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Directors' and officers' liability insurance and firm innovation☆

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ABSTRACT

In this paper, we investigate the impact of directors' and officers' insurance (D&O insurance) on firm innovation in China. We find that D&O insurance is significantly positively associated with firm innovation, which indicates that D&O insurance enhances managers' tolerance for failure. To address endogeneity concerns, we adopt the propensity score matching method and difference-in-differences approach. We find that firms with D&O insurance have a stronger risk bearing capacity. Further analyses show that the impact of D&O insurance on firm innovation is more pronounced in firms with a better legal environment, male executives, and stronger external supervision.

1. Introduction

Innovation not only enhances enterprises' competitive advantage (Porter, 1992) but also drives national economic growth (Solow, 1957). Thus, a large number of studies on how to promote innovation, such as firm characteristics (Tian and Wang, 2011; Faleye et al., 2014; Sunder et al., 2017; Custódio et al., 2017; He and Tian, 2013), firm nature (Choi et al., 2011; Aghion et al., 2013; Minetti et al., 2015), financial constraints (Hottenrott and Peters, 2012), patent protection (Lerner, 2009; Gould and Gruben, 1996), labor law (Acharya et al., 2013a, Acharya et al., 2013b) and the working environment (Bloom et al., 2011). Manso (2011) argue that tolerance for failure in the short run and reward for success in the long run are important for promoting innovation. D&O insurance is designed to protect the directors, supervisors and senior management from liability and personal property losses caused by personal negligence or misconduct in the course of performing their duties. To some extent, D&O insurance increases the job security of managers, which implies that firms that offer D&O insurance are more tolerant of managers' failure in the short run. Thus, in this paper, we attempt to examine whether D&O insurance has any real effect on corporate innovation.

One challenge in studying D&O insurance is data availability. China provides a unique setting for us to overcome the data problem. The State Council issued "Opinions on the Reform and Development of the Insurance Industry" and "Opinions on Accelerating the Development of Modern Insurance Service Industry", both of which mention that it is necessary to vigorously develop D&O insurance. Taking advantage of the unique setting in China, we are able to provide rigorous empirical evidence about the causal impact of D&O insurance on corporate innovation.

We manually collected data on D&O insurance for Chinese public firms from their annual financial reports over the 2007–2016 period. Innovation output comes from a large panel of Chinese firms covered by the State Intellectual Property Office (SIPO) and European Patent Office (EPO). We find that the purchase of D&O insurance is positively associated with firm innovation. To address the endogeneity concerns, we adopt the propensity score matching (PSM) procedure and difference-in-differences (DID) approach. We then perform additional tests to examine the underlying economic mechanism of our findings. As expected, we find that firms with D&O insurance have stronger risk bearing capacity. Innovation can be viewed as a long-term risky investment. Thus, the stronger the risk bearing capacity of an enterprise, the easier it is to try and accept new methods and knowledge, and the easier it is to take active innovative behaviors to break through the old system and constraints.

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Further analyses show that the impact of D&O insurance on firm innovation is more pronounced in firms with a better legal environment, male executives, and stronger external supervision.

This paper contributes to the literature in three ways. First, we shed light on the impact of D&O insurance on firm risk-taking. Lin, Officer, Wang, and Zou (2013) find that D&O insurance is associated with higher loan spreads, because D&O insurance increases credit risk through moral hazard and information asymmetry. Similarly, Chen et al. (2016) find a positive association between D&O insurance and firm risk in terms of a firm's stock beta. Our paper is consistent with the existing literature that a firm with D&O insurance tends to take more risks by engaging in long-term risky investment. Our paper enriches the literature research on D&O insurance. Second, our paper finds that D&O insurance is significantly positively associated with firm innovation. Therefore, this paper uncovers a new factor affecting firm innovation and further enriches the literature on firm innovation. At last, Manso (2011) shows that long-term incentives and tolerance for short-term failure are essential to motivate innovation. Empirically, Tian and Wang (2011) document that tolerance for failure has a positive impact on corporate innovation. Acharya et al., 2013a, Acharya et al., 2013b find that stringent labor laws can promote innovation since labor law protects employees from being punished for short-term failures. Moreover, D&O insurance protects directors and officials from shareholders' litigation, which increases tolerance for short-term failure. Consistent with the literature on the impact of failure tolerance on corporate innovation, we show that D&O insurance significantly promotes a firm's innovation.

The rest of the paper is organized as follows: Section 2 introduces the institutional background. Section 3 reviews the related literature. In section 4, we develop our research hypotheses. Section 5 describes the construction of our data sample. Section 6 presents the empirical results. Section 7 concludes the paper.

2. Institutional background

D&O insurance originated in the United States, and the earliest launch time can be traced back to the 1930s; it gradually matured in the late 1960s. D&O insurance is purchased by a company to cover all directors and managers for the legal liability arising from their professional activities on behalf of the company. D&O insurance has been widely used in some developed countries, such as Canada, the US, and the UK (Zou et al., 2008). For example, 97% of US firms carry D&O insurance coverage, and 86%of Canadian firms are covered by this insurance. Even in Hong Kong, the percentage of D&O insurance coverage is between 60% and 70% (Yuan et al., 2016). Based on developed capital markets, prior studies have provided empirical evidence on the negative and positive impacts of D&O insurance on corporations. However, compared with the developed capital markets, China provides a different setting to examine the effect of D&O insurance on corporations.

The Chinese corporate sector is characterized by a highly concentrated ownership structure that is often dominated by a state-owned controlling shareholder (represented by government agencies) (Choi et al., 2011; Wei et al., 2005). Given that government agencies have effective control over company decisions, corporate governance is weak and the conflicts of interest between controlling and minority shareholders are severe (Young et al., 2008). Under China's Company Law, a corporation is required to have both a board of directors and a board of supervisors, which comprise the most important monitoring mechanisms. The Chinese securities regulatory commission (CSRC) adopted an independent director system in August 2001 in the hope that independent directors can monitor controlling shareholders on behalf of minority shareholders. Based on this situation, we study the impact of D&O insurance on enterprise innovation.

The introduction of D&O insurance came relatively late in China. The CSRC's Guiding Opinions on Establishing Independent Director System in Listed Companies issued in 2001 first noted that listed companies can establish an independent director liability insurance system to reduce risks that may arise from the normal performance of duties by independent directors. Subsequently, after the promulgation of the Guidelines for the Governance of Listed Companies and the Notice on Accepting Issues Concerning Civil Tort Disputes Caused by False Statements in the Securities Market in 2002, domestic insurance companies successively introduced D&O insurance. The first D&O insurance policy was signed by Vanke and Ping An Insurance at the end of 2002. At this point, the D&O insurance was accepted by domestic companies; however, its promotion was not very satisfactory. After more than a decade of development, the actual insurance coverage rate of D&O insurance was less than 5%. The reasons for this may include the following three points: first, D&O insurance in China started late and has been promoted for less than 20 years. Second, due to the domestic macro environment, industry characteristics and enterprise nature, there is no standardized policy format for D&O insurance, which may hinder its promotion. Finally, an imperfect litigation system and a low litigation rate hinder the development of D&O insurance.

However, with the continuous improvement of the domestic legal system and litigation system, D&O insurance is receiving increasing attention from Chinese regulatory authorities. Opinions on the Reform and Development of the Insurance Industry issued by The State Council on June 26, 2006, and Opinions on Accelerating the Development of Modern Insurance Service Industry issued by The State Council on August 10, 2014, all mentioned that it is necessary to vigorously develop D&O insurance and affirmed its functionality.

3. Literature review

3.1. Firm innovation

On the one hand, the research on enterprise innovation focuses on the theoretical and empirical aspects of innovation behavior and its influencing factors and has always been the focus of and difficulty faced by the domestic and foreign literature. After Schumpeter pioneered the influence of scale and monopoly power on corporate innovation activities, a large number of studies have attempted to study the innovative behavior patterns and key influencing factors of enterprises. Early theoretical research included the hypothesis of technological opportunity factors (Scherer, 1965) and the hypothesis of demand-market size pulling factors (Schmookler, 1966).

