

# Independent Directors and Enterprise Technology Innovation

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## Abstract

Based on the data of A-share listed companies from 1996 to 2016, the paper uses the panel double fixed model to study the impact of the company's transition to a larger proportion of independent directors on corporate innovation behavior. It is concluded that the increase in the proportion of independent directors of the company can make the number of patents of the company significant. Increased conclusions. Compared with invention patents, non-invention patent applications have increased more, and the increase in independent directors has prompted managers to pay more attention to the benefits and risks of innovation. At the same time, based on the DID model, this paper analyzes the impact of the minimum independent director policy ratio on the company's innovation activities. The study finds that the minimum independent director ratio policy allows private companies to lower their minimum proportion of companies and increase their strategic innovation behavior, instead of seeking exploration and breakthroughs in new technologies.

## Keywords

Independent Director, Enterprise Technology Innovation, Strategic Innovation, Substantial Innovation

## 1. Introduction

Independent directors are an important part of the design of modern corporate governance mechanisms. Their role is to reduce the interests of small and medium-sized shareholders and improve the decision-making ability of the board of directors by introducing independent third parties that have no relationship with the company's existing stakeholders (Yiming Hu and Songlian Tang, 2008) [1]. The board of directors plays an important role in corporate governance. The

board of directors is responsible for supervising managers and making recommendations for them, which can effectively reduce the agency costs caused by the separation of ownership and control. Some scholars previously believed that independent directors are different from other directors of the company, and independent directors may not have much to do with corporate governance. However, independent directors are better suited to perform this role: they can reliably limit management by supervising and punishing managers (Fama and Jensen, 1983; Williamson, 1983) [2] [3].

From the perspective of the duties of independent directors, the increase in the number of independent directors may result in more patents; if the company's performance is not good, independent directors are more likely to terminate the manager's position (Weisbach, 1988) [4], this threat to the company manager to work hard Power is provided (Stiglitz and Weiss, 1983) [5]. The more supervision of independent directors, the more it can alleviate the company's agency problems, such as the abuse of corporate resources, and promote the effective use of scarce resources; As a company manager, it is better to take actions that are close to the interests of shareholders (Harris and Raviv, 1978; Holmstrom, 1979; Holmstrom and Milgrom, 1991) [6] [7] [8]. When the company receives more supervision and performance requirements, the company manager will focus on quantifiable results, such as more patents. Eventually, the number of patents will increase, to meet the company's performance requirements for managers.

In view of this, this paper attempts to analyze the technological innovation of enterprises from the reform of independent director system. This paper uses the panel fixed effect and the empirical method of double difference to study: 1) It is found that the company's transition to a more independent board of directors can significantly increase the number of patent applications of the company; the number of non-invention patent applications has increased more than the invention patents, and the increase of independent directors has made managers pay more attention to the improvement in performance, especially the benefits and risks of innovation. 2) This paper uses the DID model to study that the government has issued the "Guiding Opinions on Establishing an Independent Director System for Listed Companies". The law requires that the independent directors of listed companies account for no less than one-third of the independent directors. The influence of the director's proportional policy on the company's innovation activities has resulted in a minimum independent director ratio policy. Significantly, the company with a lower percentage than the lowest proportion of private companies increases their strategic innovation behavior rather than seeking new technologies. Exploration and breakthroughs reflect the decline in the number of invention patent applications.

The contribution of this paper lies in: First, after research on previous literatures, this paper is the first study to analyze enterprise technology innovation from the perspective of independent director system reform, and the existing li-

terature mostly focuses on the research of listed company performance, stock market risk and investment, and other issues. Secondly, using the policy exogenous shock of the independent director system reform, the panel data double difference model is constructed to study the impact of the independent director system reform of listed companies on enterprise technology innovation, and effectively alleviate the endogenous problems of listed companies in China. Third, on the basis of the double difference model, the listed companies are divided into state-owned enterprises and private enterprises to observe the impact of independent director system reform on them. Finally, the research in this paper can provide new perspectives and new suggestions for understanding and analyzing the policy effects of the reform of the independent director system of listed companies in China.

