon emissions above the threshold of its tradable performance standard (TPS), and the announcement of the national ETS, as an exogenous shock, increases the risk of future compliance payments and possible financial distress. However, the national ETS rules are unlikely to have much of an effect on firms' current cash flows that could influence corporate investment and financing during the preparation period. Accordingly, we can isolate the exogenous increase in firms' carbon liability risk. In addition, the launch of this program could have a differential effect on firms in industries with different *ex ante* levels of carbon emissions. As a result, to gauge the real effects of carbon liability risk, we can test whether green policies of firms in *ex ante* carbon-emission-intensive industries are adjusted after the announcement of the national ETS.

Our sample consists of all A-share-listed manufacturing, electricity and other utilities, mining, and construction companies on the Shanghai and Shenzhen stock exchanges, since these companies are the key emitters in China and have available carbon emission information. We then remove firms located in China's ETS pilot regions to avoid confounding estimations. We focus on three green policies: green innovation, green investment in construction work-in-progress (machines and buildings), and green bond issuance. According to recent literature, these policies are essential components of corporate sustainability strategies (Aghion, Bénabou, Martin, and Roulet, 2020; Cohen, Gurun, and Nguyen, 2020; Tang and Zhang, 2020; Flammer, 2021; Kim, Pantzalis, and Zhang, 2021). The national ETS was announced in December 2017 and its preparation period ends in January 2021. Our sample period therefore spans from 2013 to 2020 and we end up with a firm-year panel of 10,256 observations. Following Bertrand, Schoar, and Thesmar (2007), we employ the difference-in-differences (DiD) research design and examine treatment differences across sectors depend upon their *ex-ante* carbon emission intensity. We measure firms' exposure to the *ex-ante* carbon-emission-intensive environment using the average of total CO_2 emissions of firms in the industry during 2013-2017 (scaled between zero and one)[1] because the scale of emission matters more than the per unit emission from the regulatory and scientific perspectives.

We find that, when facing higher carbon liability risk, firms tend to engage in more green innovation which is measured as the ratio of green patents to total patents and the number of green patents. Green technology innovation may help to reduce carbon emissions, thereby lowering compliance payments and future carbon obligations (Ambec, Cohen, Elgie, and Lanoie, 2013). It could also help to achieve long-term environmental goals and maintain corporate competitiveness (Aghion, Dechezleprêtre, Hemous, Martin, and Van Reenen, 2016). However, these are generally costly to the firm since they require organizational changes that are complex in nature (Amore and Bennedsen, 2016). There is little change in green investment in construction projects in progress that are more short-term focused and require fewer managerial efforts. We also document that the exposed firms are more likely to issue green bonds, a new practice in finance of which proceeds are committed to finance environmental

[1] In our robustness test, we also use the average of total CO_2 emissions scaled by the total assets of firms in a particular industry between 2013 and 2017 as a proxy for carbon intensity. Because total production information is not available in CSMAR after 2011, we do not use total production output as the scaling factor.

and climate-friendly investments. Green bonds may serve as a credible indication of firms' commitment to environmental goals (Flammer, 2021) and are issued at a premium to otherwise similar ordinary bonds (Baker, Bergstresser, Serafeim, and Wurgler, 2018). On the other hand, such adjustments in green financing policies could lead to an increase in leverage ratios and a worsening of liability risks for firms. So far, stylized evidence suggests that a firm's exposure to carbon liability risk leads to increased managerial efforts and costly but long-term oriented actions in order to reduce carbon emissions, thus reducing future compliance obligations.

Next, we explore how firms' responses to increased carbon liability risk are related to corporate governance. There are two competing theories that predict the increase in managerial efforts. The classic principal-agency model posits that exposing a firm's managers to business risks could motivate them to work harder and exert greater efforts to improve overall firm value and efficiency and then benefit shareholders (Holmström, 1979; Grossman and Hart, 1983). For the adjustment in green policies to benefit shareholders, the avoided compliance costs should be greater than the potential costs of green innovation and green bonds. Conversely, the risk-related agency theory predicts that managers will increase their efforts to avoid the personal costs associated with carbon liability when large cash outflows and poor performance in the future may threaten their employment and reputation as environmental stewards. We then examine whether the green policies are in line with shareholders' interests. We first find that announcement returns associated with green bond issuance are positive and that green policies add value to shareholders. Further analysis reveals that firms with lower management ownership, more institutional shareholdings, and a more independent board are more likely to respond to carbon liability risk by increasing green innovation and issuing green bonds. These results demonstrate that managers' actions are motivated by the goal of maximizing shareholder value and that corporate governance schemes guide them in addressing long-term environmental problems and mitigating carbon liability risk.

Furthermore, we conduct a cross-sectional analysis to investigate whether there is heterogeneity in the effect of carbon liability risk on corporate green policies. First, we focus on ownership structure and argue that government control of state-owned enterprises (SOEs) entitles them to inherent political connections. Due to these connections, SOEs have easier access to resources (Allen, Qian, and Qian, 2005; Scott, 2005; Li, Cui, and Lu, 2014), less severe consequences of failure (Faccio, Masulis, and McConnell, 2006), and greater opportunities to communicate with regulators. We find that SOEs exposed to higher carbon liability risks are more likely to engage in green innovation and issue corporate green bonds. In addition, we investigate whether greater public exposure exacerbates undesirable costs associated with carbon liability risks. An increase in public attention intensifies external scrutiny and exacerbates the consequences of firms not exerting themselves (Dyreng, Hoopes, and Wilde, 2016). When facing more public attention, companies with carbon liability risks are more likely to modify their green policies to reduce carbon footprints. Moreover, we present evidence that young life cycle firms that are more susceptible to uncertainties and adverse consequences (Allen, Lewis-Western, and Valentine, 2022) suppress green innovation and green bond issuance.

In robustness tests, we take into account regional differences in corporate carbon-emitting behavior and find that the baseline results are generally robust to a more granular measure of carbon liability risks. Our baseline results remain robust when we use the asset-scaled measure of corporate carbon emission intensity to proxy for firms' exposure to carbon liability risks. Additionally, we examine whether electricity firms behave differently from others due to less policy uncertainty regarding the timing of inclusion. The evidence shows that electricity companies perceive greater carbon liability risks than other prospective firms and make greater efforts to promote green innovation and green bond issuance.

Our study contributes to the growing literature on how firms manage business risks or, more specifically, business risks related to climate change. In previous studies, it has been demonstrated that companies adjust their capital structure, investment decisions, and financing decisions in response to corporate idiosyncratic risk (Panousi and Papanikolaou, 2012; Jagannathan, Matsa, Meier, and Tarhan, 2016), takeover pressure (Servaes and Tamayo, 2014; Gormley and Matsa, 2016), and financial burden (Gormley and Matsa, 2011). Recent years have seen an increase in climate-change-related business risks due to their negative impacts on corporations, clients, suppliers, and institutional investors (Daniel, Litterman, Wagner, 2016; Baker et al., 2018; Ilhan, Krueger, Sautner, and Starks, 2021). Several strands of the literature examine the impact of physical climate risks (Dessaint and Matray, 2017; Massa and Zhang, 2021) on firm decisions, while a few papers investigate the regulatory risks associated with climate change and pollution (Delis, de Greiff, and Ongena, 2019; Dang et al., 2022). Our study adds to the literature on the policy risk associated with climate change by focusing on the carbon liability risk as a result of increasingly strict regulations. Our experiment, which affects firms' future carbon obligations but not their current cash flows, allows us to isolate the effects of carbon liability risk on firm decisions.

Additionally, we contribute to the literature by providing new evidence on corporate governance schemes and firm value in an era of frequent extreme weather events and volatile natural environments. The results demonstrate that green policies are generally beneficial to shareholders and that the treatment effects are more pronounced in firms with smaller management ownership, an increased involvement of professional investors, and a board with more independent directors. Our findings suggest that such responses to climate-change-related risk are unlikely to result from risk-related agency conflicts (Gormley and Matsa, 2011). In order to address long-term climate issues troubling the firm, corporate governance regimes instruct managers to prioritize shareholder value over their private interests.

Our paper is also related to the debate regarding the effectiveness of China's ETS. Cao, Ho, Ma, and Teng (2021) argue that China's ETS pilot program failed to induce regulated power plants to improve their coal efficiency. The significant reduction in coal consumption is achieved by reducing the electricity generated by the plant. However, Cui, Zhang, and Zheng (2021) find that the ETS pilot program encourages firms to adopt climate-friendly technologies. Carbon market rules differ significantly among the eight pilot regions, and the pilot program provides valuable experience into the design and implementation of a national ETS. In this paper, we focus on the effectiveness of the national ETS and explore the differential changes among firms in industries with different *ex ante* levels of carbon emission intensity. We show that the announcement of the national ETS encourages managers to reduce carbon emissions and provide new evidence of the effectiveness of the ETS in China.

The remainder of the paper proceeds as follows. Section 2 introduces the institutional background and Section 3 shows the research design and descriptive statistics. Section 4 presents the empirical results and Section 5 contains the robustness tests. Section 6 concludes the paper.

