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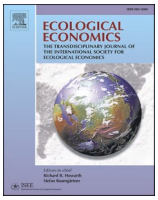

Directors' and officers' liability insurance, environmental regulation and firms' envi ronmental responsibility

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ABSTRACT

This study examines the relationship among directors' and officers' liability insurance (D&O Insurance), environmental regulation, and firms' environmental responsibility-taking. Using the data on firms' green innovation achievement and environmental protection investment from China, where the information of D&O Insurance purchases was disclosed, we find robust evidence that insured firms significantly promote firms' environmental responsibility-taking, evident in more green innovation achievement and environmental protection investment. This positive association is more pronounced for firms exposed to stronger environmental regulation. In addition, we document that the moderating effect of environmental regulation is stronger for SOEs, firms with better corporate governance, operating in heavy-polluting industries, and exposed to a stronger institutional environment. Further mechanism analysis shows that public supervision is the underlying channel through which D&O Insurance affects firms' environmental responsibility. Overall, our findings imply that D&O Insurance, one of the important corporate governance mechanisms, motivates directors and officers to actively practice firms' environmental responsibility, and environmental regulation exerts a positive influence over this governance effect.

1. Introduction

With the rapid development of society and economy for several decades, the world has witnessed vast sustainable development challenges. Earth is experiencing a severe shortage of resources and degradation of the environment. Therefore, human beings must pursue the balance between economic development and environmental protection as well as resources conservation. Accordingly, from a micro-level perspective, firms should take their environmental responsibility by putting green innovation, environmental protection investment, and the implement of environmental regulation in an important place, since green innovation and environmental protection are considered as effective ways to advance sustainable development (e.g., Zhu et al., 2021; Singh et al., 2020; Liu and Kong, 2020; Jin et al., 2019; Du and Li, 2019).

However, although green innovation and environmental protection bring about competitive advantages to firms (Wernerfelt, 1984; Porter and Linde, 1995; Barney, 1991; Porter, 1996; Chen et al., 2006; Albortmorant et al., 2016), firms have several barriers to actively practice environmental responsibility. Unlike routine investments, the idiosyncratic characteristics of green innovation and environmental protection projects (e.g., uncertainty, highly likely to fail, long payback period)[1] increase the stock return volatility, stock turnover and downside risk (Chen et al., 2001), which thus increases the likelihood of shareholders' class litigation and derivative suits (e.g., Bourveau et al., 2018). The fear of declining profits and litigation risk discourages risk-averse managers from engaging in innovation activities and environmental protection projects that are inherently risky. Therefore, improving directors' and officers' risk tolerance plays a vital role in firms' practice of environmental responsibility.

Directors' and officers' liability insurance (hereafter D&O Insurance)

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[1] Innovation projects are long-term idiosyncratic investments filled with uncertainty and highly likely to fail (Holmstrom, 1989). In addition, environmental protection investment, which needs a large amount of sustained capital investment (Porter and Linde, 1995) and hardly produces economic benefits in the short term (Orsato, 2006), often increases operating costs and reduces profits (Zhang et al., 2019).

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is a standard policy firms provide to their directors and officers to prevent litigation for directors' and officers' assets. On the one hand, the loss compensation function of D&O Insurance can mitigate managers' risk-aversion tendency, encourage them to be positive and enterprising (Holderness, 1990), which may promote firms' directors and officers to more actively pursue and practice environmental responsibility. D&O Insurance also introduces insurance issuers' supervision on managers (Core, 2000; Holderness, 1990), which forces managers to fulfill environmental responsibility to avoid litigation losses due to clients' environmental behavior.

Interestingly, given the specificity of the China insurance market, the unique role of D&O Insurance in corporate governance is manifested in the public supervision effect. Specifically, compared with the mature insurance markets in western developed countries, China insurance market is still underdeveloped. Unlike listed firms in western developed countries (such as the United States and Canada) which generally purchased D&O Insurance,[2] only about 5% (or even lower) of Chinese listed firms purchased D&O insurance (e.g., Li et al., 2022; Zou et al., 2008; Jia et al., 2019; Wang et al., 2020). Therefore, those firms that purchased D&O Insurance might have become super stars in the capital market and received stronger public supervision. In this case, public supervision shall guide public opinion through various channels such as media and the Internet, supervise the environmental behavior of insured firms, and put pressure on polluting firms to promote their environmental responsibilities proxied by corporate green innovation and environmental protection investments.

However, on the other hand, D&O Insurance may induce managers to reduce the diligence and prudence when performing their duties, which decreases the quality of decision-making and stimulates moral hazard and opportunistic behavior (Chalmers et al., 2002). Accordingly, Baker and Griffith (2010) hold that in the US insurance market apparently insurance companies do not control moral hazard (via effective risk differentiation) as a result of which moral hazard prevails. Therefore, it is an open question whether firms with D&O Insurance are more likely to actively pursue and practice environmental responsibility.

At the same time, governments around the world also put great efforts to implement environmental regulation to advance sustainable development, which may push D&O Insurance issuers to exert stricter and more comprehensive supervision on their clients' environmental performance to reduce the compensation risk caused by lawsuits against their clients' environmental behavior. As a result, firms are exposed to a high risk of administrative penalty and litigation risk. Thus, environmental regulation may significantly affect the relationship between D&O Insurance and firms' environmental responsibility-taking. However, whether and how environmental regulation motivates firms with D&O Insurance to take environmental responsibility is empirically not clear. We, therefore, examine the relationship among directors' and officers' liability insurance (D&O Insurance), environmental regulation, and firms' environmental responsibility.

Using a large sample of listed companies from China, where the information of D&O Insurance purchases was disclosed, we find that, ceteris paribus, compared with uninsured firms, insured firms achieve more green patents and invest more in environmental protection, and this association is more prominent for firms exposed to stronger environmental regulation. We further employ the propensity score matching (PSM) and entropy balancing approaches, the Heckman's two-stage method, an exogenous shock to measure the firm-level environmental regulation, fixed effects model and placebo tests to ensure our findings are not driven by certain differences between insured firms and uninsured firms, selection-bias endogeneity, measurement error for the environmental regulation, potential omitted variables and random factors.

In addition, we conduct several cross-sectional tests. Specially, we investigate whether the moderating effect of environmental regulation on the relation between D&O Insurance and firms' environmental responsibility is more pronounced in state-owned enterprises (SOEs), firms with better corporate governance, firms operating in heavy-polluting industries, and firms exposed to a stronger institutional environment. We show that the moderating effect of environmental regulation is more substantial for SOEs, firms with better corporate governance, firms belonging to heavy-polluting industries, and firms located in provinces with a stronger institutional environment. These results suggest that the effect of environmental regulation on firms' environmental responsibility is influenced by firms' own characteristics and external institutional factors. Further mechanism analysis shows that public supervision is the underlying channel through which D&O Insurance affects firms' environmental responsibility.

We contribute to the prior research in several ways. First, we enrich the literature on the outcomes of D&O Insurance purchases. The prior literature has examined the impacts of D&O Insurance on firms' financial reports, earnings conservatism, cost of equity and debt, audit pricing, auditor choice, operating activities, and acquisition activities (Chung and Wynn, 2008; Lin et al., 2013; Chi and Weng, 2014; Chung et al., 2015; Chen et al., 2016; Lin et al., 2019), but little is known on how D&O insurance would effectively be able to influence firm behavior (especially corporate environmental responsibility). Our study investigates whether D&O Insurance purchasing affects firms' environmental responsibility-taking in terms of green innovation achievement and environmental protection investment, which extends the literature on the outcomes of D&O Insurance.

Second, we contribute to the literature on the determinants of firms' environmental responsibility-taking and the impacts of environmental regulation on firms' environmental responsibility-taking. Unlike prior studies focusing mainly on the effect of government regulation or tax policy (Stucki et al., 2018; Huang et al., 2019; Borsatto and Amui, 2019; Zhang et al., 2019; Peng, 2020), and corporate strategy (Kong et al., 2019; Liu and Kong, 2020) on firms' efforts on environmental performance, we examine whether firms with D&O Insurance are more likely to actively pursue and practice environmental responsibility, and how environmental regulation motivates firms with D&O Insurance to take environmental responsibility.

Third, we contribute to the literature related to sustainability and sustainable development. Since green innovation and environmental protection are considered as effective ways to promote sustainable development (e.g., Liu and Kong, 2020; Du and Li, 2019), exploring how to promote corporate environmental responsibility through green innovation and environmental protection investment has always been one of the important topics of sustainability research. Using detailed data on green innovation and environmental investment from China, we find that D&O Insurance, as one of the important corporate governance mechanisms, plays an active role in promoting firms' green innovation and environmental investment, which enriches the research related to sustainability and sustainable development in the field of ecological economics.

Finally, our study also has generalisability and some normative implications for emerging market countries. Based on this specificity of the China insurance market, we examine the mechanism through which D&O Insurance affects corporate environmental responsibility, that is, D&O Insurance purchases are associated with stronger public supervision. Our study implies that in emerging market countries where insurance markets are not yet developed (such as China), regulators and practitioners may promote and extend D&O Insurance, such as accelerating the implementation of D&O Insurance by motivating firms to buy it and at the same time strengthening environmental regulation as well as public supervision to advance firms' environmental responsibility-taking.

[2] According to a survey conducted by Tillinghast Towers Perrin in 2005, 100% of public company respondents in both the United States and Canada purchased D&O insurance. See Tillinghast Towers Perrin, 2005 Directors and Officers Liability Survey 20 fig. 21 (2006).

The rest of the paper proceeds as follows. We review the institutional background, related literature and develop our hypothesis in Section 2. Section 3 describes the sample, data, and empirical model. Section 4 presents the main findings. Sections 5 and 6 further discuss robust tests and additional analyses, respectively. Section 7 concludes the study.

2. Institutional background, previous literature, and hypotheses development

2.1. Institutional background

D&O Insurance was born in the US at the beginning of the 20th century and was purchased by firms to cover the legal liability arising from their directors' and officers' professional activities on behalf of the company. In 1933, the Securities Act of the United States established the civil compensation system, which made it possible for shareholders to sue firms' directors and officers and led to a sharp increase in the professional risk of listed firms' managers in the US Subsequently, with the exposure of a series of financial scandals on Wall Street, D&O Insurance gradually prevailed in developed capital markets such as Canada, U.S., Europe, UK, and Japan, and became the primary tool for enterprises and managers to avoid risks. Nowadays, D&O Insurance is common among listed firms in common-law jurisdictions, such as Canada, the US, and the UK (Zou et al., 2008). According to a survey covering 2059 American and Canadian companies conducted by Tillinghast Towers Perrin's study in 2014, 96% of the American companies and 88% of the Canadian companies purchased D&O Insurance.

Compared with western developed markets, D&O Insurance started late in China. In 2002, the Supreme People's Court in China issued the "Notice on Issues Related to the Acceptance of Civil Tort Disputes Caused by False Statements in the Securities Market," which made it possible for shareholders to take civil action in China. Subsequently, several major Chinese property insurance companies successively launched D&O Insurance. Vanke Co., Ltd. purchased the first D&O Insurance in China for its chairman Mr. Wang, Shi in 2002. In 2014, the State Council of China issued "Several Opinions on Accelerating the Development of Modern Insurance Service Industry," which further promoted the development of D&O Insurance in China. However, D&O Insurance does not seem to be favored by Chinese listed companies. Compared with the higher purchase rate of western developed countries, the purchase rate of D&O Insurance in China is still <10% (Hu et al., 2019). Although the coverage rate of D&O Insurance in China is not high, with the enhancement of risk awareness of listed companies, there is a massive potential growth of D&O Insurance coverage of Chinese listed companies.

