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Corporate Governance and Technological Progress: Evidence from China

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Abstract: Studies on the relationship between corporate governance and technological innovation at regional level make it possible to investigate effectively how regional differences influent the relationship above，when considering factors like technology diffusion, industrial clusters credit resources and the other regional factors of production. Therefore, this research can be helpful in developing regional policies for promoting technological innovation. Although there are plenty of studies conducted at the enterprise level, empirical research at the regional level is still rarely studied in China. Based on Chinese provincial panel data, this paper attempts to conduct an empirical research on the relationship between corporate governance and technological innovation at the regional level. The empirical results show that after controlling for capital, human capital, economic extraversion, foreign investment, debt level and the technical output efficiency, there is a significant positive correlation between the shareholders governance index and accumulation of R&D capital at the regional level, while a significant negative correlation between the manager governance index and accumulation of R&D capital at the same level. In addition, with the increase of inputs or regional GDP, as well as improvement of openness or technical efficiency, the manager governance can have a better effect on promoting the accumulation of regional R&D capital.

Keywords: Corporate governance; Technological progress; Production, protection and predation model; Risk appetite

JEL Classifications: O31, G32, R11

1. Introduction

The topic on how to improve the innovation ability of regional enterprises has drawn a great deal of attention from researchers. Previous researches，trying to study what has influenced the technological innovation of enterprises, mainly focused on the aspects of market structure, industry characteristics, entrepreneurial ability and financial structure. However, it is hard to explain the phenomenon that the enterprise has a big gap in technological innovation under the similar condition of external environment, scale and market position. Recently, the scholars gradually have shed light on how the system factor works in technological innovation of enterprises. Hence the relevant literature argues that the improvement of technological innovation is not only closely related to the capital investment and human capital investment, but also to the enterprise system (e.g. SSLV, 1997).Corporate governance, as the most basic system arrangement, has drown scholars ‘interest first of all. Some economists find that the country with better governance shows higher productivity, suggesting that the quality of corporate governance and system can explain the

difference in growth rate of international countries (Clague et al., 1995; Keefer and Knack, 1995; Olson et al., 2000). Lazonick and O 'Sullivan (2000) emphasizes that technological innovation can make a link between corporate governance and the country's economic growth, and Hua (2002) points out that the improvement in corporate governance system, which strengthens the effect of enterprise technology innovation, is indirectly related to the productivity growth. Subsequently, some studies argue that it can provide a reliable micro basis for the economic growth theory when corporate governance is considered into the growth model, and regional corporate governance should be taken into account in economic growth (Dang, 2012).

In fact, how corporate governance can influence the technological innovation level mainly depends on the different attitudes of enterprise shareholders and managers when they face the high-risk and high-profit technological innovation. Technological innovation is primarily focused on long-term corporate profits, which will impose more burdens on the short-time financial goals and operating performance. Concretely, shareholders can disperse the risk of technological innovation through investment portfolios, while managers will undertake the pressure of short-term performance objectives caused by technological innovation activities (Alchian and Demsetz, 1972). As a consequence, the agency problem for technological innovation, generated by the differences in risk tolerance between shareholders and managers (Feng et al., 2008), will seriously weaken the managers' positivity on innovation (Wrihgt et al., 1996). The existing literature mostly supports that the moderate concentration of equity can effectively alleviate the influence of the agency problem. In other words, the existence of large shareholders can primly solve the problem of "free rider", which usually happens in an enterprise with lots of small shareholders (Shleifer and Vishny, 1986). In the pursuit of maximizing self-interests, large shareholders will supervise the operators to carry out technological innovation activities and limit their risk-averse diversification strategies (Hill and Snell, 1988). Furthermore, scholars believe that the support from top management is the most critical factor in the corporate technological innovation (Nakahara, 1997), even if the incentive mechanism generating sustainable profits between the operator and the owner can obviously enhance the operators' support for technological innovation (Jensen and Meckling 1976). Following previous researches, it is widely accepted that factors such as executives' equity incentive, tenure and resign can have significant effects on R&D expenditure (Liu and Liu, 2007).

So far, however, the research on the relationship between corporate governance and technological innovation at regional level has been lacking in China. The main reason is that scholars cannot reach an agreement on the measurement of the regional corporate governance level, causing a relative lag of the establishment of the regional governance evaluation system in China compared to other countries. Until recent years, empirical studies on corporate governance in the region have become more and more popular. In addition, another important reason for the absence of researches is that the theoretical research is still lack of a cogent model which can effectively introduce micro-level corporate governance into macro-level technological innovation. So the results of conflicts between shareholders and managers on regional technological innovation can be explained with further extend in the traditional economic growth theory.