## 2. Institutional Background and Research Hypothesis

### 1) Institutional background

Prior to 2001, companies listed in China were free to choose whether to hire independent directors for the company. In order to improve the governance of listed companies, after 2001, the China Securities Regulatory Commission required listed companies to hire independent directors to improve the company's governance; at the same time, the CSRC also stipulated that independent directors of listed companies should be independent when the company's major matters are decided. Directors must express independent opinions to the board of directors or shareholders meeting. The types of independent opinions generally include the following categories: consent; reservations; objections; failure to express opinions. However, at this time, the CSRC did not explicitly stipulate that the opinions of independent directors in the company's general meeting of shareholders and the board of directors must be disclosed to the outside world. In June 2003, the "Guiding Opinions on Establishing Independent Director System for Listed Companies" promulgated by the CSRC required at least one-third of the board members of listed companies to be independent directors, that is, the ratio of the number of independent directors to the number of board members must be More than 1/3. For listed companies, whether the completely exogenous independent director policy can strengthen the supervision of independent directors and improve the company's governance.

In view of the improvement of China's relevant legal system for independent directors, the role of independent directors in improving corporate governance will certainly be strengthened; this paper focuses on the impact of the independent director system on corporate governance oversight, and then studies the impact on corporate technological innovation; Companies that go to the board of more independent directors will increase their exploration of previously successful areas of expertise. An in-depth exploration of the transformation of the professional field was caused by the strengthening of board supervision, which increased the risk aversion ability of the company (Benjamin Balsmeier, Lee

Fleming and Gustavo Manso, 2017) [9]. This paper examines the research on technological innovation of enterprises by the board of directors who transitioned to more independent directors.

## 2) Research hypothesis

H1 (Hypothesis 1): Under the premise that other assumptions remain unchanged, the board of directors of a listed company transitioning to more independent directors may increase the company's research and development expenditures, thereby increasing the core competitiveness of the company;

H2 (Hypothesis 2): Under the premise that other assumptions remain unchanged, the board of directors whose independent transition to more independent directors may increase the number of patent applications of the company and improve the company's true creative ability;

H3 (Hypothesis 3): Under the premise that other assumptions are unchanged, the board of directors whose independent transition to more independent directors may increase the number of patent applications for strategic innovation of the company and increase the company's innovation income;

H4 (Hypothesis 4): Under the premise that other assumptions remain unchanged, the board of directors of a listed company transitioning to more independent directors may increase the number of applications for the company's invention patents and enhance the company's substantive creativity;

H5 (Hypothesis 5): Under the premise that other assumptions remain unchanged, the increase in the proportion of independent directors makes listed companies more inclined to increase the patent behavior of strategic innovation, and increase the innovation income when the innovation risk is low.

## 3. Research Design

### 1) Model design

To analyze how to transition to an independent board to influence innovative search, we follow the literature on corporate governance and innovation, and study independent directors on R&D spending, companies. The impact of innovation, the model is as follows.

#### a) Independent directors and R&D expenditure

The R&D expenditure and the ratio of independent directors to the number of board members establish the following panel fixed-effect regression equation:

$$\ln(1 + RD\_assets) = \beta_0 + \beta_1 * inde\_com_{i,t} + \gamma Z_{i,t} + \theta_t + \alpha_i + \varepsilon_{i,t} \quad (1)$$

If H1 is assumed to be true, then the coefficient of  $\beta_1$  is positive.

#### b) Independent directors and enterprise innovation

$$\ln(1 + patent_{i,t+1}) = \beta_0 + \beta_1 * inde\_com_{i,t} + \gamma Z_{i,t} + \theta_t + \alpha_i + \varepsilon_{i,t} \quad (2)$$

The article uses the number of patent applications to measure the innovation intensity of listed companies, If H2 is assumed to be true, then the coefficient of  $\beta_1$  is positive.