The follow-up research is based mainly on empirical evidence. This research tries to summarize the key factors that affect enterprise innovation activities from aspects of the external environment, firm nature, and firm characteristics. For example, Hottenrott and Peters (2012) find that financial constraints restrain innovation activities. Lerner (2009) find a puzzling result that the effect of patent protection on innovation is actually negative, which counters the findings of Gould and Gruben (1996). Acharya et al., 2013a, Acharya et al., 2013b find that laws that inhibit the common-law doctrine of employment-at-will can indeed motivate firms and their employees to undertake innovative and entrepreneurial pursuits. Feng et al. (2019) find that overall provincial globalization is associated with better innovation performance for Chinese firms. More specifically, economic, social, and political globalization present positive impacts on technological innovation. Wang, Feng et al. (2019) find that a leftist ruling party inhibits the progress of technical innovation, whereas a right-wing ruling party promotes the appearance of new technology. Wen et al. (2018a, 2018b) confirm that corruption is associated with innovation and corruption has a substantial positive impact on innovation only when it is over the threshold level.

In terms of firm nature, Choi et al., 2011 find that the influence of state and institutional ownership on innovation performance is positive but lagged. This finding is consistent with the conclusion of Aghion et al. (2013). However, they also find that insider ownership leads to lower innovation performance and that concentrated ownership has no significant impact on innovation. Similarly, Wen et al. (2018a, 2018b) confirm that the increase in stock liquidity would increase the number of patents

granted, R&D investment and the innovation efficiency of state-owned enterprises, while significantly reducing the innovation of private enterprises. In contrast, Minetti et al. (2015) argue that ownership concentration negatively affects innovation, especially by reducing R&D effort. Moreover, conflicts between large and minority shareholders appear to be a determinant of this effect.

For instance, managers' innovation incentives are motivated by corporate venture capital (Chemmanur, 2014), private equity ownership (Lerner et al., 2011; Bernstein, 2015), greater tolerance for failure (Ederer and Manso, 2013; Tian and Wang, 2011), lower analyst coverage (He and Tian, 2013), higher promotion-based tournament prizes for non-CEO executives (Jia et al., 2016) and pay gaps, which support the tournament theory (Xu et al., 2017). Beyond that, it also includes other firm characteristics (Manso, 2011; Faleye et al., 2014; Sunder et al., 2017; Custódio et al., 2017).

3.2. D&O insurance

On the other hand, regarding the research on D&O insurance, there are currently two conflicting views on D&O insurance and corporate governance. One view is that D&O insurance can provide protection for behaviors of directors and executives and has a "bottom line" role for management's property, which helps motivate managers to be aggressive, thereby alleviating potential agency problems, such as risk aversion (Romano, 1991; Core, 1997). The risk hedging mechanism of D&O insurance disperses the risk of claims caused by the manager's negligence into insurance premiums, which helps smooth the volatility of management's human capital compensation and reduces the risk of managers' practices. Therefore, to a certain extent, it can alleviate agency problems such as risk aversion or position retention (Core, 1997).

Boyer and Stern (2014) also confirm that D&O insurance enables small and medium-sized shareholders to meet the supervision and management requirements of the company's risk cash flow and risk assets at a lower cost, thereby optimizing board resolutions and improving corporate governance. Donley and Kent (2013) find that the existence of D&O insurance could lower a company's cost of bank loans (i.e., loan spreads) because the coverage could lower a firm's default risk and the insurance payout may be considered part of a company's asset base at the time of bankruptcy. Bhagat et al. (1987) use a sample of 11 New York-based firms and document a positive and marginally significant market reaction to the announcement of D&O insurance purchase.

From the perspective of corporate external governance, the insurer of D&O insurance can participate in corporate governance as an independent external supervisor (Mayers and Smith, 1990; Core, 2000). Holderness (1990) also considers that D&O insurance provides monitoring on directors and managers and forces them to engage in responsible conduct and deter wrongdoing. This type of effective external supervision mechanism of insurance companies is particularly important for large companies with a high proportion of external directors and a low shareholding ratio for managers. By externally supervising the company's investment decisions, the company's governance level may be improved (O'Sullivan, 1997).

In contrast, another view is that because D&O insurance provides protection for management's behavior, it has a "bottom line" effect that reduces the cost of management's self-interested behavior and may unintentionally induce and exacerbate the potential moral hazard problems of the management (Lin et al., 2011, 2013). Therefore, some scholars have found that D&O insurance has a negative impact on corporate governance. For example, Zou (2010) and Adams et al. (2011) show that the self-interested behavior of director executives is related to the degree of asylum of D&O insurance. When the cost of self-interested behavior is greater than the level of asylum, D&O insurance plays a positive role of "encouragement" and "supervision".

Chung and Wynn (2014) argue that D&O insurance could induce unintended moral hazard and reduce the incentive of managers to act in the best interest of stakeholders. Furthermore, D&O insurance reduces the disciplining effect of shareholder litigation (Baker and Griffith, 2010). Chen, Li and Zou find a positive association between D&O insurance and the cost of equity. At the same time, in the US, firms with protected directors by D&O insurance are more likely to accept a lower bid premium (Aguir et al., 2014). In the UK, D&O insurance is associated with higher audit fees (O'Sullivan, 2009).

Previous studies on D&O insurance have focused mainly on corporate governance, especially agency problems. For example, in terms of discussing the positive effects of D&O insurance, Core (2000) finds a significant association between D&O premiums and variables that proxy for the quality of firms' governance structures because the insurer of D&O insurance can participate in corporate governance as an independent external supervisor. Yuan et al. (2016) find that D&O insurance appears to reduce agency costs, enhance investor protection, and improve corporate governance. In discussing the negative effects of D&O insurance, Lin et al. (2013) find that D&O insurance will affect corporate lenders and loan terms and that higher levels of D&O insurance coverage are associated with higher loan spreads because D&O insurance may induce and exacerbate potential moral hazard problems. Similarly, Chung and Wynn (2014) find a positive association between D&O premiums and audit fees, suggesting that auditors charge higher fees to firms with heightened corporate governance risk. All these papers contribute to the growing literature on the corporate governance aspects of D&O insurance. However, few studies have studied the effect of D&O insurance on executives themselves. There is no doubt that the behavior and personality traits of executives will have a large impact on the company. Therefore, this paper focuses on this point and studies the effect of D&O insurance on executives themselves and then finds the impact on the company. Finally, we find that D&O insurance enhances managers' tolerance for failure and has a positive effect on firm innovation.

4. Hypotheses development

Previous studies have noted that the existence of D&O insurance can provide a "bottom line" effect for the management of the company in terms of behavior and personal property. However, this "bottom line" effect may have positive or negative effects on the management of the company. Therefore, D&O insurance may also have positive or negative effects on corporate innovation.

In terms of positive impact, D&O insurance can encourage managers to make positive progress, allowing managers to fully display management skills and improve corporate governance. Core (1997) believes that D&O insurance can motivate managers to be aggressive and alleviate potential agency problems such as risk aversion. Holderness (1990) considers that D&O insurance provides monitoring on directors and managers and forces them to engage in responsible conduct and deter wrongdoing. Meanwhile, Manso (2011) notes that long-term compensation plans, performance feedback and job security are all important for stimulating innovation when investing in innovation motives, and the "bottom line" effect of D&O insurance will also play a role in safeguarding the work of the manager. Therefore, D&O insurance may also promote innovation.

At the same time, unlike routine investments, innovation projects are long-term idiosyncratic investments that are full of uncertainty and have a high probability of failure (Holmstrom, 1989). These features of innovation projects increase the turnover and volatility of company stocks as well as the likelihood of large price declines (Chen et al., 2001). Meanwhile, prior literature suggests that stock return volatility, stock turnover, and downside risk increase the likelihood of shareholder litigation (both class actions and derivative suits) (Bourveau et al., 2018). Therefore, the fear of litigation risk provides a disincentive for risk-averse managers to engage in innovation activities that are inherently risky.