2.2. Related literature

2.2.1. Impacts of D&O insurance

As one of the vital corporate governance mechanisms, D&O Insurance, introduced to developed markets for several decades, has become a hot topic in the corporate governance and risk management research field. Prior studies mainly focus on the developed markets and examine the effect of D&O Insurance from an economic angle. Using data from Canada, literature documents unanticipated influence caused by D&O Insurance: firms with higher D&O Insurance coverage are more aggressive on earnings reporting (Chung and Wynn, 2008), less likely to report pessimistic news forecasts (Wynn, 2008), and pay for higher finance costs (Lin et al., 2013; Chen et al., 2016). In addition, insured firms are charged higher audit fees because of higher audit risk (Chung et al., 2015). Furthermore, based on data from Taiwan, Chi and Weng (2014) show that companies with excess D&O liability insurance coverage are less likely to employ high-quality auditors. However, using data from Germany, Lin et al. (2019) document that insured firms reduce their risk-taking activities related to financial reporting and operating activities. Besides, using data from China, Yuan et al. (2016) reveal D&O Insurance improves firms' corporate governance by decreasing firms' future stock price crash risk.

2.2.2. Determinants of firms' environmental responsibility

Green innovation and environmental protection are considered as effective ways to promote sustainable development. Prior studies extensively examine the determinants of firms' environmental responsibility in terms of green innovation activities and environmental protection investments. Regarding green innovation, Borsatto and Amui (2019) and Frondel et al. (2007) document environmental regulation positively associates with green innovation. Besides, government policy (e.g., subsidies and taxes) influences green innovation (Huang et al., 2019; Stucki et al., 2018). In addition, factors inside the firm (e.g., corporate governance, strategy) also impact green innovation (Liu and Kong, 2020; Amore and Bennedsen, 2016). Concerning environmental protection investments, studies show that macro factors, such as environmental regulation and institution, significantly influence firms' investments in environmental protection (e.g., Bansal, 2003; Taylor et al., 2005; Maxwell and Decker, 2006; Pagell et al., 2013; Zhang et al., 2019). Based on internal factors, the literature finds that corporate culture, board structure, and ownership structure influence firms' environmental protection investments (e.g., Sugita and Takahashi, 2013; Uwuigbe and Ajibolade, 2013; Wei et al., 2017; Wei and Zhou, 2020).

2.2.3. Impacts of environmental regulation on firms' environmental responsibility

Environmental regulation is a standard policy taken by the government to curb ecological degradation and resources shortage. Therefore, researchers put great efforts into investigating the effect of environmental regulation on firms' environmental responsibility performance. As to green innovation, Porter (1991) and Porter and Linde (1995) argue that environmental regulation significantly affects firms' green innovation, and Wang and Shen (2016) and Xie et al. (2017) provide evidence supporting the notion. In addition, literature also shows that the more severe the environmental regulation policy is, the greater the incentive effect of environmental regulation on green innovation is (Opaluch et al., 2005; Frondel et al., 2007; Borsatto and Amui, 2019). Regarding environmental protection investments, literature shows that environmental courts established by the government significantly enhance environmental investment by firms (Zhang et al., 2019).

2.3. Hypotheses development

There are two opposing views on the role of D&O Insurance in corporate governance. Proponents believe that D&O Insurance introduces insurance issuers' supervision on managers (Core, 2000; Holderness, 1990) and forces managers to engage in responsible conduct and environmental protection to avoid environmental litigation losses arising from their clients' environmental behavior.

It is worth noting that, given the specificity of the China insurance market, the role of D&O Insurance in corporate governance may be manifested in the public supervision effect. Specifically, the insurance market in developed western countries (such as the United States and Canada) is significantly more developed than China. D&O Insurance is common among listed firms in common-law jurisdictions, such as Canada, the US, and the UK (Zou et al., 2008). According to a survey conducted by Tillinghast Towers Perrin in 2005, 100% of public company respondents in both the US and Canada purchased D&O insurance.[3] Compared with the significantly higher purchasing rate of D&O Insurance in western developed countries (such as the US and Canada), only about 5% (or even lower) of Chinese listed firms purchased D&O insurance (e.g., Li et al., 2022; Zou et al., 2008; Jia et al., 2019; Wang et al., 2020). Therefore, those firms that purchased D&O Insurance

[3] See Tillinghast Towers Perrin, 2005 Directors and Officers Liability Survey 20 fig. 21 (2006).

might have become super stars in the capital market and received more attention and stronger public supervision. In this case, public supervision shall guide public opinion through media, the Internet or other channels, monitor the environmental behavior of insured firms and force insured firms to actively take on environmental responsibility, which promotes firms to engage in green innovation and environmental protection investments. To sum up, D&O Insurance may actively promote firms to fulfill their environmental responsibility due to the public supervision effect.

Opponents, however, hold that litigation risk protection provided by D&O Insurance constructs an isolation mechanism between managers' wealth and their behavioral consequences, which dramatically reduces the disciplinary effect of legal proceedings on managers. Therefore, managers will reduce the diligence and prudence when performing their duties, which decreases the quality of decision-making and stimulates moral hazard and opportunistic behavior (Chalmers et al., 2002). Accordingly, Baker and Griffith (2010) find that in the US, insurance companies do not at all engage in risk differentiation and that insurance even leads to a spectacular problem of moral hazard, which ensures corporate misconduct.[4] In this instance, directors and officers in insured firms may consume or waste corporate resources, which negatively impacts firms' investments in green innovation and environmental protection. Therefore, it is an open question whether firms with D&O Insurance are more likely to fulfill their environmental responsibility better.

Meanwhile, the world has paid increasing attention and implemented environmental regulations to advance firms' environmental performance to protect the environment. Prior research also documents that environmental regulation exerts pressure and/or motivation on firms' environmental responsibility-taking and has a positive effect on corporate environmental practice, including enhancing firms' environmental protection investments and green innovation achievement (e.g., Porter, 1991; Porter and Linde, 1995; Wang and Shen, 2016; Xie et al., 2017; Opaluch et al., 2005; Frondel et al., 2007; Borsatto and Amui, 2019; Zhang et al., 2019; Bansal et al., 2020).

Therefore, we argue that environmental regulation promotes firms to pursue economic benefits while actively fulfilling their environmental responsibility, which coordinates the development of the environment and the economy. More specifically, the government provides green finance and green credit related to environmental regulation to firms to encourage them to increase investments in green innovation and environmental protection projects, reduce pollutant emissions, and save resources. In addition, firms will be severely sanctioned according to the environmental regulation policy if they discharge pollutants, waste resources, and destroy the environment arbitrarily as they wish. Thus, insurance issuers will more actively supervise their clients' managers and urge them to engage in responsible conduct and environmental protection to avoid environmental litigation losses arising from the environmental behavior of their clients exposed to stronger environmental regulation. Therefore, environmental regulation may positively affect the relationship between D&O Insurance purchasing and firms' environmental responsibility.

Taken together, we test the following hypotheses:

H1a. Ceteris paribus, compared with uninsured firms, insured firms fulfill their environmental responsibility better, and this positive association is enhanced for firms exposed to higher environmental regulation.

H1b. Ceteris paribus, compared with uninsured firms, insured firms fulfill their environmental responsibility worse, but this negative association is alleviated for firms exposed to higher environmental regulation.

3. Research design and sample

3.1. Sample and data

Our initial sample is based on the entire population of observations for companies publicly listed on the Shanghai and Shenzhen stock exchanges in China over the period 2008–2019 (n = 30,301). As the Chinese new accounting standards came into effect in 2007, in order to avoid the impact of the transition of the old and new accounting standards on our results, we start our sample period in 2008. We then adopt the following sampling procedures: We delete: (1) 2602 observations that are under special treatment by stock exchanges (labeled as ST/*ST),[5] (2) 854 observations in the financial sector for the comparability of accounting statements, (3) 175 observations with debt to asset ratio >1 or <0, and (4) 2819 observations missing necessary financial data to compute the variables used in the empirical tests. Our final sample consists of 23,851 firm-year observations.

We manually collect green innovation data from the State Intellectual Property Office (SIPO) and corporate environmental investment data from listed firms' annual financial reports. In addition, the data for D&O Insurance comes from the Chinese Research Data Services Platform (CNRDS). Specifically, as the China's Securities and Regulatory Commission (CSRC) requires that any purchase of D&O Insurance should be proposed by the board of directors and approved at shareholders' meeting, CNRDS retrieves announcements of the board of directors, shareholders' meetings and annual reports on public websites such as Cninf[6] based on keywords such as "directors' and officers' liability insurance" and "liability insurance", and searches whether these announcements disclosed the proposal or related information about D&O Insurance. If the relevant information is proposed by the board of directors and approved at shareholders' meeting, it is considered that the listed firm has purchased the D&O Insurance. The data used for all the other variables are from the China Stock Market Accounting Research (CSMAR) database. To alleviate the undue influence of outliers, we winsorize all continuous variables at the top and bottom 1% percentiles.

3.2. Measures of firms' environmental responsibility

We use green innovation (*GI*) and environmental protection investment (*EPI*) to measure firms' environmental responsibility (*EnvRes*). Following prior literature (e.g., Chen et al., 2006; Chen, 2008; Amore and Bennedsen, 2016; Li et al., 2018; Liu and Kong, 2020), we use green patents to capture *GI*. We manually collect all patents granted from the SIPO and match their identification by international patent code (IPC) from the SIPO with the IPC Green Inventory classified by World Intellectual Property Organization (WIPO) to identify the green patent. Then, we use the *PatentI*, *PatentU,* and *PatentIU* to measure *GI*. Specifically, *PatentI* (*PatentU*) equals the logarithm of one plus the number of granted green invention patents (green utility model patents), and *PatentIU* equals the logarithm of one plus the total number of granted green invention patents and green utility model patents. In addition, firms'

[4] Our findings are contrary to the findings of Baker and Griffith (2010) mainly because of the specificity of the China insurance market relative to developed western markets. As discussed in the Section 2.3, since the insurance market in developed western countries (such as the United States and Canada) is significantly more developed than China, the role of D&O insurance in developed western countries may be more manifested as causing moral hazard and opportunistic behavior, while the role of D&O insurance in China is mainly reflected in the public supervision effect.

[5] According to the securities laws in China, a company reporting losses in two consecutive fiscal years should be labeled with a special treatment sign (ST/*ST). These firms are subject to a daily price fluctuation limit of 5% and will be terminated from listing if they report losses in four consecutive years and report negative net assets in three consecutive years.

[6] For more detail information about Cninf, please refer to http://www.cninfo.com.cn.

environmental protection investment (*EPI*) is the ratio of a given firm's environmental protection investment (including but not limited to investment in energy saving, emission reduction, sewage disposal, environmental governance monitoring) to its total assets multiplied by 100.

3.3. Measures of environmental regulation

We use government expenditure on environmental protection in each province to measure environmental regulation. To eliminate the economic scale impacts of different regions, the government expenditure on environmental protection investment is scaled by the fiscal revenue in each province.[7] Specifically, we set the environmental regulation variable *ER* equal to 100 multiply the ratio of government expenditure on environmental protection to the fiscal revenue for each province. We create a dummy variable *StrongER* equal to 1 if *ER* is equal to or above the median, and 0 otherwise. We then construct an interaction term *DOI*×*StrongER* to test our hypotheses.