2 Institutional Background

The frequent occurrence of extreme weather events like droughts and floods causes economic loss, and regulations aimed at reducing carbon emissions become increasingly important to economic stability and growth (Bank of England, 2019). As a result of its rapid development, China became the world's second largest economy[2] and the world's largest emitter of carbon dioxide (CO_2). During the 2009 United Nations Climate Change Conference in Copenhagen, China demonstrated its commitment to reducing carbon emissions, and a series of environmental regulations have been implemented since then. China's Emissions Trading System (ETS) program was first introduced in 2011. Unlike the EU ETS using the cap and trade (C&T) system, China's ETS is a tradable performance standard (TPS) program (Goulder, Long, Lu, and Morgenstern, 2019; Cui et al., 2021). While a C&T program sets a cap on total emissions, a TPS program is a market-based instrument that sets benchmarks for emitters' carbon emission intensity and allows them to trade allowances[3]. While there are heated debates comparing the relative effectiveness of different ETS programs, the general consensus is that ETS programs impose higher compliance costs on firms with more carbon emissions.

The development of China's ETS can be divided into two phases. China's ETS pilot program was announced by the National Development and Reform Commission (NDRC) in 2011 and gradually came into force across eight regions including Beijing, Shanghai, Tianjin,

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[2] Source: World Bank 2018 data.

[3] C&T policies assign a positive price to all carbon emissions. TPS puts a price only on carbon emissions above the threshold. The focus of this paper is on the real effects of increasingly tightening carbon policies instead of comparing the relative effectiveness of C&T and TPS.

Chongqing, Guangdong, Hubei, Shenzhen, and Fujian between 2013 and 2016. Each pilot can customize its carbon market rules, including covered sectors, emission targets, regulatory status, allowance allocation, monitoring, reporting, and compliance (Zhang, Karplus, Cassisa, and Zhang, 2014). For example, steel (cement) firms were not included in two (three) out of seven ETS pilots (Cui et al., 2021). In terms of the regulatory status of an entity, Shanghai, Tianjin, and Chongqing set the threshold of annual emissions at 20kt carbon emissions while Shenzhen adopts a lower bar of 3kt. The effectiveness of the ETS pilot program has been questioned by some studies, along with the notion that it is market-driven. According to Cao et al. (2021), firms reduce their carbon emissions by reducing production instead of improving efficiency, and the effects of the pilot program are in fact influenced by local government intervention. Throughout all pilots, most firms are in compliance with carbon market rules, and noncompliance may result in financial penalties, deduction of allocated emission allowances, and a record on the business credit report. The pilot program could serve as an experiment to test the effectiveness of the TPS-based ETS and lay the foundation for a national ETS.

The national ETS was announced in December 2017 and goes into effect in January 2021 after a three-year preparation period. The national ETS would initially include companies in the electricity industry and then gradually expand to include firms in other heavy carbon-emitting industries. The national ETS provides a larger market for carbon allowance trading. The cumulative amount of carbon allowances traded in the seven pilots between 2013 and November 2017 is approximately 200 million tons of CO_2, whereas electricity firms, as the first batch to be included in the national ETS, have emitted approximately 4.1 billion tons in 2017 (Caixin Weekly, 2021). In addition, all trading firms in the national ETS are subject to a consistent set of rules, which eliminates differences existing among regional pilots' customized rules. That is, compared to the pilot program involving more local government intervention, the national ETS shifts responsibility for reducing carbon emissions from the government to firms, resulting in a decreased need for the government to balance between economic growth and carbon reduction.

With the development of the national ETS over a three-year period, the expected compliance payments related to carbon emissions have increased, raising the risk of a carbon liability for the firm in the future. While in preparation, the national ETS has a negligible impact on firms' current cash flows and resources. Our empirical strategy can therefore take advantage of the three-year preparation from 2018 to 2020 as a test window to examine the real causal effects of firms' exposure to carbon liability risk on corporate behaviors.

3 Empirical Setting

3.1 The difference-in-differences estimation methodology

Despite the fact that the national ETS represents an economy-wide shock, we anticipate that it will have a greater impact on firms in industries that are more carbon-emission-intensive *ex ante*. In order to isolate the impact of carbon liability risk on firms' green policies, we examine the differential changes across industries based on carbon emission intensity. Our approach follows Bertrand et al. (2007) who study the effects of bank deregulation in France and examine post-treatment differences across sectors depending on their reliance on bank finance. Specifically, we use the following equation for baseline analyses:

$$Green\ policy_{it} = \alpha + \beta CO2(ind)_i \times ETS_t + \gamma Controls + \delta_i + \theta_j + \lambda_t + \varepsilon_{it}$$

where i, t, and j denote firms, years, and provinces, respectively. To identify firms with higher carbon liability risk arising from the exposure to the national ETS, we construct the variable *CO2(ind)* to measure the extent to which the firm is exposed to the *ex-ante* carbon-emission-intensive environment. *CO2(ind)* is defined as the average of total CO_2 emissions of all firms in the industry to which the firm belongs during 2013-2017 and then scaled between zero and one. The dummy variable, *ETS*, takes the value of one if the year is equal to or greater than 2018, and zero otherwise. Among the firm characteristics we control are size, leverage, age, profitability, intangible assets, and sales. These control variables are measured in year *t-1* and winsorized at the 1% and 99% levels. The regression model also includes firm fixed effects δ_i, province fixed effects θ_j, and year fixed effects λ_t. Firm fixed effects could control for any time-invariant heterogeneity across firms that may affect green policies. Province fixed effects control for any time-invariant province-level features. Year fixed effects λ_t account for national economic conditions. In place of province and time fixed effects, we include province-by-year fixed effects γ_{jt} to control for time-varying heterogeneity within each province. Standard errors are clustered at the industry level.

As for our dependent variables, we consider three corporate green policies with respect to investment and financing choices.

Green Innovation. It is an important component of corporate green investment policies and is usually measured by green patents (Popp, 2002; Calel and Dechezleprêtre, 2016). The green patent can be identified by the International Patent Classification (IPC) Green Inventory code of the World Intellectual Property Organization (WIPO) and is classified as either a green invention patent or a green utility model patent. It has been suggested that green technology can reduce carbon emissions, reduce compliance costs due to fewer allowances being required, and increase revenue through the sale of excess emission allowances (Ambec et al., 2013). In addition, it is imperative that technological innovations be used to address long-term environmental problems, create a sustainable environment, as well as increase productivity and competitiveness because they could have a profound impact on the entire corporate innovation trajectory (Aghion et al., 2016). Furthermore, green patents may generate positive externalities at the national and industry levels through technological spillovers (Amore and Bennedsen, 2016). Green innovation, however, generally requires changes in the research department, introduction of new methods, and an increase in managerial efforts. Companies may hesitate to leverage such changes if they are comfortable with their current business models. In this paper, we use both the intensive margin and the extensive margin to measure green innovation. *Green Innovation Ratio* is defined as the number of green invention patent applications in the company divided by the total number of patent applications, measuring the extent to which a company has focused on high-quality green innovation. We also use *Green Innovation Quantity*, which is defined as the natural logarithm of one plus the number of green invention patent applications to measure a firm's general efforts in green innovation.

Green Investment in construction work-in-progress. In response to carbon liability risk, the company could also invest in equipment and buildings for emissions control and monitoring and adjust their production processes accordingly. Adopting such policies may have immediate effects and reduce emissions in the near term. However, this type of investment may lower the incentive for inherently uncertain innovation (Rogge, Schneider, and Hoffmann, 2011), limiting the opportunity and capital required for firms to address the long-term climate change challenge systematically. We define *Green Investment* as the natural logarithm of one plus the amount invested by the firm in green construction work-in-progress.

Green Bonds. A green bond is a fixed income security that funds environmental and climate-friendly projects. Apple, for example, issued a $4.7 billion green bond on March 29, 2022, in order to support green technologies that reduce the company's carbon footprint. The study by Flammer (2021) shows that corporate green bond issuers actually deliver on what they promise, and green bonds could be value-enhancing. However, green bonds can also be used for greenwashing, in which companies portray an image of environmental responsibility while not fulfilling their commitments. The motivation for greenwashing and the resulting higher leverage ratio do not serve shareholders' best interests. In this paper, we define *Green Bond* as a dummy variable which equals one if the firm has issued green bonds in a certain year, and zero otherwise.

3.2 The sample

To begin with, we examine all A-share companies listed on the Shanghai and Shenzhen stock exchanges in the CNRDS database. The screening procedure is as follows. Since the preparation period for the national ETS lasts for three years, we set the pre-treatment period as 2013-2017 and the post-treatment period as 2018-2020. We exclude firms located in the eight pilot regions since they were affected by the ETS pilot program during the pre-treatment period. These pilot regions include Beijing, Shanghai, Tianjin, Chongqing, Guangdong, Hubei, Shenzhen, and Fujian. Then, we retain firms in the manufacturing, electricity and other utilities, mining, and construction sectors in light of the availability of carbon emission data in the

CEADs database and the fact that these sectors are the key emitters of carbon emissions in the Chinese economy (Shao, Liu, Geng, Miao, and Yang, 2016; Lu, Feng, Liu, Wang, Lu, and Wang, 2020; Cui et al., 2021). These covered sectors are represented by forty-one two-digit industry codes in the 2012 China Securities Regulatory Commission (CSRC) industry classification system. We keep observations with positive total assets and sales and exclude those with missing information on key variables. We also use the CSMAR database to supplement firm characteristics. We extract green innovation and green bonds data from the CNRDS database and green investment data from the CSMAR database. The final sample for baseline analyses consists of 10,256 firm-year observations.