However, D&O insurance can lower directors' and officers' litigation exposures, alleviate the potential risk aversion problem and increase their risk appetite, thereby improving the risk-taking ability of the

enterprise and enabling them to invest more in innovation. Coles et al. (2006) found that CEOs who are more sensitive to the stock volatility of listed companies are more likely to make riskier investments, including more R&D investments. The increase in R&D investment will promote enterprises' innovation. Mao and Zhang (2018) further noted that the risk incentives faced by CEOs have a significantly positive relationship with corporate innovation, that is, increasing the risk appetite of CEOs can promote enterprise innovation. Therefore, we obtained the following test hypothesis:

H1A. *The "bottom line" effect of D&O insurance can increase managers' risk appetite and improve the risk-taking ability of enterprises, thus promoting enterprise innovation.*

In contrast, the negative impact of D&O insurance is manifested in its "bottom line" effect that can trigger management's moral hazard, causing management to be self-interested. Zou (2010) has shown that the self-interested behavior of director executives is related to the degree of asylum of D&O insurance. Chung and Wynn (2014) argue that D&O insurance could induce unintended moral hazard and reduce the incentive of managers to act in the best interest of stakeholders. Baker and Griffith (2010) support that D&O insurance reduces the disciplining effect of shareholder litigation, which, may consume or waste corporate resources and have a negative long-term impact on business management and cause firms to reduce long-term investments. In turn, it may have a negative impact on corporate innovation. Therefore, another competitive hypothesis is as follows:

H1B. *The "bottom line" effect of D&O insurance may make management self-interested, which will cause managers to reduce long-term investments, thus hindering corporate innovation.*

5. Research design

5.1. Construction of the sample

Our sample comprised Chinese A-share listed firms from 2007 to 2016. We choose 2007 as the beginning year of our sample period because since 2007, the Shenzhen Stock Exchange and the Shanghai Stock Exchange have forced companies to disclose R&D investment data, and R&D investment is one of the most important factors affecting enterprise innovation. Therefore, it needs to be a control variable in research. The data on D&O insurance are manually collected from annual reports and disclosed minutes of boards' and shareholders' meetings, and the other financial data are from China Stock Market Accounting Research (CSMAR). We exclude financial firms (e.g., banks, insurance companies, and investment trusts), ST companies (special treatment companies, whose financial situation is abnormal) and companies with missing data. At the same time, we winsorize our sample at 1% in both tails and ultimately obtain 10,853 firm-year observations.

5.2. Variables

Following prior studies (Zou et al., 2008), we adopt a dummy variable (INSURANCE) to measure D&O insurance, which equals 1 if a firm purchases D&O insurance in a given year and 0 otherwise.

There are three types of patents granted under the Chinese patent law: invention patents, utility model patents, and design patents. Compared with invention patents, utility model patents have lower levels of creativity and technology, but they have great practical value. Therefore, people also call them "small inventions" or "small patents". Design patents are given mainly for the design of industrial products, focusing on the design of shapes, patterns and colors.

This paper refers to the studies of Tan et al. (2015) and Jia and Tian (2018) and measures enterprise innovation by the number of patent applications and final authorization. Our first measure of innovation output is Patent12, defined as the total number of invention and utility model patents that are applied and eventually granted to a firm in a given year. Our second measure of innovation output is Patent123, defined as the total number of three types of patents that are applied and eventually granted to a firm in a given year. We define the variable by application year rather than by granting year because previous research shows that application year is a better proxy for the actual time of innovation (Griliches, 1987). To address concerns related to variable skewness, we use the natural logarithm of one plus Patent12 and one plus Patent123 as the main innovation outcome measure in our analysis. We finally obtain the interpreted variables LOGPAT12 and LOGPAT123.

We first control for a set of firm-level characteristics. We adopt the R&D expenses scaled by total assets (R&D) to proxy for the innovation input. The tangible assets are measured as the property, plant and equipment scaled by total assets (PPE). Because innovative activities require substantial investment, financially constrained firms will suppress innovation (Bergemann and Hege, 2005). We include the SA index to measure financial constraints constructed by Hadlock and Pierce (2010) as an additional control variable. We also include the natural logarithm of total assets (SIZE) for firm size, return on assets (ROA) to measure firm performance, the cash-to-assets ratio (CASH) to account for the effects of cash holding, and financial leverage (LEVERAGE) for capital structure. FIRMAGE is calculated as the log value of the number of years since a firm is established and is used to control for the life-cycle effect. Additionally, we control for the Herfindahl index (HHI) and its squared term (HHI2), as Aghion et al. (2013) suggest an inverted U-shape between product market competition and innovation. Variable definitions are listed in Appendix 1.

5.3. Descriptive statistics

Table 1 reports the descriptive statistics for the variables in our sample. The mean values of LOGPAT12 and LOGPAE123 are 2.92 and 3.12, respectively. Meanwhile, the mean value of INSURANCE is 0.01, indicating that only 1% of firm-year observations carry D&O insurance in our sample, which is significantly lower than that in western countries.[1]

Table 2 shows the univariate comparison between firms that purchased D&O insurance and those that did not. $LOGPAT12_{t+1}$ is significantly lower in the without D&O insurance sample (2.9 vs. 4.635), and the difference is statistically significant at the 1 percent level. Similarly, $LOGPAT123_{t+1}$ is significantly lower in the sample without D&O insurance (3.103 vs. 4.775), and the difference is also statistically significant at the 1 percent level. This finding is consistent with the hypothesis of H1a that D&O insurance has a positive effect on enterprise innovation. FIRMAGE is significantly lower in the without D&O insurance sample than in the purchased D&O insurance sample, which indicates that the older the company is, the easier it is to buy D&O insurance. SIZE suggests that the larger the company is, the easier it is to buy D&O insurance. LEVERAGE is also significantly lower in the without D&O insurance sample than in the purchased D&O insurance sample, which indicates that firms with a higher risk of default would be more inclined to purchase D&O insurance. This phenomenon may explain why higher levels of D&O insurance coverage are associated with higher loan spreads (Lin et al., 2013).

6. Empirical analyses

6.1. Baseline OLS regression

To test our main hypothesis, we start with baseline OLS and regress a firm's innovation output on D&O insurance using the following baseline model:

[1] Since our sample excludes the data on the financial industry, we lose a significant portion of firms adopting D&O insurance.

Table 1
Summary statistics.

Variable	mean	sd	p25	p50	p75	min	max	N
LOGPAT12	2.92	1.84	1.39	3.09	4.2	0	7.13	10,853
LOGPAT123	3.12	1.85	1.95	3.33	4.41	0	7.29	10,853
INSURANCE	0.01	0.1	0	0	0	0	1	10,853
HHI	0.05	0.07	0.01	0.01	0.03	0.01	0.35	10,853
HHI^2	0.01	0.02	0	0	0	0	0.12	10,853
CASH	0.21	0.16	0.1	0.16	0.28	0.02	0.71	10,853
ROA	0.04	0.05	0.02	0.04	0.07	−0.15	0.19	10,853
FIRMAGE	1.88	0.91	1.39	1.95	2.71	0	3.14	10,853
PPE	0.23	0.15	0.11	0.2	0.31	0.01	0.67	10,853
SA	−3.45	0.27	−3.67	−3.4	−3.23	−4.05	−2.93	10,853
SIZE	21.94	1.23	21.04	21.74	22.62	19.79	25.7	10,853
R&D	0.02	0.02	0	0.01	0.02	0	0.07	10,853
LEVERAGE	0.15	0.14	0.02	0.12	0.23	0	0.54	10,853
MEAN_RISKBEARING	0.16	0.36	0	0	0	0	1	10,853
LAW_ENVIRONMENT	0.48	0.5	0	0	1	0	1	7936
FEMALE_RATIO	0.39	0.49	0	0	1	0	1	10,853
ANALYST	0.57	0.5	0	1	1	0	1	10,248

Table 2
Firm characteristics across samples. ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively. Variable definition is listed in Table 1.