#### c) Independent directors and innovative motives

The different motives of innovation are divided into substantive innovation and strategic innovation; compared with strategic innovation, substantive innovation can better reflect the creative ability of enterprises (Wenjing Li, 2016) [10]. Through the definition of innovation motivation, this paper concludes that the increase of the proportion of independent directors in the board of directors can not only promote the strategic innovation of enterprises, but also promote the substantial innovation of enterprises. Substantial innovation can better reflect the progress of technology and is the most important part of the company's core competitiveness. Strategic innovation is less risky for strategic innovation than substantive innovation. The sum of the number of applications that use new patents and design patents is used as an indicator to measure a company's strategic innovation capabilities. The panel fixed effect model regression equation for strategic innovation criteria is as follows:

$$\ln(1 + \text{stargepa}_{i,t+1}) = \beta_0 + \beta_1 * \text{inde\_com}_{i,t} + \gamma Z_{i,t} + \theta_t + \alpha_i + \varepsilon_{i,t} \quad (3)$$

The substantive innovation regression equation is as follows:

$$\ln(1 + \text{Invention}_{i,t+1}) = \alpha_0 + \alpha_1 * \text{inde\_com}_{i,t} + \gamma Z_{i,t} + \theta_t + \alpha_i + \varepsilon_{i,t} \quad (4)$$

If H3 is assumed to be true, then the coefficient of  $\beta_1$  is positive; If H4 is assumed to be true, then the coefficient of  $\alpha_1$  is positive. If the condition H5 is assumed to be true, then

$\alpha_1 < \beta_1$ .  $Z_{i,t}$  is a vector of corporate characteristics, Annual fixed-effect variables  $\theta_t$  control changes in the macroeconomic environment and systemic changes in patent activity over time. Fixed effect variables  $\alpha_i$  control any unobservable time-variant corporate heterogeneity.

## 2) Research samples and data

### a) Sample selection

Since China proposed the independent director system in 1997, in order to avoid potential selection effects and confuse our estimates of the independence and innovation of the board, we have further eliminated all companies that appeared before 2000, or in 2000 or later. Entering the sample, the remaining companies can observe the time frame of the previously described regulatory changes. Finally, this paper selects all the A-share listed companies in 1999-2016 as the research object, and uses the independent director data and the A-share listed company patent data to obtain the final observation value of 10,882. Due to the accounting disclosure criteria, R&D expenditure data can only be obtained after the end of 2007 with 6673 observations. To study the impact of independent directors on corporate innovation, the characteristics of independent directors and the number of sample data are from Guotai'an database; use the patent data of all A-share listed companies to measure enterprise innovation, and use invention patent behavior to measure the substantial innovation of enterprises. The company uses new patents and design patents to measure corporate strategic innovation, patent nature and quantitative data from the Guotai'an database. In 2003, the government issued the "Guiding Opinions on Establishing

an Independent Director System for Listed Companies”, which stipulated that the independent directors of listed companies should be required to account for no less than one-third of the policy. Under the impact of the policy, independent directors began to strengthen the governance role of the company. Use different final samples to study R&D spending and the impact of independent directors and corporate innovation.

#### b) Variable definitions

**a) Independent director policy.** This paper studies the impact of the independent director policy on the technological innovation of the company. The government issued the “Guiding Opinions on Establishing an Independent Director System for Listed Companies” in 2003, which stipulates that the independent directors of listed companies should not be less than one-third of the policy. When the board changes from a minority to a majority of independent board members, there is a key difference (Harris and Raviv, 2008) [11]. Before June 30, 2003, the number of independent directors in the board of directors was no less than 1/3. This is also a clear requirement for the government to carry out reforms. Therefore, our analysis focuses on this exogenous variable shock. Therefore, this paper studies the variables in the proportion of independent directors, expressed in *inde\_com*.

**b) Enterprise innovation ability.** References Zhou *et al.* (2012) [12] and Wenjing Li (2016) [10] define the indicators of enterprise innovation capability of this paper, and use the number of patent applications as an indicator of the true creative ability of enterprises. The number of patent applications is more reflective of the true creative ability than the number of patent grants; Because patent grants are inconsistent with patent applications, patent grants take time to test and still have to pay a certain fee, there is a large economic uncertainty; the number of patent applications will be more stable and timely than the number granted (Xuan Zhou, 2012) [12]. According to the different innovation motives, it is divided into substantive innovation and strategic innovation. Patent, Invention and *starchpa* represent the total patent application, substantive patent and strategic patent respectively.