3.3 Descriptive statistics

Table 1 presents descriptive statistics for key variables. The mean values of *Green Innovation Ratio*, *Green Innovation Quantity*, *Green Bond*, and *Green Investment* are 0.0359, 0.5790, 0.0028, and 11.4599, respectively, suggesting that green innovation and corporate green bonds are relatively emerging. There are a 0.0598 mean value of *CO2(ind)* and a 0.1837 standard deviation, indicating that firms in certain industries are much more exposed to an *ex ante* carbon-emission-intensive environment and therefore have a greater carbon liability risk. The mean value of *Size* is 22.0630 and *Leverage* has an average value of 0.4186, which is similar to prior literature (e.g., Chang, Pan, Wang, and Zhou, 2021). On average, firms are 17.7207 years old and have a return on equity of 4.93%.

[Insert Table 1 here]

4 Empirical Results

4.1 Baseline regressions

In this section, we analyze how firms respond to the increase in carbon liability risk by adjusting their corporate green policies. We illustrate the results in Table 2. Our study shows that firms put more effort into green innovation when they face greater carbon liability risks. The estimate for *Green Innovation Ratio*, reported in column (1), indicates that the exogenous increase in carbon liability risk is associated with redirection to high-quality green innovation for firms in *ex ante* more carbon-emission-intensive industries. The effect is both statistically and economically significant. For example, following the launch of the national ETS, a one-standard-deviation increase in *CO2(ind)* is associated with 0.24% increase in a typical firm's green innovation ratio, which amounts to a 6.80% increase in ratio for the sample mean. It is important to note that our results are robust to the interaction of province and year fixed effects (reported in column (2)). The high-dimensional fixed effects could help us to control for unobservable time-varying differences across provinces and ensure that our difference-in-differences estimates are robust to various types of unobservable omitted variables that might bias our estimation. We also find that, in columns (3) and (4), the number of patent applications filed by these firms also increases. However, we find that green investments in construction work-in-progress remain unchanged around the launch of the national ETS, suggesting that *ex ante* carbon-emission-intensive firms are not strictly making capital investment to reduce carbon liability risk but sparing no efforts in technological innovation which is crucial to addressing long-term climate change problems.

To shed some light on how companies fund green innovation activities, we study the effect of carbon liability risk on issuance of green bonds. As for regressions with fixed effects and binary outcome variables, we adopt the linear probability model instead of non-linear models such as Logit models because they only produce consistent estimates under strong and unrealistic assumptions (Wooldridge, 2010). The results are illustrated in columns (7) and (8) of Table 2. We find that firms in *ex ante* more carbon-emission-intensive industries are more likely to fund their innovations with green bonds. The probability of issuing green bonds increases by 5.14% on average after the rise in liability risk, and this increase is statistically significant at the 1% level. At first glance, it may seem odd that companies issue bonds in response to the increase in liability risk. A closer look at the next section reveals that this average response obscures heterogeneity and that some firms are more likely to do so than others. Overall, the results suggest that firms tend to take costly but long-term oriented actions in response to the exogenous increase in carbon liability risk.

[Insert Table 2 here]

The key assumption in the difference-in-differences estimation is the parallel trend assumption: the timing of the increase in green policies coincides with the increase in carbon liability risk. To establish causality, we adopt a "leads and lags" model described by Bertrand and Mullainathan (2003) to determine how the treatment effect evolves over time. We replace variable *ETS* in Eq. (1) with five indicator variables: *year2015* (-2) for the year 2015, *year2016* (-1) for the year 2016, *year2018* (+1) for the year 2018, *year2019* (+2) for the year 2019, and *year2020* (+3) for the year 2020[4]. Figure 1 plots the point estimates and there is no indication

4 The national ETS is announced in the end of 2017, and we exclude the transition year. When we include the year 2017 as well, we find consistent time dynamics.

of a change in green innovation and green bond issuance prior to the increase in carbon liability risk. Afterward, firms exposed to greater carbon liability risk tend to boost their green innovation and issue green bonds more frequently than others. The precise timing of the changes in green policies suggests that they are primarily a consequence of the increase in carbon liability risk rather than omitted variables from company or industry characteristics. Additionally, the time-series dynamics confirm that our findings are robust to the choice of an examination period and that the shock is exogenous.

To further alleviate the concern that the baseline results are driven by unobservable heterogeneity before the announcement of the national ETS, we conduct a placebo test by setting the pseudo shock two years earlier than the actual one. We then re-estimate Eq. (1) with firm fixed effects and province-by-year fixed effects and the results are reported in Table 3. Our results suggest that the pseudo-event has no significant impact on corporate green policies. The results of the placebo test alleviate the concern that the baseline results are driven by random shocks.

[Insert Table 3 here]

4.2 Connection with corporate governance

In this section, we examine whether firms' responses to the increase in carbon liability risk are related to corporate governance. When facing an increased risk of carbon liability that would raise firms' future compliance payments and negatively impact future cash flows, firms tend to undertake costly actions to reduce the risk. There are competing theories for the finding. On the one hand, when compliance payments are high and financial distress is likely, there is a general increase in managerial efforts to benefit shareholders and implement green policies. That is, to benefit shareholders, the avoided compliance costs should outweigh the potential costs of innovation and green bonds. Managerial efforts to benefit shareholders are more likely to increase when managers have fewer personal interests in the company. In light of this, we conjecture that the effect of carbon liability risk on corporate green policies is more pronounced in firms with lower management ownership and stronger corporate governance. In contrast, risk-related agency theory suggests that managers have a vested interest in ensuring their career and personal wealth against the company. This specific agency problem is exacerbated when managers have a larger portion of their wealth tied to the value of firms' assets (Parrino and Weisbach, 1999). As a result, they have skin in the game and are motivated to invest in costly measures to reduce the firm's risk for its long-term survival and their private benefits (Jensen and Meckling, 1976; Amihud and Lev, 1981; Smith and Stulz, 1985; Holmström, 1999; Gormley and Matsa, 2011). In this regard, carbon liability risk would have a greater impact on corporate green policies in companies with higher management ownership and weaker corporate governance.

In order to explore these interpretations, we first conduct an event study of the green bond issuance announcement. We apply the market model and calculate the cumulative abnormal returns (CAR) over the [-5, 5] window. After splitting the sample by whether the firm belongs to an industry with an above-median *CO2(ind)* value, we then sort each subsample into the before- and after-treatment subgroups. The results are reported in Table 4. The average CAR of all issuances is 2.44% and is significant at the 10% level (untabulated). We find that the raw difference-in-differences CAR estimate is around 3.89% and significant at the 10% level. The positive stock market reaction suggests that investors interpret this news positively and anticipate companies' commitment, particularly those with greater exposure to carbon liability risks.

[Insert Table 4 here]

Next, we conduct cross-sectional tests to distinguish between competing theories. We collect management shareholding data from the CNRDS database and construct the dummy variable *Manager Shareholding* which equals one if managers' shareholding of the firm is above the sample median in year *t-1*, and zero otherwise. Furthermore, institutional investors who own a block of shares in the company can mitigate the agency problem by monitoring the management (Shleifer and Vishny, 1986). We extract institutional holding data from the CNRDS database and define *Fund Shareholding* as a dummy variable equal to one if the funds' shareholding of the firm exceeds the sample median in year *t-1*, and zero otherwise. As a final point, a more independent board helps control agency conflicts more effectively and cultivates stronger corporate governance (Rosenstein and Wyatt, 1990). Based on data from the CNRDS database, we construct the dummy variable *Ratio of Independent Directors* which equals one if the firm's ratio of independent directors is above the median in year *t-1*, and zero otherwise.

Table 5 shows the cross-sectional differences in the firm's green policy response with respect to different sorting variables. In Panel A of Table 5, firms with lower management ownership are more likely to invest in green technology and issue green bonds to acquire capital. In contrast, firms with a higher level of management ownership tend to be less innovative and may even avoid green innovations. Panels B and C show that firms with higher institutional ownership and more independent boards engage in more green innovation and green bond issuance to mitigate carbon liability risks. Following Cleary (1999), we perform the permutation test (1,000 times) and obtain the empirical *p*-value that indicates the significance of differences in coefficient estimates between two groups. Our empirical *p*-values imply that the subsample difference is significant at least at the 10% level.

Collectively, the event study and corporate governance results suggest that the adjustment to corporate green policies of liability-risk-exposed firms could be driven by shareholders' interests instead of risk-agency conflicts. Our results reveal that corporate governance schemes play a vital role in firms' responses to the risk of carbon liability. Firms tend to implement more policies that address long-term environmental problems, reduce carbon emissions, and alleviate the burden of compliance costs when stronger corporate governance is in place and managers' private benefits are less of a concern.

[Insert Table 5 here]

4.3 Additional cross-sectional analysis

The purpose of this section is to explore more conditions under which the treatment effects could vary. Specifically, we analyze three factors: ownership structure, public attention, and corporate life cycle stage.

4.3.1 Ownership structure

Ownership concentration is prevalent in Chinese listed firms (Jiang and Kim, 2020) and the government being the controlling shareholder renders SOEs inherent political connections. Due to these connections, SOEs have easier access to resources (Allen et al., 2005; Scott, 2005;

Li et al., 2014) and are more likely to be bailed out when failure occurs (Faccio et al., 2006). Innovation requires tremendous inputs of resources and a high tolerance for failure (Tian and Wang, 2014) and therefore we propose that SOEs with higher carbon liability risks are more likely to engage in green innovation. Furthermore, while corporate green bonds require regulatory approval, strict scrutiny could result in a shortage of regulatory staff. SOEs' inherent political connections increase communications with and reduce information costs for the regulators (Wong, 2016), which might speed up the approval process. Thus, we propose that SOEs with greater exposure to carbon liability risks are more likely to succeed in issuing green bonds.