3.4. Empirical model

We employ the following regression model to examine the association between D&O Insurance (*DOI*) and firms' environmental responsibility and the moderating effect of environmental regulation:

$$\begin{aligned}\mathrm{EnvRes}_{i,t+1} =& \beta_0 + \beta_1 \mathrm{DOI}_{i,t} + \beta_2 \mathrm{StrongER}_{i,t} + \beta_3 \mathrm{DOI}_{i,t} \times \mathrm{StrongER}_{i,t} \\ &+ \mathrm{Controls} + \mathrm{Fixed\ Effects} + \varepsilon_{i,t}\end{aligned} \quad (1)$$

where *EnvRes* is firms' environmental responsibility measured by *GI* (*PatentI*, *PatentU,* and *PatentIU*) or *EPI*, and is measured in year $t + 1$, while all explanatory variables are measured in year *t* because the grant of green patents needs some time (e.g., Fang et al., 2014), the corporate investment decision is made in the prior one year or the initial of the current year, and the reverse causality can be alleviated when dependent variables are measured in year $t + 1$, and the explanatory variables are measured in year *t*. *DOI* is a dummy variable equal to 1 if the company purchases D&O Insurance in the fiscal year and 0 otherwise.[8] Our focus is on the effect of D&O Insurance (*DOI*) on environmental responsibility (*EnvRes*), that is, the joint significance on *DOI* + *DOI*×*StrongER*, and the moderating effect of environmental regulation, that is, the significance on interaction term *DOI*×*StrongER*.[9]

Following prior research (e.g., Zhang et al., 2019; Liu and Kong, 2020; Usman et al., 2020), we control for *SIZE* (natural logarithm of total assets), *LEV* (total liability divided by total assets), *ROA* (net income divided by total assets), *LOSS* (whether a firm suffers from a loss), *CR* (current ratio), *BM* (book to market ratio), *TOP1* (shareholding ratio of the biggest shareholder), *DUAL* (duality of CEO and chairman), *SOE* (whether the company is a state-owned enterprise). Finally, we control for the year- and industry-fixed effects. Standard errors are clustered at the firm level.

[7] Results are similar if the government expenditure on environmental protection is scaled by the GDP of each province.

[8] Most of the Chinses listed firms purchasing D&O Insurance do not disclose the insurance fees, therefore following Yuan et al. (2016) and Zou et al. (2008), we use a dummy variable to measure the behavior of firms' purchasing D&O Insurance.

[9] The moderating effect of environmental regulation refers to the significantly positive (or negative) coefficient of *DOI*×*StrongER*, indicating that environmental regulation intensifies (or mitigates) the relationship between D&O Insurance and firms' environmental responsibility-taking, that is, the relationship between D&O Insurance and firms' environmental responsibility-taking is stronger (or weaker) for firms exposed to higher environmental regulation.

4. Empirical results

4.1. Descriptive statistics

Table 1 presents the descriptive statistics of dependent and independent variables. The mean of *DOI* reveals that only 4.2% of the sample observations purchase D&O Insurance, which is significantly different from the developed western markets (such as Canada and the US). The prior literature shows that the proportion of Chinese listed firms that purchased D&O insurance is about 5% (or even lower) (e.g., Li et al., 2022; Zou et al., 2008; Jia et al., 2019; Wang et al., 2020). Overall, our results are similar to the prior literature. The means of variables $PatentI_{t+1}$, and $PatentU_{t+1}$ is 0.108 and 0.177, respectively, suggesting firms achieve 0.114 ($e^{0.108}$–1) green invention patents and 0.194 ($e^{0.177}$–1) green utility model patents on average. Overall, these findings are basically the same as Liu and Kong (2020) and indicate that Chinese firms' green innovation is relatively low. In addition, we show that the money firms spent on environmental protection, on average, accounts for 0.013% of their total assets, evident in the mean of *EPI*. Finally, the 25% and 75% quantile of variable *ER* is 0.018 and 0.028, respectively, and their difference equals about 42% of the mean of *ER*, which suggests there are relatively large variances of environmental regulation that Chinese listed firms faced.

4.2. Correlation analysis

In Table 2, the upper triangle shows Spearman rank correlation coefficients, while the lower triangle reports Pearson correlation coefficients. The results reveal that the dummy variable for purchase of D&O Insurance (*DOI*) significantly and positively associates with all the four measures for environmental responsibility ($PatentI_{t+1}$, $PatentU_{t+1}$, $PatentIU_{t+1}$, and EPI_{t+1}), indicating that firms with D&O Insurance practice their environmental responsibility better, preliminary supporting the hypothesis 1a that D&O Insurance motivates firms to pay more attention and effort to pursue better environmental responsibility performance.

4.3. Main results

Table 3 presents the regression results for hypothesis H1. Specifically, columns (1)–(3) report the results when the dependent variable is green innovation (*PatentI*, *PatentU,* and *PatentIU*), and Columns (4) report the results when the dependent variable is environmental protection investment (*EPI*). We find that the coefficients on *DOI*×*Strong*

Table 1
Descriptive Statistics.

Variables	N	Mean	S.D.	P25	Median	P75
$PatentI_{t+1}$	23,851	0.108	0.377	0.000	0.000	0.000
$PatentU_{t+1}$	23,851	0.177	0.514	0.000	0.000	0.000
$PatentIU_{t+1}$	23,851	0.246	0.615	0.000	0.000	0.000
EPI_{t+1}	23,851	0.013	0.096	0.000	0.000	0.000
ER	23,851	0.024	0.009	0.018	0.022	0.028
StrongER	23,851	0.503	0.500	0.000	1.000	1.000
DOI	23,851	0.042	0.201	0.000	0.000	0.000
SIZE	23,851	21.966	1.271	21.039	21.802	22.694
LEV	23,851	0.419	0.210	0.247	0.409	0.581
ROA	23,851	0.043	0.055	0.016	0.040	0.070
LOSS	23,851	0.082	0.275	0.000	0.000	0.000
CR	23,851	0.714	0.556	0.349	0.595	0.890
BM	23,851	0.614	0.238	0.432	0.617	0.797
TOP1	23,851	0.355	0.150	0.235	0.336	0.456
DUAL	23,851	0.263	0.440	0.000	0.000	1.000
SOE	23,851	0.392	0.488	0.000	0.000	1.000

Notes: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. All continuous variables have been winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

Table 2
Correlation matrix.

	$PatentI_{t+1}$	$PatentU_{t+1}$	$PatentIU_{t+1}$	EPI_{t+1}	*DOI*	*StrongER*	*SIZE*	*LEV*	*ROA*	*LOSS*	*CR*	*BM*	*TOP1*	*DUAL*	*SOE*
$PatentI_{t+1}$	1	0.381***	0.708***	0.091***	**0.095*****	0.004	0.122***	0.031***	0.007	−0.010	0.008	0.011	−0.008	0.005	0.016**
$PatentU_{t+1}$	0.497***	1	0.857***	0.073***	**0.083*****	0.007	0.107***	0.054***	0.001	−0.022***	0.020***	0.060***	0.024***	−0.001	−0.015**
$PatentIU_{t+1}$	0.775***	0.907***	1	0.094***	**0.085*****	0.017***	0.117***	0.037***	0.005	−0.015**	0.006	0.038***	0.006	0.008	−0.016**
EPI_{t+1}	0.057***	0.040***	0.056***	1	**0.061*****	−0.030***	0.119***	0.039***	−0.011*	0.005	0.065***	0.018***	0.038***	−0.028***	0.057***
DOI	**0.110*****	**0.100*****	**0.109*****	**0.029*****	1	−0.016**	0.152***	0.120***	−0.054***	0.022***	0.105***	0.100***	0.020***	−0.072***	0.129***
StrongER	0.011*	0.013**	0.018***	−0.022***	−0.016**	1	0.021***	−0.000	−0.006	−0.004	−0.008	0.088***	0.015**	0.007	0.031***
SIZE	0.183***	0.169***	0.187***	0.082***	0.193***	0.030***	1	0.497***	−0.129***	−0.041***	0.420***	0.501***	0.145***	−0.201***	0.334***
LEV	0.044***	0.068***	0.060***	0.026***	0.119***	0.001	0.494***	1	−0.437***	0.158***	0.803***	0.358***	0.058***	−0.167***	0.318***
ROA	0.009	0.016**	0.014**	−0.006	−0.044***	−0.011	−0.066***	−0.375***	1	−0.476***	−0.402***	−0.241***	0.103***	0.094***	−0.192***
LOSS	−0.016**	−0.025***	−0.023***	0.011*	0.022***	−0.004	−0.045***	0.169***	−0.620***	1	0.171***	−0.006	−0.078***	−0.023***	0.051***
CR	0.010	0.017***	0.012*	0.066***	0.101***	−0.005	0.335***	0.641***	−0.309***	0.188***	1	0.290***	0.037***	−0.170***	0.327***
BM	0.034***	0.079***	0.065***	0.026***	0.103***	0.090***	0.526***	0.356***	−0.192***	−0.010	0.240***	1	0.148***	−0.104***	0.185***
TOP1	0.010	0.035***	0.023***	0.029***	0.018***	0.015**	0.193***	0.064***	0.111***	−0.076***	0.040***	0.157***	1	−0.035***	0.200***
DUAL	0.001	−0.002	0.002	−0.026***	−0.072***	0.007	−0.192***	−0.166***	0.068***	−0.023***	−0.155***	−0.104***	−0.043***	1	−0.302***
SOE	0.029***	0.001	0.006	0.045***	0.129***	0.031***	0.343***	0.320***	−0.139***	0.051***	0.310***	0.190***	0.202***	−0.302***	1

Notes: This table shows Pearson and Spearmen correlation coefficients for the variables used in regression analysis. Pearson correlations are presented in the lower-left corner of the correlation matrix, and Spearman rank correlations are shown in the upper-right corner. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. All continuous variables have been winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

(β_3), and *DOI* + *DOI*×*Strong* ($\beta_1 + \beta_3$) in columns (1)–(4) are all significant and positive at the 5% (or better) level, which suggests insured firms put more effort into the practice of environmental responsibility, and environmental regulation exerts a positive moderating effect on the relationship between D&O Insurance and firms' environmental responsibility. Overall, these findings again support hypothesis 1a.

5. Robust checks

5.1. Aligning insured firms and uninsured firms in relevant covariates

Although we document that D&O Insurance advances firms' environmental responsibility, it is important to stress that our evidence on firms' environmental responsibility may be driven by specific differences between insured and uninsured firms. Moreover, to alleviate this threat to reliable identification, we implement the PSM and entropy balancing approaches to align the attributes between treatment firms (firms with D&O Insurance) and control firms (firms without D&O Insurance).

To apply the PSM, we first estimate the propensity score for treatment firms employing a logit model based on the entire sample. The covariates in the first stage are the same as the control variables used in the baseline model (Shipmen et al., 2017). Panel A column (1) in Table 4 shows the results. For each treatment firm, we identify a firm without D&O Insurance with the closest propensity score estimated as its control match. Specifically, we use one-to-one matching without replacement and set the caliper distance at 0.01. We successfully identify a total of 1070 pairs of firms, and the unmatched firms are dropped from the analyses.