**c) Enterprise innovation ability.** According to the existing literature, in order to prevent confusion between board independence and the relationship between enterprise innovation search and success, we control the vector of a company’s fixed features. We calculate all variables of company *i* in its annual *t*: board size, financial leverage (Leverage), Tobin *q* (Log(*Q*)), R&D asset ratio (RD/assets), and capital expenditure asset ratio (Cap.exp/assets) and R&D expenditure and asset ratio RD/assets. The size of the board measures the number of board members because we want to isolate the impact of board independence from changes in the number of contemporary directors; to reduce the deviation of total assets, we use the logarithm of total assets in a diversified econometric analysis. Financial leverage and capital expenditures (measured by total assets) account for financial constraints affecting corporate innovation. Finally, Tobin

Q enters the return to control the difference in growth opportunities.

## 4. Measurement Result Analysis

### 1) Descriptive statistics

**Table 1** is a descriptive statistic of the main variables that summarizes the statistics of the variables used in the study. The annual average number of patent applications is 40.41, the standard deviation is 209.7, and the maximum number of patent applications is 6327, and the minimum value is 0. It can be seen that the company's patent application has a large scope of regulation, and the innovation capabilities of each company are very different. The average value of invention patents is 18.82, which is much smaller than the average number of strategic innovations of 21.59. This shows that most companies focus on the innovation of the company's innovations in utility model patents and design patents. The inventors' ability of Chinese listed companies is not high, and the stamina is insufficient. The core competitiveness of listed companies; the average number of independent directors is 3.24, and the standard deviation is 0.69, indicating that the number of independent directors of listed companies is not much different. The financial leverage of the enterprise is 1.86, and the standard deviation is 31.78, which indicates that the financial leverage of listed companies is large, and the operating conditions of each company have a large gap. Since the R&D data is after 2007, the R&D sample is different from the total sample.

### 2) Independent directors and research and development expenditures

After the Hausmann test, the original hypothesis was rejected. This paper uses the panel fixing effect to test the model of the article. The variables explained in **Table 2** are log (R&D). All explanatory variables lag behind a period. The model assesses potential changes in R&D investment after the reform of the independent director system, which may drive subsequent changes in patent applications. Model (a) illustrates that from the industry classification, the proportion of independent directors seems to have nothing to do with the level of R&D

**Table 1.** Descriptive statistics.

Variable	N	Mean	sd	p25	p50	p75	Min	Max
Patent	10,882	40.41	209.7	4	10	24	0	6327
Invention	10,882	1.600	1.240	0.6290	1.390	2.300	0	8.660
Stargepa	10,882	1.830	1.410	0.690	1.790	2.710	0	8.070
Independent	10,882	1.150	0.200	1.100	1.100	1.100	0	2.080
Borad size	10,882	9.020	1.860	8	9	9	3	20
Inde_com	10,882	0.360	0.0600	0.330	0.330	0.380	0.0600	0.800
logQ	10,882	2.230	2.220	0.980	1.690	2.790	0.0500	92.11
log Total	10,882	21.78	1.300	20.91	21.55	22.34	16.70	30.73
cap exp	10,882	0.0700	0.0600	0.0300	0.0500	0.0900	-0.110	0.600
Leverage	10,882	1.860	31.78	0.970	1.070	1.340	-233.7	2403
RD	6763	0.0200	0.0200	0.0100	0.0200	0.0300	0	0.740

**Table 2.** Regression results of independent directors and R&D expenditures.

	(a)	(b)	(c)
	dIRD_assets	IRD_assets	IRD_assets
L.inde_com	0.135 (0.55)	0.785*** (3.03)	0.785*** (3.03)
L.log_Total	-0.0720*** (-5.51)	-0.114*** (-3.14)	-0.114*** (-3.14)
L.cap_exp	-0.112 (-0.49)	-0.266 (-1.52)	-0.266 (-1.52)
L.Leverage	0.00161 (0.79)	0.00164 (1.24)	0.00164 (1.24)
L.Borad_size	0.0143* (1.67)	0.0230** (2.11)	0.0230** (2.11)
L.logQ	0.100*** (10.80)	0.0305*** (3.45)	0.0305*** (3.45)
_cons	-3.132*** (-9.94)	-2.382*** (-3.05)	-93.38*** (-4.28)
N	4598	4598	4598
r2	0.0481	0.0198	0.0198
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes
Trend control	No	No	Yes