We divided the sample according to the firm's ownership structure. The results are presented in Table 6. The treatment effects are primarily concentrated in the group of SOEs across three green policy variables. Our findings thus reveal that ownership structure matters for the relationship between the firm's exposure to carbon liability risk and green policies. Easier access to resources, less severe consequences of failure, and more opportunities of communications may stimulate liability-risk-exposed SOEs to adjust their green policies.

[Insert Table 6 here]

4.3.2 Public attention

ETS has sparked intense discussions on climate change among policymakers, investors, corporate executives, and academics. Increasing public attention leads to stricter external scrutiny, and firms that do not strive to reduce carbon emissions could aggravate the public and suffer significant reputational damage. Public attention exerts pressure on firms (Dyck and

Zingales, 2002) and alters the costs associated with undesirable behaviors (Dyreng et al., 2016). As a result, a company attracting more public attention becomes more aware of its reputation as being green and may invest in green technology and issue green bonds in an attempt to reduce carbon emissions. To proxy for external attention, we extract web search volume index data from the CNRDS database, and it is constructed based on corporate name and ticker conducted through the main Chinese search engines such as Baidu. The sorting dummy variable, *WSVI*, equals one if the firm's web search volume index is above the median in year *t-1,* and zero otherwise. We separate the sample according to *WSVI* and re-estimate Eq. (1) for each subsample. The results are presented in Table 7. The treatment effects are most evident in the subsample with higher external attention, suggesting that in the presence of greater external attention, firms with a higher carbon liability risk invest more in high-quality green innovation.

[Insert Table 7 here]

4.3.3 Young life cycle firms

Corporate life cycle stage is an important determinant of corporate innovation. Allen et al. (2022) suggest that young firms are more vulnerable to the adverse effects of innovation and are more likely to reduce their innovation efforts. As a result of their vulnerability and resource limitations, young life cycle companies with higher carbon liability risks are less likely to engage in green innovation and therefore have less need for green bonds. In light of this, carbon liability risk should mainly influence corporate green policies for non-young life cycle companies.

We identify young life cycle (YLC) firms using the variable *Young Life Cycle*. *Young Life Cycle* is a dummy variable that equals one if the firm is in the young life cycle stage in year *t-1*, and zero otherwise. A young life cycle firm, as defined by Dickinson (2011) and Allen et al. (2022), has negative operating cash flows, negative investing cash flows, and positive financing cash flows. We divide the sample based on the sorting variable *Young Life Cycle* and conduct subsample tests. Table 8 presents the results. The treatment effects are concentrated in the non-YLC firms. Non-YLC firms in the *ex-ante* carbon-emission-intensive environment invest in green innovation and finance through green bonds, while YLC firms suppress these investment and financing activities.

[Insert Table 8 here]

5 Robustness Tests

As regional characteristics are also important determinants of carbon emissions, we incorporate regional factors and develop a framework to account for industrial and provincial differences in corporate carbon emissions. *CO2(indprov)* is defined as the average of total CO_2 emissions of all firms in a particular province and a particular industry during 2013-2017 and then scaled between zero and one. We re-estimate Eq. (1) with different sets of fixed effects. Panel A of Table 9 presents the results. Most of our treatment effect estimates remain positive and significant. The baseline results are robust when regional differences in corporate carbon-emitting behavior are taken into account.

Furthermore, we employ an alternative measure of firms' exposure to carbon liability risk. *CO2(ind)_PA* is defined as the average of total CO_2 emissions of all firms in an industry for

2013-2017 divided by the average of total assets of these firms during this period. Panel B of Table 9 presents the results. The treatment effects are significantly positive at the 1% level, suggesting that the baseline results of green innovation and green bonds are robust to the alternative measure of the exposure to carbon liability risk.

Electricity companies are the first batch to be included in the national ETS and are prone to a greater risk of carbon liability than companies in other prospective industries due to less policy uncertainty regarding the timing of inclusion. In response to more apparent carbon liability risks, we expect that companies in the electricity industry will be more incentivized to engage in green innovation and use more green bonds. We use a dummy variable to identify electricity firms in the sample and replace *CO2(ind) * ETS* in Eq. (1) with *Electricity * ETS*. Panel C of Table 9 presents the results. The treatment effect coefficients in all columns are positive and significant, suggesting that compared with other industries, electricity companies are more likely to engage in green innovation and issue green bonds since they face an apparent increase in carbon liability risk.

[Insert Table 9 here]

6 Conclusion

To examine the effect of carbon liability risk on corporate green policies, we use the national ETS as a quasi-natural experimental setting. Trading firms in the national ETS have to pay for excess carbon emissions, which causes potential cash outflows and increases the likelihood of poor performance and financial difficulties in the future. A greater carbon liability risk exposure is associated with higher ratios and quantities of high-quality green innovation and more usage of green bonds by firms. The results satisfy the parallel trend assumption and are robust to the placebo test and alternative measures.

Furthermore, we explore the possible mechanism through which carbon liability risk affects the green policies of firms. As a first step, we demonstrate that the market responds positively to announcements of the issuance of green bonds, suggesting that corporate green bonds may benefit shareholders. We also find that corporate governance plays a crucial role in inducing managerial efforts and adjusting corporate green policies when firms are exposed to greater risks associated with carbon liability. In particular, we find that firms with lower management ownership, higher professional investor ownership, and a more independent board may improve corporate governance and have more proactive responses to the increasing carbon liability risk. Moreover, the treatment effects are more pronounced for SOEs, firms that receive greater public attention, and firms that are not in the early stage of their development.

Overall, this paper provides a novel insight into corporate behaviors as a result of business risk exposure by considering an intriguing and previously unexplored source of risk - carbon liability risks. We highlight the role that corporate governance schemes play in the current era of climate change. The results of our study have direct implications for policymakers, particularly those in carbon-emitting economies, who seek to embrace the ETS as a means to control carbon emissions.

References

Aghion, P., Bénabou, R., Martin, R., & Roulet, A. (2020). Environmental preferences and technological choices: Is market competition clean or dirty? (No. w26921). National Bureau of Economic Research.

Aghion, P., Dechezleprêtre, A., Hemous, D., Martin, R., & Van Reenen, J. (2016). Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry. *Journal of Political Economy*, *124*(1), 1-51.

Allen, A., Lewis-Western, M. F., & Valentine, K. (2022). The innovation and reporting consequences of financial regulation for young life-cycle firms. *Journal of Accounting Research*, *60*(1), 45-95.

Allen, F., Qian, J., & Qian, M. (2005). Law, finance, and economic growth in China. *Journal of financial economics*, *77*(1), 57-116.

Ambec, S., Cohen, M., Elgie, S., & Lanoie, P. (2013). The Porter Hypothesis at 20: Can environmental regulation enhance innovation and competitiveness?. *Review of Environmental Economics and Policy*, *7*(1), 2-22.

Amihud, Y., & Lev, B. (1981). Risk reduction as a managerial motive for conglomerate mergers. *The Bell Journal of Economics*, 605-617.

Amore, M. D., & Bennedsen, M. (2016). Corporate governance and green innovation. *Journal of Environmental Economics and Management*, *75*, 54-72.

Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). Financing the response to climate change: The pricing and ownership of US green bonds (No. w25194). National Bureau of Economic Research.

Bank of England, B, 2019. "Climate change: what are the risks to financial stability?," Discussion paper. https://www.bankofengland.co.uk/knowledgebank/climate-change-what-are-the-risks-to-financial-stability.

Bartram, S., Hou, K., & Kim, S. (2021). Tackling climate change requires global policies. *Combatting Climate Change: a CEPR Collection*.

Bertrand, M., & Mullainathan, S. (2003). Enjoying the quiet life? Corporate governance and managerial preferences. *Journal of political Economy*, *111*(5), 1043-1075.

Bertrand, M., Schoar, A., & Thesmar, D. (2007). Banking deregulation and industry structure: Evidence from the French banking reforms of 1985. *The Journal of Finance*, *62*(2), 597-628.

Böhringer, C., Koschel, H., & Moslener, U. (2008). Efficiency losses from overlapping regulation of EU carbon emissions. *Journal of regulatory economics*, *33*(3), 299-317.

Caixin Weekly, 2021. Available at: https://weekly.caixin.com/2021-01-23/101654673.html

Calel, R., & Dechezleprêtre, A. (2016). Environmental policy and directed technological change: evidence from the European carbon market. *Review of economics and statistics*, *98*(1), 173-191.

Cao, J., Ho, M. S., Ma, R., & Teng, F. (2021). When carbon emission trading meets a regulated industry: Evidence from the electricity sector of China. *Journal of Public Economics*, *200*, 104470.

Chang, Y., Pan, X., Wang, J., & Zhou, Q. (2021). Depoliticization and corporate cash holdings: Evidence from the mandated resignation of directors in China. *Journal of Corporate Finance*, *69*, 102004.

Cleary, S. (1999). The relationship between firm investment and financial status. *The Journal of Finance*, *54*(2), 673-692.

Cohen, L., Gurun, U. G., & Nguyen, Q. H. (2020). The ESG-innovation disconnect: Evidence from green patenting (No. w27990). National Bureau of Economic Research.