Variables	INSURANCE = 0		INSURANCE = 1			
	N	Mean	N	Mean	Difference	t-Value
$LOGPAT12_{t+1}$	8455	2.9	88	4.635	−1.735***	−8.771
$LOGPAT123_{t+1}$	8455	3.103	88	4.775	−1.672***	−8.409
HHI	8455	0.049	88	0.029	0.019**	2.236
HHI^2	8455	0.009	88	0.002	0.007**	2.3
CASH	8455	0.221	88	0.155	0.066***	3.844
ROA	8455	0.047	88	0.037	0.010*	1.768
FIRMAGE	8455	1.834	88	2.486	−0.652***	−6.653
PPE	8455	0.224	88	0.283	−0.058***	−3.651
SA	8455	−3.435	88	−3.473	0.039	1.312
SIZE	8455	21.888	88	24.14	−2.252***	−17.254
R&D	8455	0.018	88	0.011	0.008***	4.366
LEVERAGE	8455	0.141	88	0.168	−0.027*	−1.844

$$Innovation_{i,t+1} = \alpha + \beta Insurance_{i,t} + Controls + Year\ Fixed\ Effect + Industry\ Fixed\ Effect + \varepsilon_{i,t} \quad (1)$$

where $Innovation_{i,t+1}$ represents the innovation output (LOGPAT12 or LOGPAE123) of firm i headquartered in year T+1. Because innovation is a long-term process, we adopt the one-year-head value of LOGPAT12 and LOGPAE123 as the dependent variables in the regression. The key independent variable is Insurance, which is an indicator variable that equals one if a firm carries D&O insurance in a given year, zero otherwise. Controls represent the firm-level control variables, including firm size, ROA, leverage, cash holding, PPE, firm age, HHI, and financial constraints. We also include industry fixed effects and year fixed effects. We adopt the robust standard errors clustered at the firm level in all regressions.

We report the results for baseline regression in Table 3. We find a positive and significant relationship between D&O insurance and innovation. The coefficients of Column (1) are positive and statistically significant at the 5% significance level, and the coefficients of Column (2) are positive and statistically significant at the 10% significance level, which indicates that firms whose directors and officers have D&O insurance have more innovation outputs. Economically, D&O insurance increases patent12 counts by almost 1.7% (=0.1*0.509/2.92) from its mean value. Similarly, D&O insurance increases patent123 counts by almost 1.5% (=0.1*0.469/3.12) from its mean value. This result is consistent with the conclusions of previous studies about the positive impact of D&O insurance on corporate governance (Core, 1997).

The coefficients of other control variables are generally consistent with those found in previous studies. For example, firm size and profitability are positively related to innovation output, suggesting that larger and profitable firms are more likely to engage in innovative activities (Lerner, 1995; Hall and Ziedonis, 2001). The coefficient on leverage is negative and highly significant, indicating that financially constrained firms are less likely to invest in long-term projects (Atanassov, 2013; Whited, 1992). As the innovation input, R&D is positively related to innovation output.

D&O insurance is not a purely random event or an exogenous decision. While we document a positive association between D&O insurance and innovation output, the results are potentially subject to endogeneity, and we still need to identify the causal effect of D&O insurance on innovation outputs. First, the purchase of D&O insurance may be self-selective, leading to a reverse causality concern. On the one hand, D&O insurance can enhance firm innovation; on the other hand, firms

Table 3
Baseline regression. In this table, we examine whether D&O insurance is related to corporate innovation. Variable definition is listed in Appendix 1. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	(1)	(2)
	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$
INSURANCE	0.509**	0.469*
	(0.240)	(0.245)
HHI	−2.273	−1.849
	(2.029)	(2.162)
HHI^2	6.112	4.812
	(3.784)	(3.958)
CASH	−0.403**	−0.266
	(0.197)	(0.202)
ROA	0.897*	1.144**
	(0.481)	(0.499)
FIRMAGE	0.118*	0.122*
	(0.0638)	(0.0649)
PPE	−0.280	−0.382
	(0.241)	(0.248)
SA	0.611**	0.552**
	(0.237)	(0.239)
SIZE	0.689***	0.693***
	(0.0343)	(0.0344)
R&D	26.87***	25.95***
	(1.938)	(1.960)
LEVERAGE	−0.461*	−0.614**
	(0.249)	(0.256)
Constant	−12.81***	−12.82***
	(0.843)	(0.863)
Year fixed effects	yes	yes
Industry fixed effects	yes	yes
Observations	8543	8543
R-squared	0.447	0.422

with higher innovation output will be more willing to buy D&O insurance because for executives, innovation is a long-term investment with high risk. Second, omitted variables that simultaneously affect D&O insurance and innovation output could also result in a spurious causality between D&O insurance and innovation, such as a brain gain among management or/and employees. Therefore, a correlation between D&O insurance and innovation output may tell us little about the causal effects of D&O insurance on innovation. To alleviate this problem, we adopt the PSM approach and the DID approach to address possible endogeneity issues.

6.2. PSM procedure

We first control for the potential endogeneity between the D&O insurance purchase decision and firm innovation by comparing insured firms with a sample of control firms matched on the propensity to purchase D&O insurance. The primary benefit of using a control sample matched on propensity scores is that it allows us to compare the D&O-insured firms with a set of firms that are the same on all observable dimensions, thus allowing us to more clearly attribute any observed effects to D&O insurance purchase itself rather than to the firm characteristics associated with D&O insurance purchase (Bowen et al., 2010).

To identify the propensity-score matched control sample, we estimate a LOGIT model using the full sample. We then calculate a propensity score for each firm, which is the conditional probability that a firm purchases D&O insurance, given all the observable data. For each D&O-insured firm, we select three control firms with the closest propensity scores; these firms constitute the propensity-score matched control sample, and we ended up with 423 firm-year observations.[2] Finally, we re-estimate model (1) using the insured and matched control samples. The results are reported in the OLS regression in Table 4.

In the OLS regression of Table 4, the coefficients of INSURANCE in columns of LOGPAT12 and LOGPAT123 are significantly positive at the 10% and 5% levels, respectively, which suggests a positive relationship between D&O insurance and firm innovation. This conclusion is consistent with the previous conclusions.

To ensure that the matching is satisfactory, we demonstrate the distribution of propensity scores before and after matching, as shown in Fig. 1. In the figure, the blue line represents the treatment group, and the red line represents the control group. Through comparative analysis, it can be seen that the score deviation between the two groups is significantly corrected by the propensity score matching, and the matching effect is relatively ideal. Moreover, we further adopt the balance test, and the test results are shown in Appendix 3. As seen from Appendix 3, the standardized deviation (% bias) of variables after matching is significantly reduced, and the standardized deviation of most variables is less than 20%, indicating that the matching effect is effective.

6.3. DID approach

In the previous section, we show that there is a positive relation between D&O insurance and firm innovation. To further alleviate the endogeneity problem, consolidate the causal relationship between D&O insurance and firm innovation, and ensure the credibility of research conclusions, we implement a DID approach to examine the impact of D&O insurance on firm innovation.

The DID approach has two key advantages. First, it rules out omitted trends that are correlated with D&O insurance and innovation in both the treatment and the control groups. Second, the DID approach helps establish causality because tests are conducted surrounding policy changes that cause exogenous variation in the change in purchasing D&O insurance (the main independent variable). As an example of a reverse causality concern, high levels of R&D and innovation may expose executives to greater litigation risk, which in turn may promote the purchase of D&O insurance.

The most important thing when using the DID approach is to find exogenous shocks. Meanwhile, O'Sullivan (2002) takes large British companies as examples and finds that companies with higher litigation risks are more likely to purchase D&O insurance to reduce the risks of their management. Therefore, in this paper, we choose the amendment of the civil procedure law on August 31, 2012, as the exogenous shock. The newly amended civil procedure law further supplements the scope of civil litigation and strengthens the status of civil procedure law, so it encourages civil litigation and promotes the occurrence of civil litigation cases.

However, the effect of the amendment of the civil procedure law is different for all industries. Because of the differences in the nature, characteristics and products of various industries, they face different litigation risks. For example, the litigation risk faced by the pharmaceutical industry is higher than that of agriculture. Therefore, we believe that the amendments of the civil procedure law will have a greater impact on industries that are already at high litigation risk. Furthermore, we make the following reasonable speculation: in industries where the risk of civil litigation is originally high, the amendment of civil procedure law will further promote the occurrence of civil litigation and thus encourage enterprises to purchase D&O insurance.