*t* statistics in parentheses.  $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

investment, but independent directors in different industries are positive for R&D expenditure, but not significant; Models (b) and (c), from individuals and individuals with time trends, have significant positive impact on R&D spending by independent directors of listed companies. From the regression results, the transition from independent enterprises to the board of directors with more independent directors can increase the company's R&D expenditure. The increase in R&D expenditure reflects the company's emphasis on the company's research and development, reflecting the company's emphasis on the company's creative ability; Innovation risk. The reform of independent directors seems to have a greater impact on companies that are more important for innovation (high R&D), perhaps because innovation tensions between these companies are more important, and independent directors need to pay more attention to their innovation strategies. If innovation is less important (low R&D), then the board may be less involved in innovation, so our results are less obvious.

### 3) Independent directors and technological innovation

**Table 3** shows the return of the total number of patents of independent directors and listed companies. Model (a), model (b), and model (d) show that the independent director system reform is significantly positive for the total number of patents at a level of 1%, regardless of industry type or individual company,



**Table 3.** Regression results of independent directors and total patents.

	(a)	(b)	(c)	(d)
	dipatent	lpatent	lpatent	lpatent
L.inde_com	0.797*** (3.00)	0.726*** (2.78)	0.726** (2.00)	0.888** (2.01)
L.log_Total	0.519*** (31.06)	0.413*** (13.81)	0.413*** (7.14)	0.416*** (6.83)
L.cap_exp	0.497** (2.17)	0.290 (1.41)	0.290 (1.17)	0.394 (1.24)
L.Leverage	-0.000373*** (-3.31)	0.000579 (1.30)	0.000579*** (5.08)	0.000664*** (9.03)
L.Borad_size	0.0135 (1.59)	0.0175* (1.81)	0.0175 (1.12)	0.0308* (1.90)
L.logQ	0.0734*** (4.65)	0.0163** (2.27)	0.0163* (1.88)	0.0114 (0.93)
year_pre2003			-0.000230 (-1.24)	-0.000226 (-1.25)
_cons	-9.834*** (-21.14)	-7.795*** (-11.64)	-7.336*** (-5.92)	-7.612*** (-5.86)
N	8185	8185	8185	8185
r2	0.202	0.189	0.189	0.191
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes
Trend control	No	No	Yes	Yes
Control*bill	No	No	No	Yes

*t* statistics in parentheses.  $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

independent directors The total patent is crucial. From the model (d), it can be concluded that the reform of the independent director system proposed by the China Securities Regulatory Commission in 2003 has a great impact on patents. Type (c) is significantly positive at the 5% level. It can be seen that after the patent rate application for removing the time trend, the independent director has a promotion effect on the patent, and the more independent directors, the more attention they attach to the patent application. From the regression results, the transition from independent enterprises to more independent directors can increase the number of patent applications of the company, strengthen the company's ability to innovate, and prevent the development of enterprises from stagnating, thus improving the performance of listed companies.

From the above table, we can see that independent directors have a very rapid impact on innovation. The effect on innovation is obvious only after one year of transition to independent directors. In general, the impact of any measure on innovation is slow, because research takes time; projects must be funded, and

staff allocation and execution take a lot of time, after which any successful results must be patented, a new R&D strategy. It is impossible to have this effect immediately. A more reasonable explanation is that the company's patent application process has changed. In particular, the company's engineers and lawyers have paid more attention to patent inventions in the company's existing portfolio. The company's employees attach importance to patents from supervised role Of the independent directors.

#### **4) Independent directors and innovative motives**

From the results of the two regressions, the different innovation motives are divided into substantive innovation and strategic innovation. The independent transition of enterprises to the board of directors with more independent directors increases the number of applications for strategic innovation and substantive innovation patents of the company, but the invention patents. The coefficient of the number of applicants to independent directors is less than the ratio of the number of strategic innovation patent applications to independent directors. And strategically, it can be seen that the number of independent directors increases the number of patent applications that may lead the company to the company's strategic innovation; independent directors may allow managers to focus on the mining of employees to maximize the workforce of employees rather than seeking. Exploration and breakthrough of new technologies. Since independent directors are more likely to dismiss managers after poor company performance, managers tend to seek fewer invention patents. As suggested in the literature review, multiple mechanisms may cause fluctuations in the independence of a company's board of directors. For example, managers may evade laziness, work harder, see greater vision, reduce risk from career issues, respond to suggestions, or reduce innovations because they fear independent boards to limit future flexibility. As a result, strategic innovations are less risky and can generate greater benefits in the short term than inventive patents. Thus, the results of **Table 4** and **Table 5** are in accordance with Hypothesis 5.