Cui, J., Zhang, J., & Zheng, Y. (2021). The impacts of carbon pricing on firm competitiveness: Evidence from the regional carbon market pilots in China. *Available at SSRN 3801316*.

Dang, V. A., Gao, N., & Yu, T. (2022). Climate policy risk and corporate financial decisions: Evidence from the NOx budget trading program. *MANAGEMENT SCIENCE*. https://doi.org/10.2139/ssrn.3677004

Daniel, K. D., Litterman, R. B., & Wagner, G. (2016). Applying asset pricing theory to calibrate the price of climate risk (No. w22795). National Bureau of Economic Research.

Delis, M. D., de Greiff, K., & Ongena, S. (2019). Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans *(September 10, 2019). EBRD Working Paper*, (231).

Dessaint, O., & Matray, A. (2017). Do managers overreact to salient risks? Evidence from hurricane strikes. *Journal of Financial Economics*, *126*(1), 97-121.

Dickinson, V. (2011). Cash flow patterns as a proxy for firm life cycle. *The accounting review*, *86*(6), 1969-1994.

Dyck, A., & Zingales, L. (2002). The corporate governance role of the media.

Dyreng, S. D., Hoopes, J. L., & Wilde, J. H. (2016). Public pressure and corporate tax behavior. *Journal of Accounting Research*, *54*(1), 147-186.

Faccio, M., Masulis, R. W., & McConnell, J. J. (2006). Political connections and corporate bailouts. *The journal of Finance*, *61*(6), 2597-2635.

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, *142*(2), 499-516.

Gormley, T. A., & Matsa, D. A. (2011). Growing out of trouble? Corporate responses to liability risk. *The Review of Financial Studies*, *24*(8), 2781-2821.

Gormley, T. A., & Matsa, D. A. (2016). Playing it safe? Managerial preferences, risk, and agency conflicts. *Journal of financial economics*, *122*(3), 431-455.

Goulder, L. H., Long, X., Lu, J., & Morgenstern, R. D. (2019). China's unconventional nationwide CO_2 emissions trading system: The wide-ranging impacts of an implicit output subsidy (No. w26537). National Bureau of Economic Research.

Grossman, S. J., & Hart, O. D. (1983). Implicit contracts under asymmetric information. *The Quarterly Journal of Economics*, 123-156.

Holmström, B. (1979). Moral hazard and observability. *The Bell journal of economics*, 74-91.

Holmström, B. (1999). Managerial incentive problems: A dynamic perspective. *The review of Economic studies*, *66*(1), 169-182.

Ilhan, E., Krueger, P., Sautner, Z., & Starks, L. T. (2021). Climate risk disclosure and institutional investors. *Swiss Finance Institute Research Paper*, (19-66).

Jagannathan, R., Matsa, D. A., Meier, I., & Tarhan, V. (2016). Why do firms use high discount rates?. *Journal of Financial Economics*, *120*(3), 445-463.

Jensen, M. C., & Meckling, W. H. (1976). Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure. *Journal of Financial Economics*, *3*(4), 305-360.

Jiang, F., & Kim, K. A. (2020). Corporate governance in China: A survey. *Review of Finance*, *24*(4), 733-772.

Kim, I., Pantzalis, C., & Zhang, Z. (2021). Multinationality and the value of green innovation. *Journal of Corporate Finance*, *69*, 101996.

Li, M. H., Cui, L., & Lu, J. (2014). Varieties in state capitalism: Outward FDI strategies of central and local state-owned enterprises from emerging economy countries. *Journal of International Business Studies*, *45*(8), 980-1004.

Lu, N., Feng, S., Liu, Z., Wang, W., Lu, H., & Wang, M. (2020). The determinants of carbon emissions in the Chinese construction industry: a spatial analysis. *Sustainability*, *12*(4), 1428.

Massa, M., & Zhang, L. (2021). The spillover effects of Hurricane Katrina on corporate bonds and the choice between bank and bond financing. *Journal of Financial and Quantitative Analysis*, *56*(3), 885-913.

Nguyen, J. H., & Phan, H. V. (2020). Carbon risk and corporate capital structure. *Journal of Corporate Finance*, *64*, 101713.

Panousi, V., & Papanikolaou, D. (2012). Investment, idiosyncratic risk, and ownership. *The Journal of finance*, *67*(3), 1113-1148.

Parrino, R., & Weisbach, M. S. (1999). Measuring investment distortions arising from stockholder–bondholder conflicts. *Journal of Financial Economics, 53*(1), 3-42.

Popp, D. (2002). Induced innovation and energy prices. *American economic review*, *92*(1), 160-180.

Rogge, K. S., Schneider, M., & Hoffmann, V. H. (2011). The innovation impact of the EU Emission Trading System—Findings of company case studies in the German power sector. *Ecological Economics, 70*(3), 513-523.

Rosenstein, S., & Wyatt, J. G. (1990). Outside directors, board independence, and shareholder wealth. *Journal of financial economics*, *26*(2), 175-191.

Scott, W. R. (2005). Institutional theory: Contributing to a theoretical research program. *Great minds in management: The process of theory development*, *37*(2), 460-484.

Seltzer, L. H., Starks, L., & Zhu, Q. (2022). Climate regulatory risk and corporate bonds (No. w29994). National Bureau of Economic Research.

Servaes, H., & Tamayo, A. (2014). How do industry peers respond to control threats?. *Management Science, 60*(2), 380-399.

Shao, S., Liu, J., Geng, Y., Miao, Z., & Yang, Y. (2016). Uncovering driving factors of carbon emissions from China's mining sector. *Applied Energy*, *166*, 220-238.

Shleifer, A., & Vishny, R. W. (1986). Large shareholders and corporate control. *Journal of political economy*, *94*(3, Part 1), 461-488.

Smith, C. W., & Stulz, R. M. (1985). The determinants of firms' hedging policies. *Journal of financial and quantitative analysis*, *20*(4), 391-405.

Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds?. *Journal of Corporate Finance, 61,* 101427.

Tian, X., & Wang, T. Y. (2014). Tolerance for failure and corporate innovation. *The Review of Financial Studies*, *27*(1), 211-255.

Wong, T. J. (2016). Corporate governance research on listed firms in China: Institutions, governance and accountability. *Foundations and Trends in Accounting*, *9*(4), 259-326.

Wooldridge, J. M. (2010). Econometric analysis of cross section and panel data. MIT press.

Zhang, D., Karplus, V. J., Cassisa, C., & Zhang, X. (2014). Emissions trading in China: Progress and prospects. *Energy policy*, *75*, 9-16.

Appendix: Variable Definitions

Variable	Definition
Green Innovation Ratio	The number of green invention patent applications filed by the listed company divided by its number of all patent applications this year. Winsorized at the 1% and 99% levels.
Green Innovation Quantity	The natural logarithm of one plus the number of green invention patent applications filed by the corporate group this year. Winsorized at the 1% and 99% levels.
Green Bond	A dummy variable equal to 1 if the firm issues green bonds this year, and 0 otherwise.
Green Investment	The natural logarithm of one plus the amount invested by the firm in green construction work-in-progress this year. Winsorized at the 1% and 99% levels.
CO2(ind)	A continuous variable defined as the average of total CO_2 emissions of all firms in the industry to which the firm belongs during 2013-2017, scaled between 0 and 1. Winsorized at the 1% and 99% levels.
ETS	A dummy variable equal to 1 if the year is equal to or greater than 2018, and 0 otherwise.
Size	The natural logarithm of total assets in year *t-1*. Winsorized at the 1% and 99% levels.
Leverage	Total liabilities divided by total assets in year *t-1*. Winsorized at the 1% and 99% levels.
Age	The firm's age in year *t-1*. Winsorized at the 1% and 99% levels.
ROE	Return on equity (in percentage) in year *t-1*. Winsorized at the 1% and 99% levels.
Intangible Assets	The natural logarithm of one plus intangible assets in year *t-1*. Winsorized at the 1% and 99% levels.
Operating Sales	The natural logarithm of one plus operating sales in year *t-1*. Winsorized at the 1% and 99% levels.
Manager Shareholding	A dummy variable equal to 1 if managers' shareholding of the firm is above the median in year *t-1*, and 0 otherwise.
Fund Shareholding	A dummy variable equal to 1 if funds' shareholding of the firm is above the median in year *t-1*, and 0 otherwise.
Ratio of Independent Directors	A dummy variable equal to 1 if the firm's ratio of independent directors is above the median in year *t-1*, and 0 otherwise.
SOE	A dummy variable equal to 1 if the firm is a state-owned enterprise, and 0 otherwise.
WSVI	A dummy variable equal to 1 if the firm's web search volume index is above the median in year *t-1*, and 0 otherwise.
Young Life Cycle	A dummy variable equal to 1 if the firm is in the young life cycle stage in year *t-1*, and 0 otherwise. Following Dickinson

	(2011) and Allen et al. (2021), young life cycle is identified if the firm has negative operating cash flows, negative investing cash flows, and positive financing cash flows.
CO2(indprov)	A continuous variable defined as the average of total CO_2 emissions of all firms in the industry and province to which the firm belongs during 2013-2017, scaled between 0 and 1. Winsorized at the 1% and 99% levels.
CO2(ind)_PA	A continuous variable defined as the average of CO_2 emissions of all firms in the industry over 2013-2017, divided by the average of total assets of all firms in the same industry during this period. Winsorized at the 1% and 99% levels.
Electricity	A dummy variable equal to 1 if the firm is in the electricity industry, and 0 otherwise.