Based on the above analysis, we construct a treatment group and a control group of firms using the median of the number of lawsuits in all industries in 2012. At the same time, we construct a dummy variable TREAT. If the number of lawsuits is greater than the median of the number of lawsuits in all industries in 2012, the industry is defined as the treatment group, and TREAT equals one. In other industries, we define it as a control group, and TREAT equals zero. We also construct another

Table 4
Propensity-matched sample analysis. The regression results are based on the estimation using PSM procedure. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

Variables	(1)	(2)
	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$
INSURANCE	0.606*	0.693**
	(0.327)	(0.326)
HHI	77.12	133.8
	(99.65)	(97.39)
HHI^2	−349.1	−662.4
	(518.9)	(505.6)
CASH	−0.328	−0.630
	(1.579)	(1.635)
ROA	−1.144	0.0784
	(3.073)	(3.678)
FIRMAGE	1.225***	1.027**
	(0.384)	(0.435)
PPE	0.320	0.108
	(1.563)	(1.577)
SA	2.852***	2.112**
	(0.910)	(0.983)
SIZE	0.678***	0.749***
	(0.212)	(0.214)
R&D	24.79*	25.35*
	(14.16)	(13.64)
LEVERAGE	1.357	0.734
	(1.532)	(1.598)
Constant	−12.54	−18.69**
	(8.033)	(8.234)
Year fixed effects	yes	yes
Industry fixed effects	yes	yes
Observations	179	179
R-squared	0.794	0.783

[2] For each D&O insured firm, we select three control firms with the closest propensity scores. After PSM, we ended up 423 firm-year observations. Given the fact that we adopt the forward value in the dependent variable, we end up with 179 observations in the subsample.

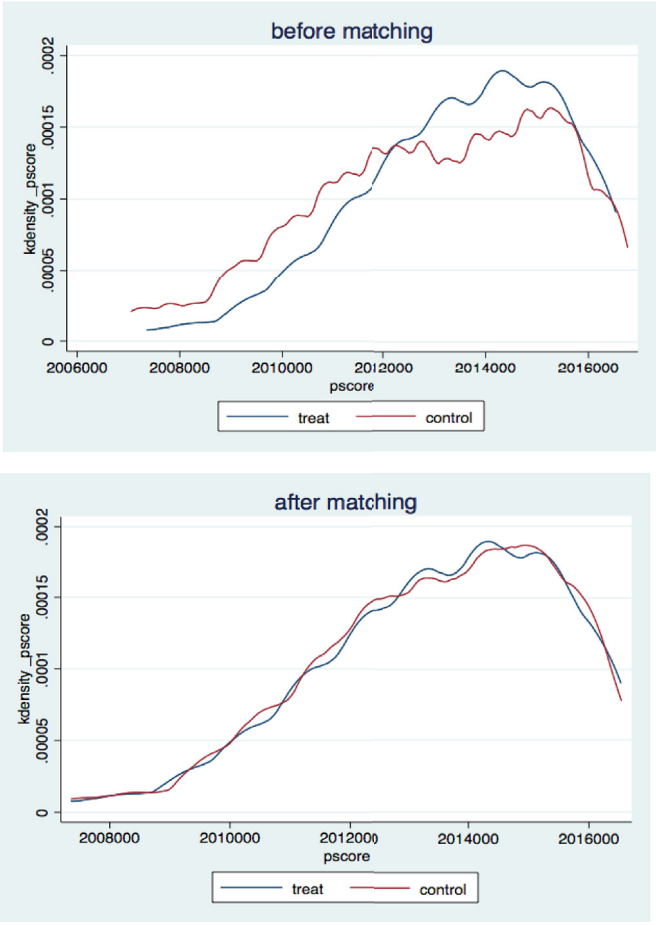

Fig. 1. The distribution of propensity scores matching process This figure reports the distribution of propensity scores before and after matching. The blue line represents the treatment group and the red line represents the control group. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

dummy variable, POST, and if the year is after 2012, POST equals one and zero in other years. The DID model is constructed referencing Bertrand and Mullainathan (2003) as follows:

$$Innovation_{i,t+1} = \alpha + \beta Treat{*}Post_{i,t} + Controls + \quad Year\ Fixed\ Effect + Firm\ Fixed\ Effect + \varepsilon_{i,t} \tag{2}$$

Table 5 reports the results of the DID model. In the case of the controlling year and firm fixed effects, the coefficients of TREAT*POST in columns of LOGPAT12 and LOGPAT123 are both positive and statistically significant at the 5% level. Therefore, it can be explained that the amendment of the civil procedure law does promote enterprises to purchase D&O insurance, thus promoting firm innovation.

Because the validity of the DID estimate critically depends on the parallel trend assumption, we first demonstrate the growth trend of firm innovation before and after exogenous shocks, as shown in Fig. 2. The average innovation is captured by the mean number of patent12 and patent123. As shown in Fig. 2, before 2013, the innovation growth trend of the treatment group (blue line) and the control group (red line) is basically the same, but after 2013, the innovation growth trend of the treatment group and the control group obviously changes, indicating that our sample met the parallel trend assumption.

At the same time, we construct estimating equation (3) to illustrate that the parallel trend assumption is satisfied, and the variable definitions in equation (3) refer to Appendix 1.

Table 5
Difference-in-Difference Approach. The regression results are based on the estimation using Difference-in-Difference approach. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	DID		Pre-trend test	
	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$	LOGPAT12	LOGPAT123
TREAT_POST	0.182**	0.167**		
	(0.0788)	(0.0812)		
Before3			−0.153	−0.205
			(0.123)	(0.133)
Before2			−0.129	−0.179
			(0.105)	(0.113)
Before1			−0.0795	−0.0439
			(0.0950)	(0.0988)
After1			0.0218	0.0591
			(0.0924)	(0.0998)
After2			0.0667	0.0817
			(0.105)	(0.111)
After3			0.223*	0.250**
			(0.117)	(0.124)
HHI	−1.476	−1.364	−1.924*	−2.620**
	(1.186)	(1.248)	(1.100)	(1.177)
HHI^2	1.985	1.157	2.402	2.993
	(2.437)	(2.519)	(2.211)	(2.347)
CASH	−0.0740	−0.0453	−0.115	−0.0242
	(0.204)	(0.205)	(0.184)	(0.188)
ROA	0.0569	−0.0431	−0.410	−0.568
	(0.461)	(0.490)	(0.398)	(0.416)
FIRMAGE	0.119	0.134*	0.0259	0.0337
	(0.0754)	(0.0769)	(0.0686)	(0.0702)
PPE	−0.0168	−0.00717	0.306	0.296
	(0.281)	(0.281)	(0.263)	(0.268)
SA	0.755*	0.652	0.295	0.258
	(0.456)	(0.464)	(0.500)	(0.527)
SIZE	0.544***	0.504***	0.537***	0.528***
	(0.0755)	(0.0785)	(0.0669)	(0.0696)
R&D	6.459***	5.709***	5.152***	4.848***
	(2.129)	(2.122)	(1.527)	(1.571)
LEVERAGE	−0.0322	−0.0453	−0.234	−0.110
	(0.278)	(0.290)	(0.236)	(0.243)
Constant	−7.525***	−6.819***	−8.922***	−8.510***
	(1.667)	(1.706)	(1.689)	(1.777)
Year fixed effects	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes
Observations	8516	8516	10,853	10,853
R-squared	0.822	0.814	0.796	0.785

$$Innovation_{i,t+1} = \alpha + + Controls + \beta_1 Before3 + \beta_2 Before2 + \beta_3 Before1 + \beta_4 After1 + \beta_5 After2 + \beta_6 After3 + Year\ Fixed\ Effect + Firm\ Fixed\ Effect + \varepsilon_{i,t} \tag{3}$$

The regression results of equation (3) can be obtained in Table 5. In the case of the controlling year and firm fixed effects, the coefficients of Before3, Before2 and Before1 are not significant. However, the coefficients of After3 in the LOGPAT12 column are positive and statistically significant at the 10% level, and in the LOGPAT123 column, the coefficients are positive and statistically significant at the 5% level. Therefore, we can assume that the DID model used in this paper meets the assumption of a parallel trend, and the regression results of the DID model are credible.