To check the covariate balance between the treatment groups and the matched control groups, we re-estimate the logit model using the matched pairs. As shown in column (2), none of the covariates are loaded with a significant coefficient, indicating the treatment and control groups are closely aligned in the relevant covariates. In addition, Fig. 1(a) and Fig. 1(b) show the kernel density functions of the treatment group and the control group, based on pre- and post-matching of the two groups, respectively. Clearly, the kernel density functions of the two groups are significantly different before matching. Prior studies use all firms in the control group to compare with the treatment group, and thus their results are biased (Lian et al., 2011). In contrast, we choose firms from the control group to match those in the treatment group based on propensity scores. After matching, as shown in Fig. 1(b), the kernel density functions of the two groups are a lot closer, indicating the characteristics of the variables in the two groups are similar after matching.

Finally, we re-estimate our baseline models using the matched samples, and Panel B reports the results. We find that the coefficients on *DOI*×*StrongER* and *DOI* + *DOI*×*StrongER* continue to be significantly positive ($p < 0.05$). Therefore, our results are robust after considering the alternative explanation that the results are driven by certain differences between insured and uninsured firms.

In addition, we implement an entropy balancing approach. Specifically, following Hainmueller (2012), we use an entropy balancing approach to balance the first three moments (i.e., mean, variance, and skewness) of the control variables across the treatment and control firms. For the sake of brevity, untabulated tests confirm that there are no significant post-weighting differences in the three moments across the treatment and control firms.

Table 5 reveals the results from the estimation of our primary analyses based on the reweighted variables. We show that the coefficients on *DOI*×*StrongER* and *DOI* + *DOI*×*StrongER* are still significant and positive ($p < 0.01$). Thus, our main results hold after balancing pretreatment confounders across the treated and control groups.

Table 3
D&O Insurance, environmental regulation, and firms' environmental responsibility.

Variables	(1) $y = PatentI_{t+1}$	(2) $y = PatentU_{t+1}$	(3) $y = PatentIU_{t+1}$	(4) $y = EPI_{t+1}$
DOI	0.031	0.025	0.039	−0.006
	(1.142)	(0.633)	(0.844)	(−1.145)
StrongER	0.018**	0.014	0.029**	−0.002
	(2.327)	(1.445)	(2.305)	(−1.050)
DOI*×*StrongER	**0.248*****	**0.343*****	**0.424*****	**0.026*****
	(3.923)	**(4.636)**	**(4.965)**	**(2.972)**
SIZE	0.075***	0.073***	0.110***	0.003***
	(9.797)	(7.534)	(9.519)	(2.846)
LEV	−0.002	0.085*	0.062	−0.015**
	(−0.068)	(1.897)	(1.151)	(−2.285)
ROA	0.027	0.391***	0.356***	0.030
	(0.353)	(3.651)	(2.744)	(1.519)
LOSS	−0.000	0.012	0.014	0.005
	(−0.038)	(0.757)	(0.705)	(1.545)
CR	−0.025**	−0.026*	−0.035**	0.012***
	(−2.515)	(−1.714)	(−1.972)	(4.453)
BM	−0.053**	0.043	0.002	0.019***
	(−2.553)	(1.543)	(0.047)	(3.713)
TOP1	−0.038	0.028	−0.013	0.011
	(−1.005)	(0.593)	(−0.229)	(1.562)
DUAL	0.023**	0.017	0.028*	−0.002
	(2.307)	(1.300)	(1.769)	(−1.021)
SOE	0.004	−0.031**	−0.024	0.007***
	(0.326)	(−2.149)	(−1.251)	(2.746)
Intercept	−1.506***	−1.505***	−2.215***	−0.076***
	(−9.445)	(−7.490)	(−9.226)	(−3.476)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	23,851	23,851	23,851	23,851
Adj. R^2	0.110	0.146	0.165	0.041
DOI* + *DOI*×*StrongER	**0.279*****	**0.368*****	**0.463*****	**0.020****
(*P*-value)	(0.000)	(0.000)	(0.000)	(0.015)

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

5.2. Heckman's two-stage regression results

A firm's decision to purchase D&O Insurance may be non-random, and this may cause a self-selection bias that those firms that purchased D&O were also the "best kids in the class" and therefore have better environmental performance. For instance, firms with more green innovation or environmental protection investment may with more risk and may be more likely to purchase D&O Insurance. To mitigate this potential endogeneity concern, we employ the Heckman (1979) two-stage approach to conduct robust checks. In the first step, we estimate a probit model with a dummy *DOI* for D&O Insurance purchases as the dependent variable using the whole sample. Following prior research (Chung and Wynn, 2008; Yuan et al., 2016), we add the following determinants of D&O Insurance purchases: firm size (*SIZE*), financial leverage (*LEV*), the return on assets (*ROA*), whether a given firm has issued H-shares or B-shares (*FOREIGN*), whether a given firm is a state-owned enterprise (*SOE*), the proportion of independent directors (*BOARDINDEP*), equity ownership of the management (*MANHOLD*), whether a given firm has a violation record (*VIOLATION*), controlling shareholder's power, measured by the sum of shareholdings of the second to fifth largest shareholders divided by the shareholdings of the largest shareholder (*BALANCE*), book-to-market ratio (*BM*), and the mean incidence of D&O Insurance purchases for firms in the same industry in the same year, excluding the firm concerned (*MeanIndDOI*). All the above variables are defined in Appendix.

Firms in the same industry likely compete for the same pool of managerial talent. To compete effectively, compensation packages (e.g., including D&O Insurance coverage) need to be comparable to those offered by industry competitors (Adams et al., 2011; Chung et al., 2015). In addition, firms in the same industry face similar business conditions, including litigation risk. Therefore, we use *MeanIndDOI* as an exogenous IV because industry D&O Insurance mean coverage will correlate with a firm's D&O Insurance coverage but is unlikely to directly influence the firm's green innovation and environmental protection investment except through the firm's D&O coverage. The specification of the probit model is as follows:

$$\begin{aligned}\mathrm{DOI}_{i,t} =& \beta_0 + \beta_1 \times \mathrm{MeanIndDOI} + \beta_2 \times \mathrm{SIZE}_{i,t} + \beta_3 \times \mathrm{LEV}_{i,t} + \beta_4 \times \mathrm{ROA}_{i,t} \\ &+ \beta_5 \times \mathrm{FOREIGN}_{i,t} + \beta_6 \times \mathrm{SOE}_{i,t} + \beta_7 \times \mathrm{BOARDINDEP}_{i,t} + \beta_8 \\ &\times \mathrm{MANHOLD}_{i,t} + \beta_9 \times \mathrm{VIOLATION}_{i,t} + \beta_{10} \times \mathrm{BALANCE}_{i,t} + \beta_{11} \\ &\times \mathrm{BM}_{i,t} + \mathrm{Year\ Fixed\ Effects} + \mathrm{Industry\ Fixed\ Effect} + \varepsilon_{i,t}\end{aligned} \quad (2)$$

The inverse Mills ratio (*IMR*) is generated and then included in the second-step model to control for the potential sample selection bias. The specification of the second-step model is the same as the estimate models described in Section 3.4. Table 6 reports the regression results of the Heckman model. The results of the first-step regression in Panel A show that *SIZE*, *LEV*, *FOREIGN*, *SOE* and *BALANCE* have significant and positive impacts on a firm's decision to purchase D&O Insurance, whereas *ROA* and *MANHOLD* have significantly negative effects, which is basically consistent with prior research (e.g., Yuan et al., 2016). In Panel B, we can see that the coefficients on *DOI*×*StrongER* and *DOI* + *DOI*×*StrongER* continue to be significant and positive ($p < 0.05$) after controlling for the variable *IMR*, which indicates our results are robust after controlling for potential selection bias.

The environmental regulation variable *ER* (*StrongER*) used in our above tests is measured as government expenditure on environmental protection scaled by the fiscal revenue in each province, and thus it measures environmental regulation at the province-level. To make our

Table 4
PSM method.

Panel A: First stage		
Variables	$y = DOI$	
	(1) Logit regression	(2) Balance test
SIZE	0.581***	0.045
	(6.813)	(0.513)
LEV	0.861	0.354
	(1.542)	(0.589)
ROA	−1.138	−0.515
	(−0.744)	(−0.327)
LOSS	0.141	0.008
	(0.781)	(0.033)
CR	0.022	−0.082
	(0.127)	(−0.453)
BM	−0.529	−0.031
	(−1.306)	(−0.066)
TOP1	−1.407***	−0.534
	(−2.660)	(−0.913)
DUAL	−0.487***	−0.255
	(−2.588)	(−1.212)
SOE	0.689***	0.150
	(3.316)	(0.682)
Intercept	−15.540***	−0.866
	(−8.252)	(−0.471)
Year FE	Yes	Yes
Industry FE	Yes	Yes
N	23,851	2140
Pseudo R^2	0.146	0.0208

Panel B: Second stage				
Variables	(1)	(2)	(3)	(4)
	$y = PatentI_{t+1}$	$y = PatentU_{t+1}$	$y = PatentIU_{t+1}$	$y = EPI_{t+1}$
DOI	0.021	0.022	0.019	−0.004
	(0.607)	(0.475)	(0.333)	(−0.537)
StrongER	0.020	−0.019	−0.005	−0.002
	(0.625)	(−0.509)	(−0.101)	(−0.347)
DOI×StrongER	**0.170*** **	**0.303*** **	**0.354*** **	**0.028** **
	(3.057)	**(4.678)**	**(4.549)**	**(2.579)**
Controls	Yes	Yes	Yes	Yes
Intercept	−2.831***	−2.115***	−3.464***	−0.078
	(−6.275)	(−3.997)	(−5.629)	(−1.582)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	2140	2140	2140	2140
Adj. R^2	0.255	0.278	0.330	0.071
DOI + DOI×StrongER	**0.191*** **	**0.325*** **	**0.373*** **	**0.024*** **
(P-value)	(0.000)	(0.006)	(0.000)	(0.006)

Notes: Estimates in Panel A (B) are based on Logit (OLS) regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with z(t)-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

findings more robust, we employ the policy "Measures for environmental credit evaluation of enterprises (for Trial Implementation)"[10] jointly issued by the Ministry of environmental protection, National Development and Reform Commission, People's Bank of China, and China Banking Regulatory Commission at the end of the year 2013 to measure environmental regulation in the firm-level.

Specifically, this policy clearly stated that some types of enterprises should be included in the scope of environmental credit assessment, and the environmental protection department evaluated the environmental credit rating of enterprises according to their environmental behavior, including four grades: enterprises with environmental integrity, enterprises with good environmental protection, enterprises with environmental protection warnings, and enterprises with poor environmental protection. The government shall implement an incentive system for environmental protection integrity and a punishment system for environmental protection dishonesty.[11] This policy motivates firms to actively practice corporate environmental credit, to protect the environment, and to save resources, which leads to an exogenous shock of environmental regulation that firms exposed to. Therefore, we set a dummy variable *ShockER* for the exogenous shock of environmental regulation at the firm level, which suggests the environmental regulation that firms exposed to has increased. *ShockER* equals 1 for firm-year observations of firms influenced by the policy in and after 2014, and 0 otherwise. We then create an interaction term of *DOI* and *ShockER* to provide additional evidence for our hypothesis 1.

Table 7 reports the results. We show that the coefficients on the interaction term *DOI*×*ShockER* and *DOI* + *DOI*×*ShockER* are all significantly positive at the 10% (or better) level, which indicates D&O Insurance significantly advances firms' environmental responsibility performance, and this effect is more pronounced for firms exposed to increased environmental regulation. Therefore, these results provide supportive evidence for our hypothesis 1a.