### **5. Further Research Design**

The CSRC promulgated the "Guidance Opinion" in 2001, and requested that the minimum proportion of independent directors of listed companies at the end of June 2003 should not be less than 1/3. From the perspective of listed companies, the reform of the independent director system proposed by the "Guiding Opinions" has led to the increase in the proportion of independent directors, which is completely exogenous. This provides us with a rare opportunity to study the impact of independent director system reform on corporate technological innovation in natural experiment conditions. In the context of the concentration of equity in most listed companies in China and the large shareholder sitting alone, the more independent directors in the listed companies suppress the control of the major shareholders, the greater the resistance of the major shareholders to the board of directors to increase the proportion of independent directors.

**Table 4.** Regression results of independent directors and substantive patents.

	(a)	(b)	(c)	(d)
	dIInvention	IInvention	IInvention	IInvention
L.inde_com	0.795*** (3.08)	0.395 (1.46)	0.395 (1.08)	0.395 (0.87)
L.log_Total	0.515*** (29.97)	0.400*** (12.88)	0.400*** (6.47)	0.404*** (6.28)
L.cap_exp	0.671*** (2.85)	0.359* (1.68)	0.359 (1.31)	0.356 (1.01)
L.Leverage	-0.000203* (-1.70)	0.000619 (1.34)	0.000619*** (6.11)	0.000689*** (10.55)
L.Borad_size	0.0432*** (5.04)	0.0212** (2.11)	0.0212 (1.26)	0.0334* (1.88)
L.logQ	0.0747*** (4.35)	0.0225*** (3.01)	0.0225*** (2.99)	0.0185* (1.89)
year_pre2003			-0.000396** (-2.26)	-0.000385** (-2.25)
_cons	-11.48*** (-23.40)	-8.895*** (-12.78)	-8.104*** (-5.97)	-8.304*** (-5.90)
N	8185	8185	8185	8185
r2	0.218	0.219	0.219	0.220
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes
Trend control	No	No	Yes	Yes
Control*bill	No	No	No	Yes

*t* statistics in parentheses.  $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

Therefore, some listed companies are more likely to maintain the proportion of independent directors at the minimum level required by the CSRC after the SFC stipulates the minimum proportion of independent directors. Therefore, we have made the company with a minimum proportion of independent directors in 2002 as the experimental group. We can compare the changes in patent innovations before and after the reform by comparing the companies with less than the standard of independent directors before the reform and those with at least the level of compliance (Difference in difference) to identify the actual effects of the policy of independent director system reform. In this paper, the DID model is used to reform the proportion of independent directors in 2003 as the event year, and the 1999-2015 is the event window. The reform of the independent directors in 2003 is equal to the minimum proportion of listed companies as the experimental group, with independent directors before and after the reform in 2003. The listed company with a higher ratio than the minimum level specified by the CSRC is the control group; then the following regression equation is

**Table 5.** Strategic innovation regression results.

	(a)	(b)	(c)	(d)
	dIstargepa	Istargepa	Istargepa	Istargepa
L.inde_com	0.705** (2.41)	0.834*** (2.89)	0.834** (2.06)	0.995** (1.99)
L.log_Total	0.456*** (26.76)	0.393*** (11.87)	0.393*** (6.44)	0.401*** (6.15)
L.cap_exp	0.140 (0.57)	0.156 (0.68)	0.156 (0.57)	0.199 (0.56)
L.Leverage	-0.000639*** (-5.69)	0.0000330 (0.07)	0.0000330 (0.25)	0.000115 (1.34)
L.Borad_size	-0.0113 (-1.24)	0.0162 (1.51)	0.0162 (0.95)	0.0242 (1.33)
L.logQ	0.0550*** (5.25)	0.0153* (1.92)	0.0153* (1.74)	0.0128 (1.18)
year_pre2003			-0.000138 (-0.82)	-0.000137 (-0.83)
_cons	-8.538*** (-19.18)	-7.664*** (-10.34)	-7.388*** (-5.69)	-7.713*** (-5.54)
N	8185	8185	8185	8185
r2	0.133	0.118	0.118	0.119
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes
Trend control	No	No	Yes	Yes
Control*bill	No	No	No	Yes