6.4. Possible mechanism

Previous studies have concluded that D&O insurance can guarantee the behavior of directors and senior executives and play a role in determining the management's "bottom line". It can help to encourage the management to be aggressive, increase the risk preference of the management, and make managers adopt more aggressive management and

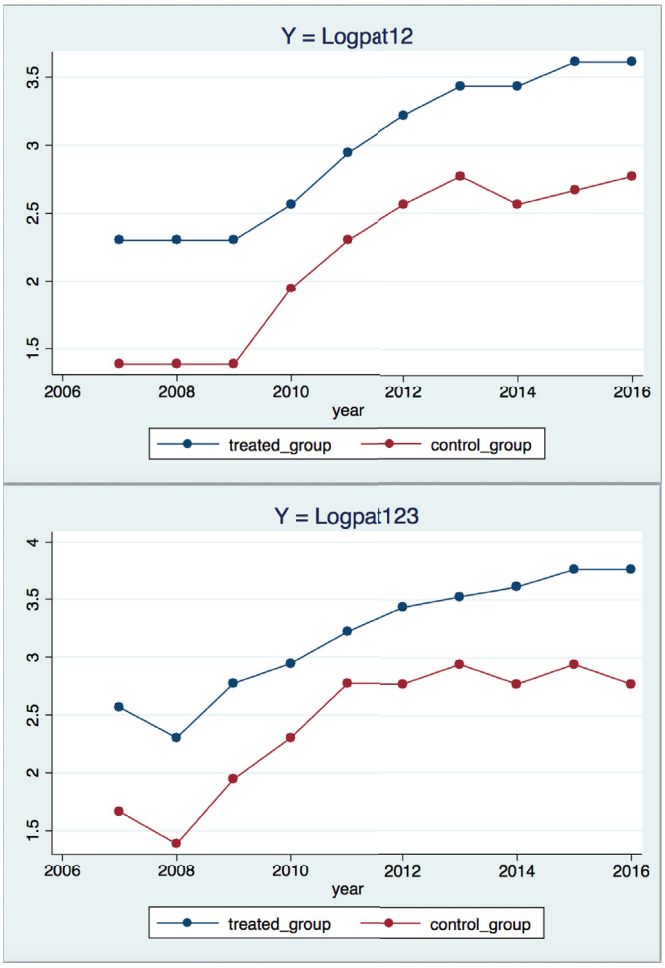

Fig. 2. The growth trend of firm innovation.

investment strategies to improve the risk bearing capacity of the enterprise. The stronger the risk bearing capacity of an enterprise is, the easier it is to try and accept new methods and knowledge and to take active innovative behaviors to break through the old system and constraints. Therefore, it will be more conducive to firm innovation. To make the conclusion of this paper more convincing, we further test whether the "bottom line" effect of D&O insurance is real, that is, whether the purchase of D&O insurance will improve enterprises' risk bearing ability.

Referring to the study of Lin et al. (2013), this paper takes the variance of the annual stock return of an enterprise as an index to measure its risk bearing capacity and names it TOTAL_RISK.

In addition, we take TOTAL_RISK as a dependent variable and INSURANCE as an independent variable. Under the control of a series of control variables and fixed effects of year and industry, the OLS results are shown in Table 6 below. The regression results show that the coefficient of INSURANCE is positive and statistically significant at the 5% level. In other words, enterprises with D&O insurance have higher risk bearing capacity and find it easier to adopt active management and investment strategies to promote firm innovation.

Furthermore, if this argument is valid, we should expect that the increase in innovation output is more pronounced in firms that have lower risk bearing capacity because managers of such firms stand to benefit more from D&O insurance. To test for this, we then assign firms based on their risk bearing capacity. Firms whose risk bearing capacity is greater than the median value across all samples are assigned to the high risk bearing capacity group, and the rest are assigned to the low risk bearing capacity group. Then, we re-estimate model (1) for the two groups of data, and the results are shown in Table 7 below. In the low-risk bearing

Table 6
D&O insurance and firm risk. The regression examines the relationship between D&O insurance and the risk bearing capacity of the enterprise. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	(1)
	TOTAL_RISk
INSURANCE	0.0187**
	(0.00747)
HHI	−0.190
	(0.613)
HHI^2	−0.262
	(1.060)
CASH	0.0160
	(0.0422)
ROA	0.110**
	(0.0528)
FIRMAGE	−0.0231*
	(0.0128)
PPE	0.0865
	(0.0749)
SA	−0.0339
	(0.0219)
SIZE	−0.0155***
	(0.00505)
R&D	−0.00432
	(0.239)
LEVERAGE	0.0468**
	(0.0188)
Constant	0.281**
	(0.125)
Year fixed effects	yes
Industry fixed effects	yes
Observations	10,721
R-squared	0.041

capacity group, in the case of controlling year and industry fixed effects, the coefficients of INSURANCE in columns of LOGPAT12 and LOGPAT123 are both positive and statistically significant at the 5% level. However, in the high-risk bearing capacity group, the coefficients of INSURANCE in both columns are not significant. Thus, these results support our claim that D&O insurance can improve the risk bearing capacity of managers that fosters corporate innovation.

6.5. *Additional analysis based on the legal environment*

Obviously, where the legal environment is sound, the law can be better implemented and the effect of the law should be greater. Therefore, a good legal environment is not only conducive to the implementation of D&O insurance but also should help promote the positive role of D&O insurance in corporate governance.

We adopt the index of "development of intermediary organizations and legal environment" in the Fan Gang index of each year to measure the development of the legal environment in each province. We divide our sample into two groups based on the median of the index of "development of intermediary organizations and legal environment". If a province-year observation is greater than the median of the index of "development of intermediary organizations and legal environment", the dummy variable LAW_ENVIRONMENT equals one, and zero otherwise. Then, we re-estimate model (1) for the two groups of data, and the results are shown in Table 8 below.[3] In the group with strong legal environment (LAW_ENVIRONMENT = 1), in the case of controlling year and industry fixed effects, the coefficients of INSURANCE in columns of LOGPAT12

[3] The total number observation of non-missing LAW_ENVIRONMENT is 7936. Given the fact that we adopt the forward value in the dependent variable, we end up with 6931 observations in the full sample.

Table 7
Subsample analysis—firm risk. The table is based on the subsample analysis regarding firm risk. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	High risk bearing capacity		Low risk bearing capacity	
	(1)	(2)	(3)	(4)
	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$
INSURANCE	−0.526	−0.561	0.620**	0.581**
	(-0.738)	(-0.766)	(2.548)	(2.359)
HHI	−2.892	−5.257	−1.986	−1.488
	(-0.618)	(-1.142)	(-0.733)	(-0.509)
HHI^2	7.999	10.784	5.082	3.683
	(1.009)	(1.399)	(1.142)	(0.779)
CASH	−0.186	0.076	−0.454**	−0.336
	(-0.452)	(0.190)	(-2.049)	(-1.468)
ROAA	0.755	0.595	1.051**	1.423***
	(0.774)	(0.581)	(1.992)	(2.625)
FIRMAGE	0.066	0.038	0.106	0.112
	(0.612)	(0.348)	(1.457)	(1.511)
PPE	0.298	0.284	−0.343	−0.446
	(0.610)	(0.591)	(-1.312)	(-1.638)
SA	0.497	0.356	0.619**	0.565**
	(1.240)	(0.887)	(2.446)	(2.218)
SIZE	0.690***	0.726***	0.683***	0.682***
	(11.889)	(12.157)	(18.759)	(18.678)
R&D	21.159***	23.368***	27.462***	26.105***
	(5.435)	(6.053)	(13.108)	(12.250)
LEVERAGE	−1.144**	−1.399***	−0.382	−0.471*
	(-2.400)	(-2.868)	(-1.402)	(-1.694)
Constant	−12.414***	−13.030***	−12.764***	−12.668***
	(-7.063)	(-7.261)	(-13.692)	(-13.348)
Year fixed effects	yes	yes	yes	yes
Industry fixed effects	yes	yes	yes	yes
Observations	1024	1024	6879	6879
R-squared	0.484	0.465	0.452	0.426