To make our findings more robust, we employ the policy "Several Opinions on Accelerating the Development of Modern Insurance Service Industry" issued by the State Council of China issued in the year 2014 as a shock, which strengthens the compensation service of insurance issuers for their clients,[12] to perform a difference-in-differences (DID) test. According to the policy, to further protect the insured's interests, the government will strengthen the supervision over the insurance issuers. For example, the government encourages insurance issuers to provide insurance products and services with high quality, low price, and good faith for their clients. In addition, the government shall supervise insurance issuers to fulfill their obligations to insurance consumers fully, and seriously investigate and deal with all kinds of acts that damage the legitimate rights and interests of insurance consumers (such as implementing credit evaluation system and punishment mechanism for the dishonesty of the insurance institutions), to advance the quality of insurance issuers' claim settlement services.

Specifically, we perform the DID test using a balanced period with three years before and after the issuance of the policy (the year 2011–2016). We set a dummy variable *ShockDOI* equal to 1 for observations of treatment firms (firms purchase D&O Insurance throughout the entire 2011–2016 period) in and after 2014, and 0 otherwise. Firms with *ShockDOI* equal to 1 suggests the insurance compensation service for them improves. We also create an interaction term of *ShockDOI* and *StrongER* to provide additional evidence for our hypothesis 1. There are only 87 treatment firms that purchased D&O Insurance for the entire 2011–2016 period, therefore we use the characteristics of treatment firms in 2013 (the right year before the announcement of the policy) to match the control firms that do not purchase D&O Insurance for the entire 2011–2016 period. Particularly, we employ the one-to-one PSM matching without replacement and with a caliper of 0.01, using all the control variables used in our main regressions as the covariates in the first stage to match control firms. We obtain 87 pairs of matched firms by

[10] For more detail information, please refer to http://www.gov.cn/gongbao/content/2014/content_2667624.htm.

[11] In particular, for enterprises with environmental integrity, the government adopted incentive measures, such as giving priority to special funds for environmental protection and the establishment of environmental technology projects. For enterprises with poor environmental protection, the government adopted disciplinary measures, such as ordering them to regularly report the rectification of environmental problems to environmental protection departments, and increasing the frequency of law enforcement and supervision.

[12] For more detail information, please refer to http://www.gov.cn/zhengce/content/2014-08/13/content_8977.htm.

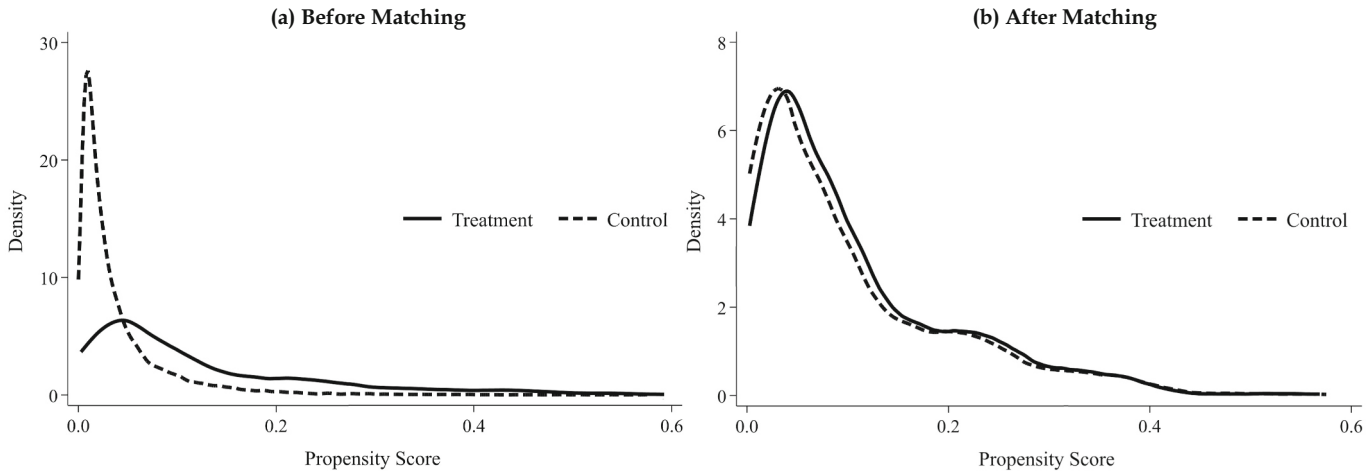

Fig. 1. Kernel density of propensity score before and after PSM.
The figure presents the distributions of propensity scores before and after propensity score matching (PSM). Specifically, Fig. 1(a) presents the propensity score before matching, and Fig. 1(b) presents the propensity score after matching.

Table 5
Entropy Balancing method.

Variables	(1) y = $PatentI_{t+1}$	(2) y = $PatentU_{t+1}$	(3) y = $PatentIU_{t+1}$	(4) y = EPI_{t+1}
DOI	0.016	0.033	0.033	−0.006
	(0.782)	(1.288)	(1.112)	(−1.451)
StrongER	−0.021	−0.013	−0.027	−0.002
	(−1.209)	(−0.595)	(−1.091)	(−0.706)
DOI*×*StrongER	**0.225*****	**0.286*****	**0.376*****	**0.027*****
	(5.804)	**(6.015)**	**(6.989)**	**(3.271)**
Controls	Yes	Yes	Yes	Yes
Intercept	−2.892***	−2.430***	−3.740***	−0.105***
	(−13.735)	(−10.009)	(−13.340)	(−3.170)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	23,851	23,851	23,851	23,851
R^2	0.267	0.284	0.332	0.078
DOI* + *DOI*×*StrongER	**0.241*****	**0.319*****	**0.409*****	**0.021*****
(P-value)	(0.000)	(0.001)	(0.000)	(0.003)

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

matching the nearest propensity score. Untabulated balance tests ensure no significant differences between the treatment and control groups in the relevant covariates in the year 2013.

We then use these 87 pairs' firm-year observations between 2011 and 2016 as the regression sample in this analysis. Table 8 reports the results. We show that the coefficients on *ShockDOI*×*StrongER* and *ShockDOI* + *ShockDOI*×*StrongER* are significantly positive at the 10% (or better) level, indicating firms' environmental responsibility performance increases with the compensation service of D&O Insurance, and this effect is more pronounced for firms exposed to higher environmental regulation. Therefore, these results provide supportive evidence for our hypothesis 1a.

5.3. Controlling for firm fixed effects

Although a fixed-effects (change analysis) estimating would alleviate the threat posed by correlated omitted variables including time-invariant selectivity, data inspection reveals that *DOI* status is highly stable during the sample period, with only 0.57% (0.03%) of the observations changing from *DOI* = 0 to *DOI* = 1 (*DOI* = 1 to *DOI* = 0). Notably, the poor within the variation of variable *DOI* would leave a fixed-effects (change analysis) estimating prone to failing to detect a significant relationship between *DOI* and environmental responsibility (e.g., Zhou, 2001; El Ghoul et al., 2016). Therefore, because *DOI* status suffers from minimal time-series variation in our setting, a fixed-effects (change analysis) estimating would yield inefficient estimates on the *DOI* test variable (Beck, 2001; Plümper and Troeger, 2007).

However, to ensure that our baseline regression results do not suffer from omitted variables, which may not vary with time, we continue to add firm fixed effects to our baseline model in Section 3.4. Results are reported in Table 9. Although a fixed-effects estimate in our setting is prone to failing to detect a significant coefficient estimating, we still show that the coefficients on *DOI*×*StrongER* and *DOI* + *DOI*×*StrongER* are all positive and significant ($p < 0.1$). Therefore, our findings are not likely to suffer from potential omitted variables.

5.4. Placebo tests

Given the firms that purchased D&O insurance account for only 4.2% of the sample observations, one may be concerned about whether the effect we document is simply a random outcome. To address this concern, we conduct placebo tests as follows. We randomly assign 1001 non-DOI firms (4.2% of the sample observations) as the pseudo DOI firms and use these firms as the treatment sample to re-run Eq. (1). Repeating this procedure for 1000 times, we generate 1000 sets of coefficients on *DOI*×*StrongER* for the four dependent variables. Fig. 2 plots the distributions of these coefficients. For all the dependent variables, the unreported *t*-tests fail to reject the null that the means are equal to zero. In fact, the actual estimate(s) of *DOI*×*StrongER* for the *PatentI* (*PatentU, PatentIU*, and *EPI*) regression(s) is (are) larger than *any* corresponding coefficients generated from the placebo data.[13] It follows that the chance to obtain coefficients for all the firms' environmental responsibility measures, as significant as we document from the actual data, is virtually zero.

[13] For the *PatentI*, *PatentU, PatentIU,* and *EPI* models, the maximum placebo-test (actual) estimates of the coefficients on *DOI*×*StrongER* are 0.155 (0.248), 0.266 (0.343), 0.276 (0.424) and 0.024 (0.026), respectively.

Table 6
Heckman-two stage analysis.

Panel A: First stage			
Variables	$y = DOI$		
	Coefficients		*Z*-statistics
MeanIndDOI	4.168***		12.959
SIZE	0.123***		6.551
LEV	0.555***		5.034
ROA	−0.598*		−1.693
FOREIGN	0.874***		17.407
SOE	0.161***		4.047
BOARDINDEP	0.498		1.563
MANHOLD	−1.983***		−8.370
VIOLATION	−0.054		−1.287
BALANCE	0.112***		3.724
BM	−0.132		−1.314
Intercept	−5.099***		−12.655
Year FE		Yes	
Industry FE		Yes	
N		23,851	
Pseudo R^2		0.210	

Panel B: Second stage				
Variables	(1)	(2)	(3)	(4)
	$y = PatentI_{t+1}$	$y = PatentU_{t+1}$	$y = PatentIU_{t+1}$	$y = EPI_{t+1}$
DOI	0.037	0.034	0.056	−0.006
	(1.360)	(0.861)	(1.179)	(−1.215)
StrongER	0.017**	0.013	0.027**	−0.001
	(2.244)	(1.333)	(2.162)	(−0.892)
DOI×StrongER	**0.249*****	**0.344*****	**0.426*****	**0.025*****
	(3.924)	**(4.637)**	**(4.964)**	**(2.945)**
IMR	0.028**	0.041**	0.071***	−0.002
	(2.165)	(2.367)	(3.284)	(−0.805)
Controls	Yes	Yes	Yes	Yes
Intercept	−1.729***	−1.825***	−2.760***	−0.064**
	(−10.196)	(−8.366)	(−10.261)	(−2.153)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
N	23,851	23,851	23,851	23,851
Adj. R^2	0.111	0.147	0.166	0.041
DOI + DOI×StrongER	**0.286*****	**0.378*****	**0.482*****	**0.019****
(P-value)	(0.000)	(0.000)	(0.000)	(0.018)

Notes: Estimates in Panel A (B) are based on Probit (OLS) regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses in Panel B. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix. 5.3 Firm-level environmental regulation based on an exogenous shock.

6. Additional tests

6.1. Cross-sectional tests based on state-owned-enterprises

Chinese SOEs are inherently politically connected to the government (Wang et al., 2008) and thus associated with considerable attention of the society and the government, which may exert pressure on them to actively practice their environmental responsibility (Buysse and Verbeke, 2003; Zhang, 2017; Liu and Kong, 2020). In this situation, insured SOEs may put more effort into environmental responsibility, and insured SOEs exposed to stronger environmental regulation have more motivations to achieve better environmental responsibility performance. Therefore, the moderating effect of environmental regulation between D&O Insurance and firms' environmental responsibility may be stronger for SOEs.