Figure 1: Parallel Trend Analysis

The Figure plots the coefficients in the parallel trend test (leads and lags model) for three green policies. The leads and lags models include the interaction terms between the treatment variable *ETS* and index years: *year2015* (-2), *year2016* (-1), *year2018* (+1), *year2019* (+2), and *year2020* (+3).

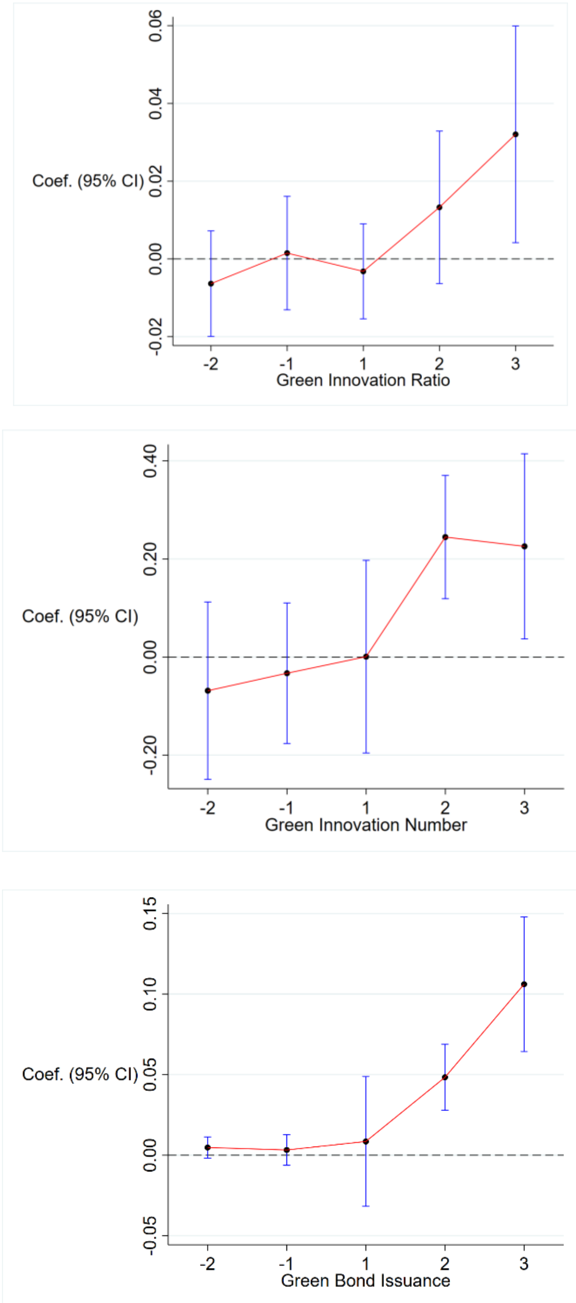

Table 1: Descriptive Statistics of Key Variables

Variable	N	Mean	SD	Min	Max
Green Innovation Ratio	10,252	0.0359	0.1141	0.0000	0.8333
Green Innovation Quantity	10,252	0.5790	0.9151	0.0000	4.2195
Green Bond	10,256	0.0028	0.0531	0.0000	1.0000
Green Investment	4,412	11.4599	8.0799	0.0000	21.7790
CO2(ind)	10,256	0.0598	0.1837	0.0002	1.0000
ETS	10,256	0.4439	0.4969	0.0000	1.0000
Size	10,256	22.0630	1.1892	19.6937	26.6227
Leverage	10,256	0.4186	0.2088	0.0534	0.9431
Age	10,256	17.7207	4.8884	7.0000	34.0000
ROE	10,256	4.9281	15.7392	-100.3600	38.1400
Intangible Assets	10,256	18.7085	1.4970	12.5649	23.2004
Operating Sales	10,256	21.3921	1.3683	18.0080	25.7938
CO2(indprov)	10,170	0.0201	0.0665	0.0000	0.4554
CO2(ind)_PA	10,256	1.9683	4.3169	0.0244	21.9990
Electricity	10,256	0.0299	0.1704	0.0000	1.0000

Table 2: Baseline Regressions

	Green Innovation Ratio		Green Innovation Quantity		Green Investment		Green Bond	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CO2(ind) * ETS	**0.0133****	**0.0140****	**0.1063****	**0.1585*****	**-0.1513**	**-0.1278**	**0.0514*****	**0.0527*****
	(2.38)	**(2.61)**	**(2.16)**	**(3.44)**	**(-0.14)**	**(-0.11)**	**(16.19)**	**(13.21)**
Size	0.0102*	0.0112*	0.1801***	0.1809***	-1.1511**	-1.0792*	0.0039	0.0038
	(1.73)	(1.96)	(3.33)	(3.38)	(-2.23)	(-1.71)	(1.11)	(1.03)
Leverage	-0.0051	-0.0091	-0.1312	-0.1294	-3.9776***	-3.7298**	-0.0042	-0.0039
	(-0.39)	(-0.66)	(-1.19)	(-1.17)	(-2.81)	(-2.51)	(-0.72)	(-0.68)
Age	-0.0124	-0.0122	-0.0963**	-0.0968**	0.1878	0.2214	-0.0005	-0.0008
	(-1.05)	(-1.02)	(-2.40)	(-2.29)	(0.57)	(0.64)	(-0.31)	(-0.51)
ROE	-0.0000	-0.0000	0.0013**	0.0014**	0.0077	0.0089	0.0000*	0.0000*
	(-0.10)	(-0.14)	(2.32)	(2.40)	(1.13)	(1.35)	(1.88)	(1.77)
Intangible Assets	-0.0017	-0.0013	0.0136	0.0159	0.8532**	0.8704**	0.0006	0.0006
	(-0.87)	(-0.68)	(0.71)	(0.85)	(2.61)	(2.26)	(0.45)	(0.46)
Operating Sales	-0.0036	-0.0043	0.0689**	0.0618*	0.9255**	1.0136**	0.0007	0.0005
	(-0.76)	(-0.93)	(2.10)	(1.85)	(2.24)	(2.45)	(0.24)	(0.17)
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	NO	YES	NO	YES	NO	YES	NO
Province FE	YES	NO	YES	NO	YES	NO	YES	NO
Province-year FE	NO	YES	NO	YES	NO	YES	NO	YES
N	10,252	10,252	10,252	10,252	4,412	4,412	10,256	10,256
adj. R^2	0.379	0.379	0.647	0.648	0.599	0.598	0.032	0.026

Notes: This table explores the effects of carbon liability risks on corporate green policies. The dependent variables are *Green Innovation Ratio*, which is the number of green invention patent applications in the firm divided by its number of all patent applications in year *t*, *Green Innovation Quantity*, which is the natural logarithm of one plus the number of green invention patent applications in the corporate group in year *t*, and *Green Bond*, an indicator variable which equals one if the firm issues green bonds in year *t*. *CO2(ind)* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry during 2013-2017, scaled between zero and one. *ETS* is a dummy variable which equals one for post-treatment years from 2018 to 2020, and zero otherwise. Control variables are measured at year *t-1*. All variables are defined in the Appendix. Robust standard errors are clustered at the industry level and t-statistics are reported in parentheses. All models include a constant and fixed effects as shown on the table, but the coefficients are not reported. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3: Placebo Tests

	Green Innovation Ratio	Green Innovation Quantity	Green Bond
	(1)	(2)	(3)
CO2(ind) * Placebo_ETS	**0.0077**	**0.0763**	**0.0060**
	(1.60)	**(1.41)**	**(0.70)**
Size	0.0085	0.2051***	0.0042
	(1.08)	(3.06)	(1.03)
Leverage	-0.0125	-0.0492	0.0011
	(-1.02)	(-0.40)	(0.15)
Age	-0.0049	-0.1037**	0.0012*
	(-0.47)	(-2.43)	(1.81)
ROE	0.0000	0.0014*	0.0000
	(0.17)	(1.83)	(1.53)
Intangible Assets	0.0016	0.0005	-0.0011
	(0.63)	(0.02)	(-1.07)
Operating Sales	-0.0049	0.0701*	0.0016
	(-0.94)	(1.73)	(0.95)
Firm FE	YES	YES	YES
Province-year FE	YES	YES	YES
N	6989	6989	6993
adj. R^2	0.392	0.672	-0.015

Notes: This table presents the results of the placebo tests using year 2016 as the pseudo treatment year for a sample period of 2013 to 2018. The dependent variables are *Green Innovation Ratio*, which is the number of green invention patent applications in the firm divided by its number of all patent applications in year *t*, *Green Innovation Quantity*, which is the natural logarithm of one plus the number of green invention patent applications in the corporate group in year *t*, and *Green Bond*, an indicator variable which equals one if the firm issues green bonds in year *t*. *CO2(ind)* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry during 2013-2015, scaled between zero and one. *Placebo_ETS* is a dummy variable which equals one for pseudo-post-treatment years from 2016 to 2018, and zero otherwise. Control variables are measured at year *t-1*. All variables are defined in the Appendix. Robust standard errors are clustered at the industry level and t-statistics are reported in parentheses. All models include a constant and fixed effects as shown on the table, but the coefficients are not reported. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 4: Market Reactions

t-test, CAR [-5, 5]	Low CO2(ind)	High CO2(ind)	Difference (High – Low)
Before	-0.0094	0.0172	0.0266
	(-0.44)	(0.77)	(0.86)
After	-0.0079	0.0576*	0.0656
	(-0.25)	(1.91)	(1.35)
Difference (After – Before)	0.0015	0.0404	**0.0389***
	(0.04)	(0.82)	**(1.87)**