Table 8
Subsample analysis—legal environment. The table is based on the subsample analysis regarding legal environment. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	Strong Legal Environment		Weak Legal Environment	
	(1)	(2)	(3)	(4)
	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$
INSURANCE	0.994***	0.970***	0.398	0.338
	(0.366)	(0.372)	(0.423)	(0.437)
HHI	−5.785*	−5.327	1.897	1.870
	(3.493)	(3.635)	(3.723)	(4.117)
HHI^2	10.44*	9.272	0.0712	−0.801
	(5.744)	(5.996)	(5.764)	(6.201)
CASH	−0.452	−0.383	−0.345	−0.163
	(0.288)	(0.297)	(0.302)	(0.318)
ROA	1.322	1.432*	0.808	1.065
	(0.806)	(0.785)	(0.673)	(0.746)
FIRMAGE	0.117	0.112	0.113	0.117
	(0.0843)	(0.0856)	(0.0952)	(0.101)
PPE	−0.220	−0.435	−0.508	−0.535
	(0.347)	(0.355)	(0.352)	(0.368)
SA	0.385	0.336	0.668**	0.557
	(0.303)	(0.304)	(0.335)	(0.350)
SIZE	0.698***	0.703***	0.689***	0.694***
	(0.0489)	(0.0490)	(0.0487)	(0.0499)
R&D	21.77***	21.51***	31.82***	30.69***
	(2.616)	(2.644)	(2.887)	(2.940)
LEVERAGE	−0.466	−0.501	−0.261	−0.519
	(0.337)	(0.342)	(0.366)	(0.385)
Constant	−12.51***	−12.86***	−13.26***	−13.23***
	(1.121)	(1.140)	(1.170)	(1.221)
Year fixed effects	yes	yes	yes	yes
Industry fixed effects	yes	yes	yes	yes
Observations	3287	3287	3644	3644
R-squared	0.484	0.476	0.444	0.402

and LOGPAT123 are both positive and statistically significant at the 1% level. However, in the group with weak legal environment (LAW_ENVIRONMENT = 0), the coefficients of INSURANCE in both columns are not significant. Therefore, where the legal environment is better, the positive economic effect of D&O insurance on corporate governance is more obvious.

6.6. Additional analysis based on gender of directors and officers

Globally, female managers are far less likely than males to enter top leadership positions, and women face more barriers to growth than men, including a male-dominated culture and male-biased corporate policies (Oakley, 2000). This situation inevitably leads to female executives being more risk-averse and more conservative. Faccio et al. (2016) also noted that the gender of executives is an important factor affecting corporate risk taking, and compared with males, females are more prudent and conservative. Therefore, it is reasonable to believe that the "bottom line" effect of D&O insurance on management is more obvious among males than among females.

We first calculate the proportion of females in director and senior management roles. Then, we divide our sample into two groups based on the median proportion of females. If a firm-year observation is greater than the median proportion of females, the dummy variable FEMALE_RATIO equals one, and zero otherwise. Finally, we re-estimate model (1) for the two groups of data, and the results are shown in Table 9 below. In the group with less female directors and officers (FEMALE_RATIO = 0), in the case of controlling year and industry fixed effects, the coefficients of INSURANCE in columns of LOGPAT12 and LOGPAT123 are positive and statistically significant at the 5% and 10% levels, respectively. However, in the group with more female directors and officers (FEMALE_RATIO = 1), the coefficients of INSURANCE in both columns are not significant. Therefore, the higher the proportion of males in director and senior management roles, the more obvious the influence of D&O insurance on firm innovation.

6.7. Additional analysis based on analyst coverage

Based on the content of the previous article, in the case of external supervision, the positive effect of D&O insurance on corporate governance is more significant. According to Wu and Liu (2016), increasing attention among analysts can reduce the company's earnings management and play a certain supervisory role in corporate governance. Therefore, our paper measures the strength of external supervision by the number of analysts of listed companies.

Therefore, we believe that the existence of analysts can promote the positive effect of D&O insurance on corporate governance. Therefore, we divided the sample into two groups according to the median of the number of analysts tracking listed companies every year.

If a firm-year observation is greater than the median number of analysts, the dummy variable ANALYST equals one, and zero otherwise. Then, we re-estimate model (1) for the two groups of data, and the results are shown in Table 10 below. In the group with more analysts (ANALYST = 1), in the case of controlling year and industry fixed effects, the coefficients of INSURANCE in columns of LOGPAT12 and LOGPAT123 are both positive and statistically significant at the 10% level. However, in another group (ANALYST = 0), the coefficients of INSURANCE in both columns are not significant. Therefore, the larger the number of analysts is, the greater the impact of D&O insurance on firm innovation will be. That is, the existence of analysts as an external supervision does promote the positive effect of D&O insurance on enterprise governance.

6.8. Additional analysis based on alternative measures for dependent variables

Given that patent application or grant may be the result of years' efforts, it is reasonable to think that D&O insurance may affect corporate innovation over a long-term period, as the innovation process usually takes time. To provide more robust check, we adopt the two-year-head value of LOGPAT12 and LOGPAE123 as the dependent variables.

Table 9
Subsample analysis—female directors and officers. The table is based on the subsample analysis regarding the proportion of female directors and officers. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	More female directors and officer		Less female directors and officer	
	(1)	(2)	(3)	(4)
	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$
INSURANCE	0.399	0.420	0.496**	0.432*
	(0.571)	(0.554)	(0.222)	(0.231)
HHI	−4.750	−5.514*	−0.135	0.798
	(3.148)	(3.307)	(2.479)	(2.656)
HHI^2	9.341	10.15*	2.342	0.220
	(5.864)	(6.135)	(4.306)	(4.504)
CASH	−0.100	−0.0255	−0.563**	−0.369
	(0.247)	(0.264)	(0.278)	(0.280)
ROA	1.838***	1.912***	0.363	0.593
	(0.665)	(0.701)	(0.623)	(0.634)
FIRMAGE	0.162*	0.145	0.0678	0.0919
	(0.0872)	(0.0894)	(0.0770)	(0.0788)
PPE	0.110	−0.0759	−0.553*	−0.627**
	(0.329)	(0.350)	(0.304)	(0.307)
SA	0.578*	0.458	0.557**	0.568**
	(0.334)	(0.338)	(0.274)	(0.277)
SIZE	0.621***	0.654***	0.709***	0.704***
	(0.0544)	(0.0553)	(0.0378)	(0.0383)
R&D	23.13***	23.43***	28.19***	26.40***
	(2.750)	(2.817)	(2.364)	(2.379)
LEVERAGE	−0.243	−0.483	−0.608*	−0.731**
	(0.315)	(0.327)	(0.326)	(0.330)
Constant	−11.51***	−12.02***	−13.43***	−13.18***
	(1.153)	(1.192)	(1.083)	(1.102)
Year fixed effects	yes	yes	yes	yes
Industry fixed effects	yes	yes	yes	yes
Observations	3231	3231	5312	5312
R-squared	0.457	0.440	0.452	0.428