However, prior studies find that Chinese SOEs can obtain favorable treatment and support from the government (Wang et al., 2008). In this scene, insured SOEs' directors and officers and insurance issuers may not have a solid motivation to advance SOEs' environmental responsibility, and the effect of environmental regulation is weakened because the political connection can protect firms and their managers from litigation risk (Jia et al., 2019) and weaken environmental penalties (Lyon and Maxwell, 2008). Therefore, the moderating effect of environmental regulation may be stronger for Non-SOEs.

To test the above conjects, we divide the total sample into a subsample consisting of SOEs and another subsample consisting of Non-SOEs and perform a cross-sectional test. Table 10 reports the results. We show that the coefficients on *DOI×StrongER* are all significant for SOEs and overall significant for Non-SOEs, and the coefficients on *DOI×StrongER* are statistically larger for SOEs, which suggests that environmental regulation has a stronger positive moderating effect on the relationship between D&O Insurance and firms' environmental responsibility-taking for SOEs.

Table 7
Firm-level environmental regulation based on an exogenous shock.

Variables	(1)	(2)	(3)	(4)
	$y = PatentI_{t+1}$	$y = PatentU_{t+1}$	$y = PatentIU_{t+1}$	$y = EPI_{t+1}$
DOI	0.096**	0.062	0.109**	0.010
	(2.315)	(1.406)	(2.157)	(0.956)
ShockER	0.001	0.002	0.002	0.010***
	(0.117)	(0.141)	(0.149)	(2.916)
DOI×ShockER	**0.089****	**0.173*****	**0.208*****	**0.028***
	(1.988)	**(3.133)**	**(3.368)**	**(1.889)**
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Constant	−0.191*	−0.077	−0.162	0.042
	(−1.680)	(−0.490)	(−0.882)	(1.070)
Observations	23,851	23,851	23,851	23,851
Adj. R^2	0.578	0.602	0.665	0.254
DOI + DOI×ShockER	**0.185*****	**0.235*****	**0.317*****	**0.039****
(P-value)	(0.000)	(0.000)	(0.000)	(0.026)

Notes: *ShockER* is a dummy variable equal to 1 for observations in and after the year 2014 of firms influenced by the policy "Measures for environmental credit evaluation of enterprises (for Trial Implementation)," which is jointly issued by the Ministry of environmental protection, National Development and Reform Commission, People's Bank of China and China Banking Regulatory Commission at the end of the year 2013 to improve firms' environmental integrity and environmental protection performance. Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix. 5.4 Analysis of an exogenous shock for D&O Insurance.

6.2. Cross-sectional tests based on corporate governance

Prior literature documents that corporate governance significantly influences firms' environmental responsibility (e.g., Zhang et al., 2019). We argue that firms' environmental responsibility performance depends on corporate governance because firms need a good corporate governance environment to fulfill environmental responsibility. In a similar vein, the moderating effect of environmental regulation varies across firms with different corporate governance.

To provide evidence for this conjecture, we partition the whole sample into subsamples where firms with stronger corporate governance (*StrongGov* = 1) and firms with weaker corporate governance (*StrongGov* = 0). Prior literature documents that institutional investors play a positive role in corporate governance (e.g., An and Zhang, 2013; Callen

Table 8
Analysis of an exogenous shock for D&O Insurance.

Variables	(1) $y = PatentI_{t+1}$	(2) $y = PatentU_{t+1}$	(3) $y = PatentIU_{t+1}$	(4) $y = EPI_{t+1}$
ShockDOI	−0.034	−0.036	−0.089	−0.023
	(−0.473)	(−0.739)	(−1.253)	(−1.208)
StrongER	0.003	−0.025	−0.026	−0.003
	(0.074)	(−0.713)	(−0.639)	(−0.300)
ShockDOI×StrongER	**0.241****	**0.188***	**0.333****	**0.125****
	(1.999)	**(1.659)**	**(2.223)**	**(2.133)**
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Constant	−0.693	−0.250	−0.385	−0.118
	(−0.740)	(−0.264)	(−0.346)	(−0.489)
Observations	1039	1039	1039	1039
Adj. R^2	0.757	0.718	0.801	0.187
ShockDOI + ShockDOI×StrongER>0	**0.207****	**0.152***	**0.244****	**0.102****
(P-value)	(0.030)	(0.086)	(0.047)	(0.014)

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

Table 9
Fixed effects model.

Variables	(1) $y = PatentI_{t+1}$	(2) $y = PatentU_{t+1}$	(3) $y = PatentIU_{t+1}$	(4) $y = EPI_{t+1}$
DOI	0.093**	0.043	0.093*	0.012
	(2.495)	(0.999)	(1.926)	(1.092)
StrongER	0.007	−0.002	0.008	−0.001
	(1.393)	(−0.336)	(1.094)	(−0.774)
DOI×StrongER	**0.068****	**0.156*****	**0.174*****	**0.014***
	(2.179)	**(4.220)**	**(4.406)**	**(1.660)**
Controls	Yes	Yes	Yes	Yes
Intercept	−0.181	−0.047	−0.134	0.057
	(−1.609)	(−0.302)	(−0.732)	(1.462)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
N	23,851	23,851	23,851	23,851
Adj. R^2	0.578	0.602	0.665	0.252
DOI + DOI×StrongER	**0.161*****	**0.199*****	**0.267*****	**0.026****
(P-value)	(0.001)	(0.000)	(0.000)	(0.021)

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

and Fang, 2013), we, therefore, employ institutional investors' shareholding (*INS*) to measure corporate governance. Specifically, observations with *INS* equal to or above the median are classified into a subsample with stronger corporate governance (*StrongGov* = 1), and the rest are classified into another subsample with weaker corporate governance (*StrongGov* = 0). We then perform a cross-sectional test, and Table 11 reports the results. We show that the coefficients on *DOI*×*StrongER* are all significantly positive for firms with stronger corporate governance, but overall insignificant for firms with weaker corporate governance, and the coefficients on *DOI*×*StrongER* are overall statistically larger for firms with stronger corporate governance, which suggests the moderating effect of environmental regulation is stronger for firms with stronger corporate governance.

This section further investigates whether the moderating effects of environmental regulation are influenced by whether firms operate in heavy-polluting industries. Compared with firms in non-heavy-polluting industries, firms in heavy-polluting sectors are subject to stricter regulations. For example, firms in heavy-pollution industries suffer from more stringent verification for listing or refinancing applications by the State Environmental Protection Administration (State Environmental Protection Administration [2003] No.101, and [2007] No. 105). In addition, local environmental protection departments are increasingly strengthening the supervision of heavy-polluting industries. Therefore, we argue that the moderating effects of environmental regulation will be more substantial for firms in heavy-polluting industries because these firms are exposed to a higher risk of government sanction and litigation, and their directors and officers will have stronger motivation to practice environmental responsibility to avoid being sanction or sued, and the insurance issuers will exert stricter supervision on their environmental behavior to avoid potential compensation.

To test this conjecture, according to the classification standard of heavy-polluting industry provided by State Environmental Protection Administration [2003] No. 101 and [2007] No. 105, we divide the whole sample into a subsample consisting of firms in heavy-polluting industries (*Heavy* = 1) and another subsample consisting of firms in non-heavy-polluting industries (*Heavy* = 0)[14] and then conduct a cross-sectional test. Table 12 reports the results. We show that the coefficients on *DOI*×*StrongER* are all significant and positive in all columns except column (8), and the coefficients on *DOI*×*StrongER* are statistically larger for heavy-polluting industries firms, which suggests the moderating effect of environmental regulation is more pronounced for firms operating in heavy-polluting industries.

6.3. Cross-sectional tests based on the institutional environment

The institutional environment has a significant effect on corporate environmental orientation and practices (e.g., Roxas and Coetzer, 2012) because firms faced with the different institutional environments are exposed to various environmental costs and risks, which affects the environmental responsibility behavior of firms. We argue that the moderating effect of environmental regulation is more substantial in firms exposed to a stronger institutional environment because environmental regulation and institution environment form a joint force in

[14] For year prior in and prior 2006, we use the classification standard of heavy pollution industry provided by Environmental Protection Office [2003] No. 101 to classify the heavy-polluting industries firms, and for years in and after 2007, we the classification standard of heavy pollution industry provided by Environmental Protection Office [2007] No. 105 to classify the heavy-polluting industries firms.

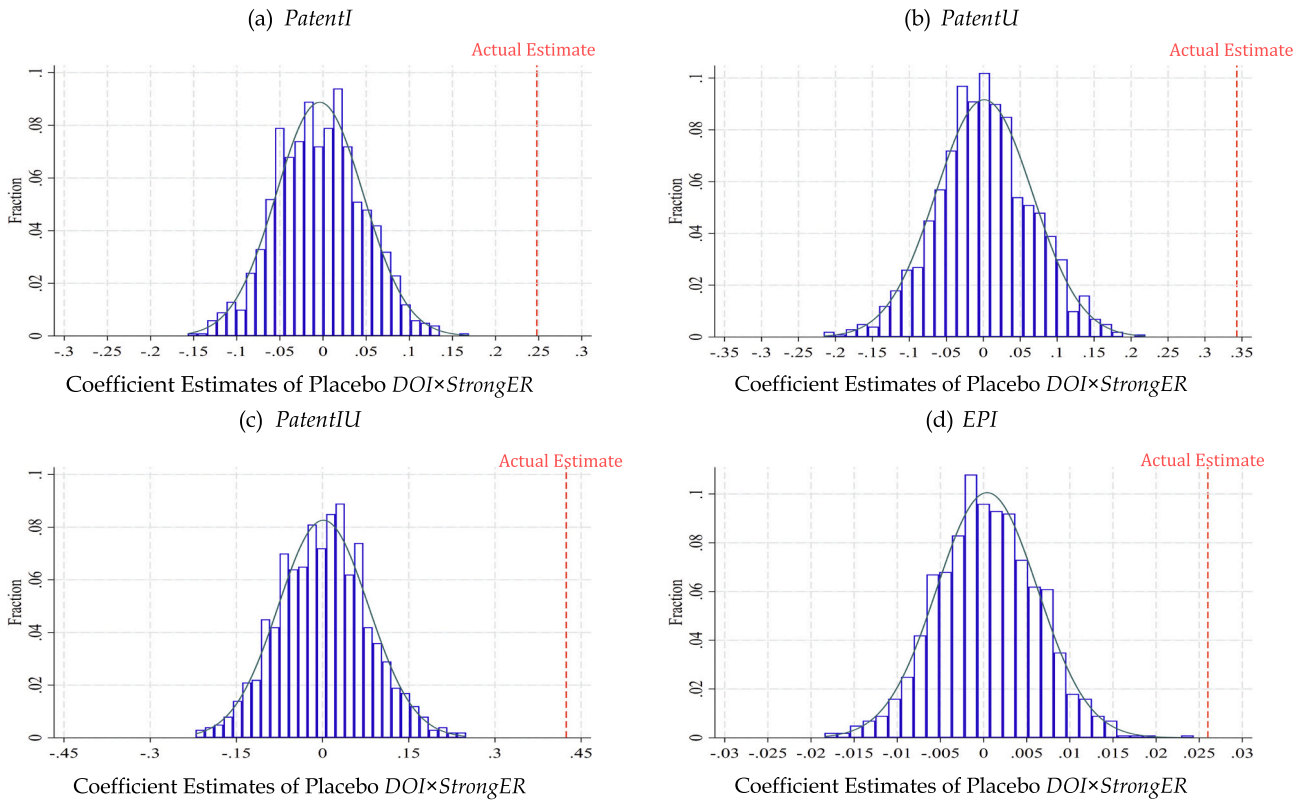

Fig. 2. Placebo tests.
The figure shows the distributions of the coefficients of *DOI×StrongER* estimated on 1000 samples where we randomly assign 1001 non-DOI firms (4.2% of the sample observations) as the pseudo DOI firms and use these firms as the treatment, relative to the coefficients estimated from the actual data.