*t* statistics in parentheses.  $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

established according to the above description:

$$\ln(1 + \text{patent}) = \beta_0 + \beta_1 \text{dum\_t} + \beta_2 * \text{dum\_u} + \beta_3 * \text{dum\_t} * \text{dum\_u} + \gamma Z_{i,t} + \varepsilon_i$$

$$\ln(1 + \text{Invention}) = \beta_0 + \beta_1 \text{dum\_t} + \beta_2 * \text{dum\_u} + \beta_3 * \text{dum\_t} * \text{dum\_u} + \gamma Z_{i,t} + \varepsilon_i$$

$$\ln(1 + \text{stargepa}) = \beta_0 + \beta_1 \text{dum\_t} + \beta_2 * \text{dum\_u} + \beta_3 * \text{dum\_t} * \text{dum\_u} + \gamma Z_{i,t} + \varepsilon_i$$

The release variables refer to Benjamin (2017) [9], which are total patents, substantive patents, and strategic patents. Dum\_t indicates that  $t > 2003$  is defined as 1 and vice versa. 0; dum\_u indicates that the number of independent directors in 2002 is 1 or less, and vice versa is 0.

The regression results (Table 6) show that the listed company with less than the minimum proportion after the completion of the reform of the independent directors in 2002 is relatively higher than the listed company with the pre-reformed independent directors in 2002, which is higher than the minimum level set by the CSRC. The number of patent applications and the number of applications for substantive patents decreased, and the number of applications for

**Table 6.** DID regression results for independent directors and patent types.

	lpatent	lInvention	lstargepa
dum_t	0.153 (0.92)	0.505*** (3.00)	-0.173 (-0.92)
dum_u	0.222 (1.19)	0.244 (1.29)	0.128 (0.60)
dum_t#dum_u	-0.144 (-0.75)	-0.209 (-1.07)	0.0120 (0.05)
L.log_Total	0.594*** (32.01)	0.592*** (31.55)	0.534*** (25.38)
L.cap_exp	-0.842** (-2.07)	0.0757 (0.18)	-1.908*** (-4.13)
L.Leverage	-0.000464 (-0.84)	-0.000193 (-0.03)	-0.000992 (-1.58)
L.Borad_size	-0.0396*** (-3.48)	-0.00241 (-0.21)	-0.0607*** (-4.71)
L.logQ	0.0818*** (4.85)	0.0943*** (5.53)	0.00285 (0.15)
_cons	-10.34*** (-24.09)	-11.98*** (-27.59)	-9.028*** (-18.54)
N	3374	3374	3374
r2	0.247	0.258	0.176

*t* statistics in parentheses.  $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

strategic innovation patents increased; strategic patents and substantive patents, the risk of innovation is smaller, and the gains obtained are greater. In the short term, the number of strategic innovation applications can make the company's performance look better and make the company's market valuation higher. Because the coefficient of policy effectiveness is not significant, we have not found that transitioning to an independent board affects innovation efficiency (Cohen, Dieher and Malloy, 2013) [13]. Then, in order to further explain the empirical results, we need to group return the listed companies, and divide them into private listed companies and state-owned listed companies through the actual controllers of listed companies, and obtain the following empirical regression results (Table 7).

The sample data of (1), (4) and (7) in Table 7 are from the full sample. The sample data of (2), (5) and (8) in Table 7 are from state-owned enterprises. (3), (6) and (9) sample data from private companies. The empirical results in Table 7 show that the policy effect coefficient of strategic innovation of private enterprises is significantly positive. In 2003, the minimum proportion of independent directors policy was more inclined to increase the strategic innovation of listed private companies with less than the minimum proportion of private independent directors in 2002. The number of patent applications has increased the