Table 10
Subsample analysis—analyst coverage. The table is based on the subsample analysis regarding the analyst coverage. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	More analysts		Less analyst	
	(1)	(2)	(3)	(4)
	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$	$LOGPAT12_{t+1}$	$LOGPAT123_{t+1}$
INSURANCE	0.516*	0.497*	0.335	0.269
	(0.285)	(0.290)	(0.371)	(0.388)
HHI	−3.737	−3.344	−0.642	1.244
	(2.746)	(2.855)	(3.079)	(3.275)
HHI^2	8.743*	7.122	3.751	0.611
	(5.299)	(5.425)	(5.074)	(5.374)
CASH	−0.471*	−0.386	−0.319	−0.185
	(0.279)	(0.284)	(0.251)	(0.260)
ROAA	0.359	0.549	0.687	0.674
	(0.725)	(0.764)	(0.666)	(0.688)
FIRMAGE	0.164	0.177*	0.0660	0.0667
	(0.101)	(0.102)	(0.0775)	(0.0793)
PPE	−0.206	−0.397	−0.425	−0.457
	(0.348)	(0.359)	(0.287)	(0.298)
SA	0.728**	0.640*	0.267	0.272
	(0.339)	(0.343)	(0.318)	(0.321)
SIZE	0.665***	0.661***	0.635***	0.657***
	(0.0444)	(0.0444)	(0.0602)	(0.0606)
R&D	26.61***	25.50***	24.59***	23.88***
	(2.444)	(2.490)	(2.916)	(2.920)
LEVERAGE	−0.506	−0.773*	−0.529*	−0.658**
	(0.385)	(0.397)	(0.302)	(0.305)
Constant	−11.87***	−11.68***	−12.60***	−13.10***
	(1.344)	(1.361)	(1.124)	(1.154)
Year fixed effects	yes	yes	yes	yes
Industry fixed effects	yes	yes	yes	yes
Observations	4787	4787	3340	3340
R-squared	0.479	0.449	0.394	0.378

Under the control of a series of control variables and fixed effects of year and industry, we re-estimate model (1) and the result is shown in Table 11. And we can see that our results still hold if we adopt the two-year-head value of LOGPAT12 and LOGPAE123 as the dependent variables.

7. Conclusions

This paper investigates the impact of D&O insurance on corporate innovation. We first document a strong positive relation between D&O insurance and firm innovation. Using the method of PSM and the DID approach, we show that D&O insurance has a causal positive effect on firm innovation. We then examine the possible mechanism that could contribute to this finding. D&O insurance has a significant positive impact on the risk bearing capacity of enterprises. Enterprises with stronger risk bearing capacity are more likely to try and accept new methods and knowledge and are more likely to adopt active investment and management methods, which are conducive to firm innovation.

On the basis of previous studies, this paper further demonstrates that D&O insurance can have positive economic effects on corporate governance. Our study adds to the growing literature on D&O insurance and promotes its implication for firms, especially in China. We also extend prior studies on firm innovation by identifying a new factor that has a positive effect on firm innovation. Our findings point to new ways for companies and countries to promote innovation.

Table 11
Alternative measures for dependent variables– two-year-head value of LOGPAT12 and LOGPAE123. In this table, we examine whether D&O insurance promotes corporate innovation, if we adopt the two-year-head value of LOGPAT12 and LOGPAE123 as the dependent variables. The robust standard errors clustered at the firm level are reported in parentheses. The symbols ***, **, and* denote significance level at the 1%, 5%, and 10% levels, respectively.

VARIABLES	(1)	(2)
	$LOGPAT12_{t+2}$	$LOGPAT123_{t+2}$
INSURANCE	0.520**	0.514**
	(0.250)	(0.247)
HHI	−1.734	−2.684
	(2.616)	(2.758)
HHI^2	4.860	5.721
	(4.517)	(4.699)
CASH	−0.352	−0.220
	(0.221)	(0.229)
ROA	2.027***	2.381***
	(0.563)	(0.586)
FIRMAGE	0.107	0.132*
	(0.0718)	(0.0737)
PPE	−0.303	−0.349
	(0.266)	(0.274)
SA	0.589**	0.576**
	(0.268)	(0.271)
SIZE	0.682***	0.681***
	(0.0378)	(0.0382)
R&D	26.40***	25.18***
	(2.032)	(2.062)
LEVERAGE	−0.282	−0.440
	(0.273)	(0.280)
Constant	−12.50***	−12.07***
	(0.946)	(0.978)
Year fixed effects	yes	yes
Industry fixed effects	yes	yes
Observations	6877	6877
R-squared	0.439	0.416

Appendix 1. Variable definitions.

Variables	Definition
LOGPAT12	the log of one plus Patent12
LOGPAT123	the log of one plus Patent123
INSURANCE	A dummy variable that equals 1 if a firm purchases D&O insurance in a given year, and 0 otherwise
HHI	Herfinal index of sales
HHI^2	Square term of Herfinal index of sales
CASH	Cash holding scaled by total asset
ROA	the ROA of the firm
FIRMAGE	Log value of firm age
PPE	PPE scaled by the total asset
SA index	Financial constraint index
SIZE	the log of total assets
R&D	R&D expense scaled by total asset
LEVERAGE	the ratio of total debt over total asset

(*continued on next column*)

(*continued*)

Variables	Definition
Before3	A dummy that equals one if a firm-year observation is from the treatment group and three or more years before exogenous shock year (2007–2009), and zero otherwise.
Before2	A dummy that equals one if a firm-year observation is from the treatment group and two years before exogenous shock year (2010), and zero otherwise.
Before1	A dummy that equals one if a firm-year observation is from the treatment group and the year before exogenous shock year (2011), and zero otherwise.
Current	A dummy that equals one if a firm-year observation is from the treatment group and exogenous shock year (2012), and zero otherwise.
After1	A dummy that equals one if a firm-year observation is from the treatment group and the year after exogenous shock year (2013), and zero otherwise.
After2	A dummy that equals one if a firm-year observation is from the treatment group and two years after exogenous shock year (2014), and zero otherwise.
After3	A dummy that equals one if a firm-year observation is from the treatment group and three or more years after exogenous shock year (2015–2016), and zero otherwise.

Appendix 2. The logit regression of PSM procedure

	INSURANCE
HHI	9.552
	(11.86)
HHI^2	−147.5
	(112.4)
CASH	0.224
	(1.087)
ROA	−4.218**
	(2.103)
FIRMAGE	0.276
	(0.313)
PPE	0.489
	(0.620)
SA	−0.376
	(0.651)
SIZE	0.991***
	(0.115)
R&D	−4.410
	(7.990)
LEVERAGE	−2.897***
	(0.920)
Constant	−28.70***
	(4.160)
Year fixed effects	yes
Industry fixed effects	yes
Observations	10,853
R-squared	0.2197

Appendix 3. The balance test after PSM

	Unmatched	Mean		%reduct		*t*-test		V(T)/
Variable	Matched	Treated	Control	%bias	|bias|	t	p>|t|	V(C)
HHI	U	0.03179	0.04666	−25.4		−2.01	0.044	0.14*
	M	0.03179	0.03153	0.4	98.2	0.07	0.946	1.04
HHI^2	U	0.00186	0.00818	−31.5		−2.35	0.019	0.01*
	M	0.00186	0.00181	0.2	99.2	0.12	0.901	1.11
CASH	U	0.15112	0.214	−44		−4.19	0	0.65*
	M	0.15112	0.16974	−13	70.4	−1.07	0.285	0.95
ROA	U	0.0307	0.04293	−22.6		−2.35	0.019	0.98
	M	0.0307	0.03245	−3.3	85.6	−0.24	0.809	1
FIRMAGE	U	2.4916	1.8707	76.9		7.13	0	0.57*
	M	2.4916	2.4185	9	88.2	0.8	0.424	1.08
PPE	U	0.28185	0.22582	33.5		3.85	0	1.45
	M	0.28185	0.27225	5.7	82.9	0.41	0.682	1.23
SA	U	−3.4712	−3.4453	−7.2		−0.97	0.334	2.34*
	M	−3.4712	−3.5635	25.8	−256.9	1.91	0.057	2.33*
SIZE	U	24.076	21.919	148.2		18.21	0	1.80*
	M	24.076	23.417	45.3	69.4	3.31	0.001	1.66*
R&D	U	0.00972	0.01616	−45.4		−4.13	0	0.52*
	M	0.00972	0.0121	−16.8	63	−1.35	0.177	0.68*
LEVERAGE	U	0.17131	0.14522	19.3		2.01	0.044	1
	M	0.17131	0.17143	−0.1	99.5	−0.01	0.995	1.06

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