Table 10
Cross-sectional tests based on state-owned-enterprises.

Variables	$y = PatentI_{t+1}$		$y = PatentU_{t+1}$		$y = PatentIU_{t+1}$		$y = EPI_{t+1}$	
	(1) *SOE* = 1	(2) *SOE* = 0	(3) *SOE* = 1	(4) *SOE* = 0	(5) *SOE* = 1	(6) *SOE* = 0	(7) *SOE* = 1	(8) *SOE* = 0
DOI	0.014	0.055	0.048	−0.014	0.043	0.028	−0.010	0.001
	(0.442)	(1.125)	(0.969)	(−0.218)	(0.730)	(0.377)	(−1.334)	(0.129)
StrongER	0.008	0.024***	0.012	0.014	0.013	0.038**	−0.002	−0.002
	(0.591)	(2.716)	(0.775)	(1.207)	(0.613)	(2.553)	(−0.513)	(−1.465)
DOI×StrongER	**0.274*** **	**0.166** **	**0.349*** **	**0.257*** **	**0.446*** **	**0.321*** **	**0.035*** **	**0.006**
	(3.470)	**(2.438)**	**(3.794)**	**(3.299)**	**(4.195)**	**(3.323)**	**(3.221)**	**(0.448)**
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	−1.874***	−1.185***	−1.872***	−1.192***	−2.747***	−1.794***	−0.057*	−0.090***
	(−7.230)	(−6.473)	(−5.783)	(−5.066)	(−7.036)	(−6.453)	(−1.821)	(−2.910)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	9339	14,512	9339	14,512	9339	14,512	9339	14,512
Adj. R^2	0.154	0.086	0.181	0.144	0.207	0.160	0.058	0.027
DOI* + *DOI×StrongER	**0.288*** **	**0.221*** **	**0.397*** **	**0.243*** **	**0.489*** **	**0.349*** **	**0.025** **	**0.007**
(P-value)	(0.000)	(0.003)	(0.000)	(0.002)	(0.000)	(0.001)	(0.011)	(0.542)
Coefficient differences tests for the interaction term *DOI×StrongER*								
Differences	**0.108*** **		**0.092*** **		**0.125*** **		**0.029*** **	
(P-value)	(0.000)		(0.000)		(0.010)		(0.000)	

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

advancing insured firms to pursue better environmental protection and green innovation performance and push insurance issuers to exert more stringent supervision on their clients' environmental responsibility practice. If the insured firms expose to a weaker institutional environment, environmental regulation may have little effect on client firms because the client can hardly be sanctioned or punished severely, and issuers suffer from low litigation risk without a strong institutional environment.

Therefore, we perform a cross-sectional test to test this conjecture. Specifically, following prior literature, we employ the marketization of each province to measure the institutional environment that firms are exposed to (e.g., Wang et al., 2008; Guan et al., 2016). We partition the whole sample into a subsample where firms located in provinces with marketization index (Wang et al., 2019) equal to or above the median (*StrongEnv* = 1) and another subsample where firms located in provinces with marketization index below the median (*StrongEnv* = 0). We then

Table 11
Cross-sectional tests based on corporate governance.

Variables	$y = PatentI_{t+1}$		$y = PatentU_{t+1}$		$y = PatentIU_{t+1}$		$y = EPI_{t+1}$	
	(1) *StrongGov* = 1	(2) *StrongGov* = 0	(3) *StrongGov* = 1	(4) *StrongGov* = 0	(5) *StrongGov* = 1	(6) *StrongGov* = 0	(7) *StrongGov* = 1	(8) *StrongGov* = 0
DOI	0.031	0.021	0.007	0.081	0.016	0.098	−0.006	−0.006
	(0.926)	(0.591)	(0.161)	(1.187)	(0.292)	(1.286)	(−0.871)	(−0.851)
StrongER	0.009	0.026***	0.016	0.008	0.021	0.032**	−0.002	−0.002
	(0.793)	(2.963)	(1.142)	(0.724)	(1.178)	(2.223)	(−0.684)	(−1.143)
DOI*×*StrongER	**0.274*** **	**0.121***	**0.392*** **	**0.108**	**0.486*** **	**0.147**	**0.027*** **	**0.017**
	(3.779)	**(1.944)**	**(4.768)**	**(1.100)**	**(5.029)**	**(1.343)**	**(2.701)**	**(1.187)**
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	−1.892***	−0.974***	−1.941***	−0.877***	−2.826***	−1.382***	−0.046	−0.110***
	(−8.467)	(−5.335)	(−7.022)	(−3.586)	(−8.506)	(−4.943)	(−1.609)	(−2.816)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	12,707	11,144	12,707	11,144	12,707	11,144	12,707	11,144
Adj. R^2	0.145	0.077	0.168	0.139	0.197	0.149	0.048	0.028
DOI* + *DOI*×*StrongER	**0.305*** **	**0.142** **	**0.399*** **	**0.189** **	**0.502*** **	**0.245** **	**0.021** **	**0.011**
(P-value)	(0.000)	(0.041)	(0.000)	(0.046)	(0.000)	(0.027)	(0.021)	(0.374)
Coefficient differences tests for the interaction term *DOI*×*StrongER*								
Differences	**0.153*** **		**0.284*** **		**0.339*** **		**0.010**	
(P-value)	(0.000)		(0.000)		(0.000)		(0.110)	

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the listed client company level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix. 6.3 Cross-sectional tests based on heavy-polluting industries.

Table 12
Cross-sectional tests based on heavy-polluting industries.

Variables	$y = PatentI_{t+1}$		$y = PatentU_{t+1}$		$y = PatentIU_{t+1}$		$y = EPI_{t+1}$	
	(1) *Heavy* = 1	(2) *Heavy* = 0	(3) *Heavy* = 1	(4) *Heavy* = 0	(5) *Heavy* = 1	(6) *Heavy = 0*	(7) *Heavy* = 1	(8) *Heavy = 0*
DOI	0.063	0.006	0.046	0.006	0.065	0.018	−0.009	−0.004
	(1.603)	(0.153)	(0.921)	(0.103)	(1.055)	(0.255)	(−0.798)	(−1.515)
StrongER	0.012	0.023**	0.011	0.020	0.017	0.040**	−0.004	−0.001
	(1.142)	(2.153)	(0.844)	(1.407)	(1.021)	(2.277)	(−1.026)	(−1.333)
DOI*×*StrongER	**0.279*** **	**0.237*** **	**0.418*** **	**0.284*** **	**0.494*** **	**0.381*** **	**0.045*** **	**0.006**
	(3.014)	**(2.865)**	**(3.799)**	**(3.071)**	**(3.962)**	**(3.431)**	**(2.641)**	**(1.622)**
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	−1.086***	−1.886***	−1.259***	−1.794***	−1.797***	−2.657***	−0.056	−0.063***
	(−5.801)	(−7.799)	(−4.853)	(−6.167)	(−5.966)	(−7.481)	(−1.257)	(−4.065)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	10,005	13,846	10,005	13,846	10,005	13,846	10,005	13,846
Adj. R^2	0.108	0.123	0.168	0.150	0.173	0.175	0.048	0.014
DOI* + *DOI*×*StrongER	**0.342*** **	**0.243*** **	**0.464*** **	**0.290*** **	**0.559*** **	**0.399*** **	**0.036** **	**0.002**
(P-value)	(0.000)	(0.003)	(0.000)	(0.002)	(0.000)	(0.000)	(0.021)	(0.425)
Coefficient differences tests for the interaction term *DOI*×*StrongER*								
Differences	**0.042** **		**0.134*** **		**0.113*** **		**0.039*** **	
(P-value)	(0.050)		(0.000)		(0.000)		(0.000)	

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

perform a cross-sectional test, and Table 13 reports the results. We show that the coefficients on *DOI*×*StrongER* are both significant and positive when firms are exposed to a stronger or weaker institutional environment, and the coefficients on *DOI*×*StrongER* are overall statistically larger for firms exposed to a stronger institutional environment. Overall, these finds support our above conjecture.

6.4. Discussion of the channel: the role of public supervision

Our evidence suggests that insured companies do better than non-insured ones in environmental responsibility-taking, evident in more green innovation achievement and environmental protection investment. In this section, we try to seek the economic mechanisms through which D&O Insurance may affect firms' environmental responsibility. As discussed in the Section 2.3, we explore two potential economic mechanisms: (1) whether D&O Insurance introduces insurance issuers' supervision on managers; and (2) whether firms with D&O Insurance receives stronger public supervision. However, due to the unavailability of data on insurance issuers' supervision on managers, we only empirically examine the economic mechanism (2), i.e., whether firms with D&O Insurance receives stronger public supervision.

Specifically, we first examine the impact of D&O insurance on the degree of public supervision using the following model:

$$PublicS_{i,t} = \beta_0 + \beta_1 DOI_{i,t} + \beta_2 SIZE_{i,t} + \beta_3 ROA_{i,t} + \beta_4 BM_{i,t} + \beta_5 TRADE_{i,t} + \beta_6 RETURN_{i,t} + \beta_7 STD_{i,t} + \beta_8 RD_{i,t} + \beta_9 CSI\ 800_{i,t} + Fixed\ Effects + \varepsilon_{i,t} \quad (2)$$

where *PublicS* is the degree of public supervision on the firms, measured

Table 13
Cross-sectional tests based on the institutional environment.

Variables	$y = PatentI_{t+1}$		$y = PatentU_{t+1}$		$y = PatentIU_{t+1}$		$y = EPI_{t+1}$	
	(1) *StrongEnv* = 1	(2) *StrongEnv* = 0	(3) *StrongEnv* = 1	(4) *StrongEnv* = 0	(5) *StrongEnv* = 1	(6) *StrongEnv* = 0	(7) *StrongEnv* = 1	(8) *StrongEnv* = 0
DOI	0.033	0.024	0.020	0.029	0.026	0.048	−0.008	−0.003
	(0.828)	(0.772)	(0.362)	(0.624)	(0.404)	(0.856)	(−1.480)	(−0.380)
StrongER	0.029***	0.014	0.031**	0.009	0.053***	0.021	−0.002	−0.002
	(2.744)	(1.315)	(2.243)	(0.667)	(3.107)	(1.196)	(−0.774)	(−0.654)
DOI*×*StrongER	**0.317*** **	**0.187** **	**0.424*** **	**0.271*** **	**0.556*** **	**0.305*** **	**0.027** **	**0.023***
	(4.007)	**(2.493)**	**(5.136)**	**(2.845)**	**(5.379)**	**(2.820)**	**(2.510)**	**(1.665)**
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	−1.640***	−1.434***	−1.388***	−1.634***	−2.242***	−2.258***	−0.089***	−0.066**
	(−7.204)	(−7.055)	(−4.926)	(−6.314)	(−6.481)	(−7.371)	(−3.076)	(−2.103)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	11,567	12,284	11,567	12,284	11,567	12,284	11,567	12,284
Adj. R^2	0.122	0.106	0.162	0.137	0.184	0.156	0.040	0.041
DOI* + *DOI*×*StrongER	**0.350*** **	**0.211*** **	**0.444*** **	**0.300*** **	**0.582*** **	**0.353*** **	**0.019***	**0.020***
(P-value)	(0.000)	(0.006)	(0.000)	(0.002)	(0.000)	(0.001)	(0.093)	(0.085)
Coefficient differences tests for the interaction term *DOI*×*StrongER*								
Differences	**0.130*** **		**0.153*** **		**0.251*** **		**0.004**	
(P-value)	(0.000)		(0.000)		(0.000)		(0.276)	

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

by standardization of the number of web searches for a listed companies in the current year. Following Dai et al. (2015), we control for firm characteristics that affect public supervision, including firm size (*SIZE*), return-on-asset ratio (*ROA*), book-to-market ratio (*BM*), whether a given firm engaged in insider trading in the current year (*TRADE*), annual stock return (*RETURN*), stock return volatility (*STD*), research & development (*RD*), and CSI 800 index membership (*CSI 800*). The detail definitions are provided in Appendix. We also include industry fixed effects and year fixed effects. We adopt the robust standard errors clustered at the firm level. Table 14, column (1) reports the results. As expected, the coefficient of *DOI* is significantly positive, suggesting that firms that purchased D&O Insurance receive stronger public supervision.