Notes: This table analyzes the stock market's reaction to the announcement of issuing green bonds. The dependent variable *CAR* is the average cumulative abnormal returns over the [-5, 5] window around the announcement of issuance. The before- and after-treatment groups are based on the announcement of issuance. Based on whether the firm belongs to an industry with above-median *CO2(ind)* values, we sort the low- and high-CO2(ind) groups. Parentheses indicate t-statistics. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5: Relation with Corporate Governance

Panel A: Managers' shareholdings

Manager Shareholding	Green Innovation Ratio		Green Innovation Quantity		Green Bond	
	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
CO2(ind) * ETS	-0.0066	**0.0174****	0.0476	**0.1994*****	0.0030	**0.0612*****
	(-0.07)	**(2.54)**	(0.17)	**(4.58)**	(0.51)	**(11.08)**
Size	0.0173*	0.0182**	0.2513**	0.1358***	0.0043	0.0011
	(1.78)	(2.55)	(2.27)	(2.76)	(0.66)	(0.21)
Leverage	-0.0243	-0.0052	-0.2278	-0.1611	0.0060	-0.0104
	(-1.58)	(-0.31)	(-1.20)	(-1.24)	(0.92)	(-1.10)
Age	-0.0102	-0.0161	-0.1243	-0.0642	-0.0003	0.0025
	(-1.45)	(-0.64)	(-1.58)	(-0.76)	(-0.31)	(0.98)
ROE	-0.0001	-0.0000	0.0023**	0.0008*	-0.0000	0.0000
	(-0.46)	(-0.16)	(2.57)	(1.79)	(-0.28)	(0.96)
Intangible Assets	-0.0032	-0.0024	0.0011	0.0186	-0.0020*	0.0014
	(-0.91)	(-1.18)	(0.03)	(0.74)	(-1.73)	(0.65)
Operating Sales	-0.0021	-0.0083	0.1641**	0.0206	0.0031	0.0015
	(-0.28)	(-1.30)	(2.29)	(0.51)	(1.22)	(0.27)
Empirical p-value	0.068		0.035		0.003	
Firm FE	YES	YES	YES	YES	YES	YES
Province-year FE	YES	YES	YES	YES	YES	YES
N	5,094	4,856	5,094	4,856	5,098	4,856
adj. R^2	0.457	0.319	0.641	0.672	-0.061	0.039

Panel B: Funds' shareholdings

Fund Shareholding	Green Innovation Ratio		Green Innovation Quantity		Green Bond	
	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
CO2(ind) * ETS	**0.0481*****	-0.0149***	**0.4986*****	0.0338	**0.0943*****	0.0283***
	(4.52)	(-2.88)	**(4.55)**	(0.44)	**(6.31)**	(5.32)
Size	0.0145	0.0136*	0.1746*	0.1754**	0.0087	0.0018
	(0.79)	(1.79)	(1.72)	(2.37)	(1.10)	(0.70)
Leverage	-0.0001	-0.0076	-0.0826	-0.1287	-0.0062	-0.0032
	(-0.00)	(-0.49)	(-0.37)	(-1.08)	(-0.36)	(-0.95)
Age	0.0077	-0.0341	0.0540	-0.2016**	0.0018	-0.0030
	(0.68)	(-1.40)	(0.66)	(-2.32)	(1.17)	(-0.77)
ROE	-0.0002	0.0001*	-0.0001	0.0012**	-0.0000	0.0000
	(-1.01)	(1.95)	(-0.04)	(2.18)	(-0.21)	(0.66)
Intangible Assets	-0.0032	-0.0017	-0.0137	0.0232	-0.0023	0.0000
	(-0.49)	(-0.86)	(-0.43)	(0.96)	(-0.77)	(0.02)
Operating Sales	-0.0004	-0.0064*	0.0838	0.0338	-0.0046	0.0006
	(-0.04)	(-1.85)	(1.06)	(0.97)	(-0.77)	(0.43)
Empirical p-value	0.000		0.000		0.000	
Firm FE	YES	YES	YES	YES	YES	YES
Province-year FE	YES	YES	YES	YES	YES	YES
N	4,612	5,115	4,612	5,115	4,612	5,118
adj. R^2	0.422	0.351	0.697	0.545	0.036	0.095

Panel C: Ratio of independent directors

Ratio of Independent Directors	Green Innovation Ratio		Green Innovation Quantity		Green Bond	
	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
CO2(ind) * ETS	**0.0297****	0.0010	**0.3127*****	0.0657	**0.0687*****	0.0412***
	(2.69)	(0.10)	**(5.97)**	(0.89)	**(5.66)**	(4.25)
Size	0.0267***	-0.0012	0.2377***	0.1399**	0.0024	0.0070
	(2.75)	(-0.14)	(3.21)	(2.16)	(0.58)	(1.14)
Leverage	-0.0248**	0.0212	-0.1010	-0.1553	0.0018	-0.0083
	(-2.11)	(0.71)	(-0.76)	(-0.84)	(0.15)	(-0.70)
Age	0.0023	-0.0359	-0.0326	-0.1636**	0.0001	0.0008
	(0.25)	(-1.02)	(-0.56)	(-2.28)	(0.17)	(0.36)
ROE	0.0000	-0.0001	0.0024**	0.0006	0.0000	0.0001
	(0.05)	(-0.81)	(2.55)	(0.70)	(0.95)	(1.34)
Intangible Assets	-0.0020	0.0000	0.0166	0.0139	-0.0004	0.0022
	(-0.63)	(0.00)	(0.46)	(0.57)	(-0.26)	(0.61)
Operating Sales	-0.0147*	0.0042	0.0167	0.1148**	0.0045	-0.0054
	(-1.82)	(0.57)	(0.37)	(2.05)	(0.94)	(-1.36)
Empirical p-value	0.039		0.004		0.115	
Firm FE	YES	YES	YES	YES	YES	YES
Province-year FE	YES	YES	YES	YES	YES	YES
N	5,485	4,350	5,485	4,350	5,489	4,350
adj. R^2	0.389	0.386	0.657	0.634	0.041	-0.009

Notes: This table explores the mechanism through which carbon liability risks affect corporate green policies. The dependent variables are *Green Innovation Ratio*, which is the number of green invention patent applications in the firm divided by its number of all patent applications in year *t*, *Green Innovation Quantity*, which is the natural logarithm of one plus the number of green invention patent applications in the corporate group in year *t*, and *Green Bond*, an indicator variable which equals one if the firm issues green bonds in year *t*. *CO2(ind)* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry during 2013-2017, scaled between zero and one. *ETS* is a dummy variable which equals one for post-treatment years from 2018 to 2020, and zero otherwise. In Panel A, *Manager Shareholding* is a dummy variable which equals one if the managers' shareholding of the firm is above the median in year *t-1*, and zero otherwise. In Panel B, *Fund Shareholding* is a dummy variable which equals one if the funds' shareholding of the firm is above the median in year *t-1*, and zero otherwise. In Panel C, *Ratio of Independent Directors* is a dummy variable which equals one if the firm's ratio of independent directors is above the median in year *t*, and zero otherwise. Control variables are measured at year *t-1*. All variables are defined in the Appendix. Robust standard errors are clustered at the industry level and t-statistics are reported in parentheses. All models include a constant and fixed effects as shown on the table, but the coefficients are not reported. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6: Heterogeneity Test: Ownership Structure

	Green Innovation Ratio		Green Innovation Quantity		Green Bond	
SOE	LSOE	Non-LSOE	LSOE	Non-LSOE	LSOE	Non-LSOE
	(1)	(2)	(3)	(4)	(5)	(6)
CO2(ind) * ETS	**0.0326****	0.0012	**0.2275****	0.1509	**0.0562*****	0.0432***
	(2.49)	(0.09)	**(2.61)**	(1.66)	**(4.31)**	(5.31)
Size	0.0056	0.0106*	0.1914**	0.1593**	0.0026	0.0036
	(0.49)	(1.70)	(2.17)	(2.56)	(0.37)	(0.83)
Leverage	-0.0158	-0.0007	0.0718	-0.1127	0.0018	-0.0042
	(-0.44)	(-0.05)	(0.46)	(-0.94)	(0.09)	(-0.58)
Age	-0.0346	-0.0119	-0.5461**	-0.0890*	-0.0047	-0.0015
	(-1.19)	(-0.99)	(-2.16)	(-2.00)	(-1.39)	(-0.92)
ROE	-0.0001	0.0001	0.0001	0.0018**	0.0001	0.0000
	(-0.78)	(0.76)	(0.13)	(2.58)	(1.11)	(0.80)
Intangible Assets	0.0004	-0.0025	0.0399	0.0193	0.0059	-0.0001
	(0.07)	(-1.15)	(0.75)	(0.83)	(1.16)	(-0.04)
Operating Sales	-0.0032	-0.0044	-0.0250	0.0830**	-0.0080	0.0022
	(-0.37)	(-0.89)	(-0.50)	(2.08)	(-1.62)	(0.55)
Empirical p-value	0.000		0.014		0.097	
Firm FE	YES	YES	YES	YES	YES	YES
Province-year FE	YES	YES	YES	YES	YES	YES
N	2,076	8,037	2,076	8,037	2,076	8,041
adj. R^2	0.286	0.400	0.716	0.629	0.040	0.034