**Table 7.** Double difference total regression results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	lpatent	lpatent	lpatent	lInvention	lInvention	lInvention	lstargepa	lstargepa	lstargepa
dum_t	0.153 (0.92)	0.356* (1.92)	-0.909** (-2.39)	0.505*** (3.00)	0.570*** (3.11)	0.0669 (0.16)	-0.173 (-0.92)	0.0983 (0.46)	1.415*** (-3.36)
dum_u	0.222 (1.19)	0.338 (1.61)	-0.498 (-1.19)	0.244 (1.29)	0.291 (1.41)	-0.0571 (-0.13)	0.128 (0.60)	0.306 (1.28)	-0.838* (-1.81)
dum_t#dum_u	-0.144 (-0.75)	-0.276 (-1.26)	0.611 (1.43)	-0.209 (-1.07)	-0.224 (-1.04)	0.0296 (-0.06)	0.0120 (0.05)	-0.212 (-0.85)	1.080** (2.28)
L.log_Total	0.594*** (32.01)	0.584*** (27.94)	0.660*** (15.65)	0.592*** (31.55)	0.595*** (28.84)	0.572*** (12.44)	0.534*** (25.38)	0.533*** (22.33)	0.581*** (12.44)
L.cap_exp	-0.842** (-2.07)	-0.876* (-1.87)	-0.941 (-1.14)	0.0757 (0.18)	0.294 (0.64)	-0.738 (-0.82)	-1.908*** (-4.13)	-2.081*** (-3.89)	-1.471 (-1.62)
L.Leverage	-0.000464 (-0.84)	-0.000458 (-0.82)	-0.00826 (-0.48)	-0.0000193 (-0.03)	-0.0000406 (-0.07)	0.000599 (0.03)	-0.000992 (-1.58)	-0.000973 (-1.52)	-0.0130 (-0.69)
L.Borad_size	-0.0396*** (-3.48)	-0.0526*** (-3.98)	0.0206 (0.90)	-0.00241 (-0.21)	-0.0295** (-2.26)	0.0981*** (3.94)	-0.0607*** (-4.71)	-0.0699*** (-4.63)	-0.0309 (-1.22)
L.logQ	0.0818*** (4.85)	0.0664*** (3.21)	0.127*** (4.42)	0.0943*** (5.53)	0.0695*** (3.40)	0.169*** (5.42)	0.00285 (0.15)	0.0302 (1.28)	-0.0480 (-1.51)
_cons	-10.34*** (-24.09)	-10.17*** (-20.98)	-11.33*** (-11.68)	-11.98*** (-27.59)	-11.83*** (-24.74)	-12.03*** (-11.40)	-9.028*** (-18.54)	-9.188*** (-16.59)	-9.066*** (-8.45)
N	3374	2560	814	3374	2560	814	3374	2560	814
r2	0.247	0.254	0.247	0.258	0.280	0.204	0.176	0.178	0.187

*t* statistics in parentheses.  $p < 0.1$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

importance that independent directors attach to the patented inventions of private enterprises. This shows that the policy makes managers more inclined to strategic innovation rather than seeking to explore and break through new technologies, seeking fewer invention patent projects and avoiding new technologies. The independent directors in state-owned enterprises are not significant at all for patent inventions, indicating that state-owned enterprises are protected by the national government policy, and the phenomenon of rent-seeking between enterprise executives and the government has caused the company's development to stagnate, not only disregarding the new technology. Innovation and the original results are not new, may lead to the formation of "zombie enterprises", and may eventually be annexed by other companies. Since the sample of private enterprises is smaller than that of state-owned enterprises, the total sample data is similar to the sample data of state-owned enterprises, which is also the inadequacy of empirical research in this paper.

## 6. Summary

This paper uses the patent data of A-share listed companies from 1999 to 2016,

and analyzes the impact of listed companies' independent transition to independent directors and more board of directors on corporate innovation behavior. Through the construction of the panel fixed model and the double difference model in this paper, the following conclusions are obtained: First, the board of directors of a listed company that has independently transitioned to more independent directors has a clear positive effect on innovation activities. After, the definition of the nature of innovation shows that, in terms of strategic innovation and substantive innovation, the board of directors whose independent transition to more independent directors is more inclined to let the CEO carry out strategic innovation and obtain innovative income. Third, the paper draws from the DID model that the minimum independent director proportional policy allows private companies to increase their strategic innovation behavior relative to the lowest proportion of companies, rather than seeking new technology exploration and breakthrough.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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