Second, we examine the impact of D&O insurance on the firms' environmental responsibility. We use *DOI* in year *t* as the independent variable, and *GI* (*PatentI*, *PatentU,* and *PatentIU*) and *EPI* in year $t + 1$ as dependent variables, respectively. All control variables are the same as Eq. (1). We include industry fixed effects and year fixed effects. We adopt the robust standard errors clustered at the firm level. For *GI* (*PatentI*, *PatentU,* and *PatentIU*), Columns (2), (4) and (6) of Table 14 show that the coefficients on *DOI* are significantly positive at the 1% level, indicating that insured firms significantly promote green innovation. For *EPI*, Column (8) of Table 14 indicates that insured firms significantly promote environmental protection investment, evident in the significantly positive coefficient of *DOI*. To sum up, insured firms significantly promote firms' environmental responsibility-taking.

Third, to estimate the direct effect of D&O Insurance on the firms' environmental responsibility, we use the following model to control for the degree of public supervision on the firms (*PublicS*):

$$EnvRes_{i,t+1} = \alpha_0 + \alpha_1 DOI_{i,t} + \alpha_2 PublicS_{i,t} + Controls + Fixed\ Effects + \varepsilon_{i,t} \quad (3)$$

Columns (3), (5) and (7) of Table 14 show that the coefficients of *DOI* remain significantly positive, indicating a positive and direct effect of D&O Insurance on green innovation. Similarly, Column (9) of Table 14 shows a positive and direct effect of D&O Insurance on environmental protection investment, evident in the significantly positive coefficient of *DOI*. Moreover, the coefficients on *PublicS* are all significantly positive in Columns (3), (5), (7) and (9) of Table 14. The result establishes a positive association between D&O insurance and public supervision.

In addition, to test the mediating effect of public supervision on the relation between D&O Insurance and firms' environmental responsibility, we multiply the coefficients from Eq. (2) (β_1) and Eq. (3) (α_2) and test the significance of the multiplicative coefficient ($\alpha_2 \times \beta_1$) using Sobel's test (Baron and Kenny, 1986). The results of Sobel's tests in Table 14 indicate that the multiplicative coefficients are all significantly positive at the 1% level, supporting that public supervision is an important channel through which D&O Insurance affects firms' environmental responsibility.

7. Conclusion

Employing the data on firms' green innovation achievement and environmental protection investment from China, where the information of D&O Insurance purchases was disclosed, we examine the relationship among directors' and officers' liability insurance, environmental regulation, and firms' environmental responsibility-taking. Our analyses show that insured firms significantly promote firms' environmental responsibility-taking, evident in more green innovation achievement and environmental protection investment. This positive association is more pronounced for firms exposed to stronger environmental regulation. In addition, we document that environmental regulation has a stronger positive moderating effect on the relationship between D&O Insurance and firms' environmental responsibility-taking for SOEs, firms with better corporate governance, operating in heavy-polluting industries, and exposed to a stronger institutional environment. Further mechanism analysis shows that public supervision appears to be the underlying channel through which D&O Insurance affects firms' environmental responsibility.

We provide novel evidence on whether firms with D&O Insurance are more likely to actively pursue and practice environmental responsibility and how environmental regulation motivates firms with D&O Insurance to take environmental responsibility. Our study contributes to the growing literature on the outcomes of D&O Insurance purchases and the determinants of firms' environmental responsibility-taking, as well as enriches the literature on the impacts of environmental regulation on firms' environmental responsibility-taking. We also contribute to the research related to sustainability and sustainable development in the field of ecological economics. Our findings imply that as one of the vital corporate governance mechanisms, D&O

Table 14
Economic mechanisms: D&O insurance and public supervision.

Variables	$y = PublicS$	$y = PatentI_{t+1}$		$y = PatentU_{t+1}$		$y = PatentIU_{t+1}$		$y = EPI_{t+1}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
DOI	**0.165****	**0.148*****	**0.144*****	**0.188*****	**0.185*****	**0.241*****	**0.236*****	**0.016*****	**0.016*****
	(2.074)	**(3.902)**	**(3.898)**	**(3.917)**	**(3.908)**	**(4.221)**	**(4.206)**	**(3.040)**	**(3.010)**
PublicS			**0.035*****		**0.026***		**0.039****		**0.002****
			(3.126)		**(1.948)**		**(2.545)**		**(2.227)**
LEV		−0.027	−0.018	0.041	0.048	0.008	0.019	−0.007**	−0.007**
		(−0.772)	(−0.513)	(0.853)	(1.009)	(0.145)	(0.332)	(−2.144)	(−2.017)
LOSS		−0.010	−0.008	0.001	0.003	−0.001	0.000	0.001	0.001
		(−0.760)	(−0.636)	(0.090)	(0.161)	(−0.063)	(0.024)	(0.282)	(0.321)
CR		−0.023**	−0.025**	−0.022	−0.023	−0.030	−0.032*	0.005***	0.005***
		(−2.373)	(−2.545)	(−1.365)	(−1.438)	(−1.637)	(−1.735)	(3.771)	(3.707)
TOP1		−0.026	−0.002	0.036	0.054	0.002	0.030	0.006	0.007**
		(−0.663)	(−0.046)	(0.715)	(1.098)	(0.029)	(0.488)	(1.644)	(1.999)
DUAL		0.020*	0.020*	0.012	0.012	0.022	0.022	−0.002**	−0.002**
		(1.862)	(1.892)	(0.890)	(0.901)	(1.309)	(1.326)	(−2.025)	(−2.019)
SOE		0.004	0.001	−0.033**	−0.035**	−0.024	−0.028	0.003**	0.003**
		(0.338)	(0.077)	(−2.182)	(−2.351)	(−1.253)	(−1.443)	(2.473)	(2.321)
SIZE	0.389***	0.083***	0.069***	0.081***	0.070***	0.121***	0.105***	0.003***	0.002***
	(15.781)	(9.421)	(8.923)	(7.410)	(7.063)	(9.251)	(8.843)	(4.117)	(3.015)
ROA	−1.629***	−0.078	−0.010	0.249**	0.299***	0.169	0.246*	0.005	0.009
	(−13.238)	(−0.895)	(−0.116)	(2.136)	(2.614)	(1.187)	(1.758)	(0.384)	(0.695)
BM	−1.001***	−0.077***	−0.042*	0.017	0.043	−0.033	0.006	0.007**	0.009***
	(−13.872)	(−3.183)	(−1.690)	(0.528)	(1.289)	(−0.835)	(0.145)	(2.335)	(2.891)
TRADE	−0.039								
	(−0.709)								
RETURN	−0.169***								
	(−9.283)								
STD	15.531***								
	(12.405)								
RD	−1.017*								
	(−1.875)								
CSI 800	0.113***								
	(4.730)								
Intercept	−8.199***	−1.639***	−1.367***	−1.641***	−1.436***	−2.397***	−2.086***	−0.063***	−0.048***
	(−15.918)	(−9.086)	(−8.641)	(−7.334)	(−7.036)	(−8.950)	(−8.578)	(−4.640)	(−3.643)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	21,282	21,282	21,282	21,282	21,282	21,282	21,282	21,282	21,282
Adj. R^2	0.481	0.110	0.115	0.144	0.145	0.164	0.166	0.030	0.031
Sobel tests for analysis of mediated relationships									
Sobel *Z*-value		**5.238*****		**5.174*****		**5.251*****		**4.200*****	
(P-value)		(0.000)		(0.000)		(0.000)		(0.000)	

Notes: Estimates are based on OLS regressions with standard errors adjusted for heteroscedasticity and clustered at the firm level. Numbers reported are regression coefficients with t-statistics in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively, based on two-tailed tests. All continuous variables are winsorized at the 1st and 99th percentiles. Variable definitions are presented in Appendix.

Insurance motivates directors and officers to actively practice firms' environmental responsibility by enhancing public supervision, and environmental regulation exerts a positive influence over this governance effect, which should be of interest to policymakers, enterprises, and other stakeholders in emerging market countries.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Data availability

The authors do not have permission to share data.

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Appendix A. Variable Definitions

Variables	Definitions
Panel A: Variables used in main empirical tests	
Dependent variables	
PatentI	The logarithm of one plus the number of granted green invention patents

(*continued on next page*)

(*continued*)

Variables	Definitions
PatentU	The logarithm of one plus the number of granted green utility model patents
PatentIU	The logarithm of one plus the total number of granted green invention patents and green utility model patents
EPI	Firms' environmental protection investment scaled by total assets then multiplied by 100
Key independent variables	
DOI	A dummy variable equals 1 if a given firm purchases D&O insurance in the fiscal year and 0 otherwise
ER	Environmental regulation, measured by the ratio of government expenditure on environmental protection to the fiscal revenue for each province where the listed firms are located
StrongER	A dummy variable equals 1 if *ER* is equal to or above the median and 0 otherwise
Control variables	
SIZE	Firm size, measured by the logarithm of the year-end total assets
LEV	Total liabilities divided by total assets at the end of the year
ROA	Net income divided by the total assets at the end of the year
LOSS	A dummy variable equals 1 if a given firm reports a loss in the current year and 0 otherwise
CR	Current assets divided by current liabilities at the end of the year
BM	Book to market ration
TOP1	The percentage of shares held by the largest shareholder at the year-end
DUAL	A dummy variable equals 1 if the CEO of a given firm is also the chairman and 0 otherwise
SOE	A dummy variable equals 1 if the ultimate controller of the firm is the government and 0 otherwise
Panel B: Other variables used in robust checks and additional tests	
MeanIndDOI	The mean incidence of D&O Insurance purchases for firms in the same industry in the same year, excluding the firm concerned
FOREIGN	A dummy variable equals 1 if a given firm issues H-shares or B-shares, and 0 otherwise
BOARDINDEP	The number of independent directors divided by the total number of directors for a given firm
MANHOLD	The proportion of shares held by top executives
VIOLATION	A dummy variable equals 1 if a given firm has a violation record in the current year and 0 otherwise
BALANCE	The ratio of the sum of the shareholdings held by the second to the fifth-largest shareholders divided by the shareholdings held by the largest shareholder
PublicS	Standardization of the number of web searches for a listed companies in the current year
TRADE	A dummy variable equals 1 if a given firm engaged in insider trading in the current year and 0 otherwise
RETURN	The annual stock return of an enterprise
STD	Standard deviation of daily stock returns over the fiscal year
RD	Research and development expenses divided by total assets at the end of the year
CSI 800	A dummy variable equals 1 if a given firm is included in the CSI 800 index

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