Notes: This table explores the heterogeneity in treatment effects across different ownership structures. The dependent variables are *Green Innovation Ratio*, which is the number of green invention patent applications in the firm divided by its number of all patent applications in year *t*, *Green Innovation Quantity*, which is the natural logarithm of one plus the number of green invention patent applications in the corporate group in year *t*, and *Green Bond*, an indicator variable which equals one if the firm issues green bonds in year *t*. *CO2(ind)* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry during 2013-2017, scaled between zero and one. *ETS* is a dummy variable which equals one for post-treatment years from 2018 to 2020, and zero otherwise. *SOE* is a dummy variable which equals one if the firm is a state-owned enterprise, and zero otherwise. Control variables are measured at year *t-1*. All variables are defined in the Appendix. Robust standard errors are clustered at the industry level and t-statistics are reported in parentheses. All models include a constant and fixed effects as shown on the table, but the coefficients are not reported. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7: Heterogeneity Test: Public Attention

	Green Innovation Ratio		Green Innovation Quantity		Green Bond	
WSVI	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)
CO2(ind) * ETS	**0.0262*****	0.0070	**0.3320*****	0.0906*	**0.0795*****	0.0370***
	(2.78)	(0.41)	**(3.45)**	(1.89)	**(5.79)**	(4.74)
Size	0.0061	0.0102	0.1881***	0.1495**	-0.0054	0.0060
	(0.58)	(0.85)	(2.76)	(2.26)	(-0.77)	(0.84)
Leverage	-0.0107	-0.0088	-0.3943*	-0.0070	0.0102	-0.0106*
	(-0.39)	(-0.41)	(-1.73)	(-0.06)	(0.81)	(-2.00)
Age	-0.0346	-0.0040	-0.0146	-0.1307**	0.0006	-0.0025
	(-0.71)	(-0.69)	(-0.09)	(-2.37)	(0.32)	(-0.65)
ROE	0.0000	-0.0002	0.0017***	0.0016	0.0001	-0.0000
	(0.50)	(-1.15)	(2.76)	(1.36)	(1.10)	(-0.43)
Intangible Assets	-0.0007	0.0001	0.0122	0.0224	0.0038	0.0007
	(-0.19)	(0.06)	(0.29)	(0.88)	(0.84)	(0.55)
Operating Sales	0.0019	-0.0073	0.1009*	0.0269	0.0081	-0.0003
	(0.26)	(-0.93)	(1.75)	(0.88)	(0.73)	(-0.08)
Empirical p-value	0.097		0.000		0.012	
Firm FE	YES	YES	YES	YES	YES	YES
Province-year FE	YES	YES	YES	YES	YES	YES
N	3,944	4,391	3,944	4,391	3,944	4,391
adj. R^2	0.351	0.394	0.704	0.577	0.050	0.090

Notes: This table explores the heterogeneity in treatment effects across different levels of public attention. The dependent variables are *Green Innovation Ratio*, which is the number of green invention patent applications in the firm divided by its number of all patent applications in year *t*, *Green Innovation Quantity*, which is the natural logarithm of one plus the number of green invention patent applications in the corporate group in year *t*, and *Green Bond*, an indicator variable which equals one if the firm issues green bonds in year *t*. *CO2(ind)* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry during 2013-2017, scaled between zero and one. *ETS* is a dummy variable which equals one for post-treatment years from 2018 to 2020, and zero otherwise. *WSVI* is a dummy variable which equals one if the firm's web search volume index is above the median in year *t-1*, and zero otherwise. Control variables are measured at year *t-1*. All variables are defined in the Appendix. Robust standard errors are clustered at the industry level and t-statistics are reported in parentheses. All models include a constant and fixed effects as shown on the table, but the coefficients are not reported. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 8: Heterogeneity Test: Young Life Cycle Firms

	Green Innovation Ratio		Green Innovation Quantity		Green Bond	
Young Life Cycle	YLC	Non-YLC	YLC	Non-YLC	YLC	Non-YLC
	(1)	(2)	(3)	(4)	(5)	(6)
CO2(ind) * ETS	-0.1337	**0.0147****	-0.3297	**0.1699*****	0.0229	**0.0552*****
	(-1.25)	**(2.50)**	(-0.74)	**(3.28)**	(0.74)	**(11.62)**
Size	0.0018	0.0148*	0.2278	0.1764***	0.0226	-0.0007
	(0.16)	(1.84)	(0.95)	(3.15)	(0.85)	(-0.22)
Leverage	-0.0177	-0.0035	-0.0254	-0.1251	-0.1074*	-0.0015
	(-0.50)	(-0.24)	(-0.13)	(-0.96)	(-2.00)	(-0.20)
Age	-0.0409	-0.0098	0.1426	-0.1173**	-0.0127	-0.0000
	(-0.80)	(-0.70)	(0.58)	(-2.10)	(-0.30)	(-0.07)
ROE	-0.0002	-0.0000	-0.0011	0.0016*	0.0003	0.0000
	(-0.83)	(-0.09)	(-0.74)	(1.77)	(1.29)	(1.19)
Intangible Assets	0.0082	-0.0020	0.0702	0.0139	0.0118	0.0010
	(1.06)	(-0.90)	(0.86)	(0.59)	(0.97)	(0.71)
Operating Sales	0.0088	-0.0070	0.0618	0.0582	0.0118	0.0022
	(0.86)	(-1.12)	(0.64)	(1.53)	(0.80)	(0.61)
Empirical p-value	0.000		0.000		0.000	
Firm FE	YES	YES	YES	YES	YES	YES
Province-year FE	YES	YES	YES	YES	YES	YES
N	832	8,934	832	8,934	832	8,938
adj. R^2	0.620	0.354	0.679	0.647	-0.239	0.010

Notes: This table explores the heterogeneity in treatment effects across different corporate life cycle stages. The dependent variables are *Green Innovation Ratio*, which is the number of green invention patent applications in the firm divided by its number of all patent applications in year *t*, *Green Innovation Quantity*, which is the natural logarithm of one plus the number of green invention patent applications in the corporate group in year *t*, and *Green Bond*, an indicator variable which equals one if the firm issues green bonds in year *t*. *CO2(ind)* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry during 2013-2017, scaled between zero and one. *ETS* is a dummy variable which equals one for post-treatment years from 2018 to 2020, and zero otherwise. *Young Life Cycle* is a dummy variable which equals one if the firm is in young life cycle stage in year *t-1*, and zero otherwise. Control variables are measured at year *t-1*. All variables are defined in the Appendix. Robust standard errors are clustered at the industry level and t-statistics are reported in parentheses. All models include a constant and fixed effects as shown on the table, but the coefficients are not reported. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9: Robustness Tests

Panel A: Industry-province level analysis

	Green Innovation Ratio		Green Innovation Quantity		Green Bond	
	(1)	(2)	(3)	(4)	(5)	(6)
CO2(indprov) * ETS	**0.0255**	**0.0283**	**0.3286****	**0.4478*****	**0.1456*****	**0.1513*****
	(1.53)	**(1.60)**	**(2.43)**	**(4.14)**	**(5.49)**	**(5.23)**
Controls	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	NO	YES	NO	YES	NO
Province FE	YES	NO	YES	NO	YES	NO
Province-year FE	NO	YES	NO	YES	NO	YES
N	10,166	10,166	10,166	10,166	10,170	10,170
adj. R^2	0.382	0.381	0.647	0.648	0.033	0.027

Panel B: Alternative measure

	Green Innovation Ratio	Green Innovation Quantity	Green Bond
	(1)	(2)	(3)
CO2(ind)_PA * ETS	**0.0008*****	**0.0081*****	**0.0018****
	(3.16)	**(3.89)**	**(2.26)**
Controls	YES	YES	YES
Firm FE	YES	YES	YES
Province-year FE	YES	YES	YES
N	10,252	10,252	10,256
adj. R^2	0.379	0.648	0.022

Panel C: Electricity firms

	Green Innovation Ratio	Green Innovation Quantity	Green Bond
	(1)	(2)	(3)
Electricity * ETS	**0.0140*****	**0.1347*****	**0.0516*****
	(6.71)	**(5.67)**	**(15.77)**
Controls	YES	YES	YES
Firm FE	YES	YES	YES
Province-year FE	YES	YES	YES
N	10,252	10,252	10,256
adj. R^2	0.379	0.648	0.024

Notes: This table considers various measures of firms' exposure to carbon liability risks and their impact on corporate green policies. The dependent variables are *Green Innovation Ratio*, which is the number of green invention patent applications in the firm divided by its number of all patent applications in year *t*, *Green Innovation Quantity*, which is the natural logarithm of one plus the number of green invention patent applications in the corporate group in year *t*, and *Green Bond*, an indicator variable which equals one if the firm issues green bonds in year *t*. In Panel A, *CO2(indprov)* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry and a province during 2013-2017, scaled between zero and one. In Panel B, *CO2(ind)_PA* is a continuous variable defined as the average of total CO_2 emissions of all firms in an industry during 2013-2017 divided by the average of total assets of all firms in the same industry during this period. In Panel C, *Electricity* is a dummy variable which equals one if the firm is in the electricity industry, and zero otherwise. Control variables are measured at year *t-1*. All variables are defined in the Appendix. Robust standard errors are clustered at the industry level and t-statistics are reported in parentheses. All models include a constant and fixed effects as shown on the table, but the coefficients are not reported. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.