In this paper, we attempt to break through the present limitations. Specifically, we adopt to the evaluation index of the provincial corporate governance from *Chinese listed corporate governance evaluation report* issued by Nankai University to measure the corporate governance at the provincial level. Particularly, the theoretical model of *production, protection and predation* was first established to elaborate how regional corporate governance works on the technological innovation (Hirshleifer, 1988). Based on Chinese provincial panel data from 2003 to 2008, this paper conducts a regional empirical research on the relationship between corporate governance and technological innovation. The empirical results show that after controlling capital, human capital, economic extraversion, foreign investment, debt level and the technical output efficiency, the structure of shareholder governance aimed at protecting the interests of small shareholders weakens large

shareholders' enthusiasm for supervision. Therefore there is a significant negative correlation between the index of regional shareholder governance and the accumulation of regional R&D capital. On the contrary, the structure of manager governance to strengthen managers 'executive power improves the diversity of risk preference for technological innovation activities between shareholders and managers, which leads to a significant positive correlation between the index of regional manager governance and the accumulation of regional R&D capital. In addition, with the increase of resources inputs and regional GDP, and improvement of openness and technical efficiency, the manager governance can better promote the accumulation of regional R&D capital.

The main contributions of this paper can be summarized as follows: First, from the perspective of theoretical innovation, our study explains the gambling behavior of the shareholders and managers on technological innovation in terms of production, protection and predation model, and then on equilibrium condition, the role of corporate governance is extended to the economic growth model. Second, this paper tries to break through the limitation of the previous empirical studies at enterprise level, and tests the influence of corporate governance on the technological innovation at regional level. Thirdly, in the aspect of policy formulation, the analysis of this paper will be benefit to provide a theoretical basis and operation methods to promote technological innovation by improving regional corporate governance.

2. Literature Review and Theoretical Model

A simple model of Production, Protection and Predation is first proposed by Hirshleifer (1988). Afterwards, many scholars contribute to further studies to extend his model, which is then applied to analyze the effect of protection and predation in long-term economic growth, by combining it with long-term economic growth model (Grossman and Kim 1995; Mauro 1998; Sarte 2000).

In the assumption of Production, Protection and Predation models, individuals will be divided into two categories, the producer (protector) and the predator. This paper defines the shareholder as "producer", and the manager layer as "predator". Resources have three kinds of functions: production, protection and predation. More specifically, the predator tries to capture others' products, while the role of the producer is to produce product utilizing the resources and to protect it free from predation. As a result, this model aims to achieve optimized resource allocation between shareholders' production and protection in view of individuals 'utility maximization and to make sure that the marginal revenue of protection and predation activity are equal. Similarly, individuals should make a choice between to be a shareholder or a manager to assure the equality of the private marginal revenue.

Assume that each person is given 1 unit of time or resources. F refers to the proportion of time or resources for the protection of a representative shareholder. Therefore the output of the representative shareholder is *(1 – F)*, and *L* is the proportion of the yield lost to the manager. Furthermore, it is supposed that the production of final product is in accordance with the inclusive human capital (H) of the expanded Solow model, in which the physical capital share of output is α, human capital output share is β and marginal product of capital is $\alpha Y/K$, so the production function takes the form:

$$Y = AK^{\alpha}H^{\beta}\ ,\ 0 < \alpha, \beta < 1 \qquad (1)$$

Considering the ratio of the output which the shareholders keep is only (1 - L), the private marginal product of capital equals (1 - L) multiplied by $\alpha Y/K$. Therefore, it can be initially concluded that the larger L value will hinder the accumulation of capital. If there is no depreciation, capital can flow freely between regions, and the private marginal product of capital is equal to the average rate of social return r^*, thus, the equilibrium condition is:

$$(1-L)\alpha\ \frac{Y}{K} = r^* \ or\ \frac{K}{Y} = \frac{(1-L)\alpha}{r^*} \qquad (2)$$

From the above equation, we can infer that the increasing amount of the manager's predation (referred to L) will reduce the capital to output ratio. Besides, the behavior of predation decreases the proportion of economic inputs for production. Furthermore, considering the risk of the existence of capital itself being predation, the above mentioned effect will be strengthened. Meanwhile, hypothesizing that the probability of each unit of capital (K) the rent-seekers can obtain is P, undoubtedly, the expected private income of one unit of capital is $[(1-L)\alpha \mathrm{Y}/\mathrm{K}]\text{-}\ p$. If the private income has to be equal to the average rate of social return r^*, we can draw a conclusion that the capital-output ratio will gradually decline with the increasing L and P when it comes to an equilibrium state:

$$\frac{K}{Y} = \frac{(1-L)\alpha}{r^*+p} \qquad (3)$$

Following Nishimizu and Page's (1982) analysis for the growth of total factor productivity growth, total factor productivity (A) can be divided into technological progress (TP) and technical efficiency (TE), without considering the condition of non-efficiency allocation of resources.

$$A = TP \cdot TE \qquad (4)$$

Due to the technological progress (TP) is closely related to technology capital stock (K_A) and the economic system environment (such as GDP, open, loan), the formula (4) can be expounded as:

$$TP = \frac{1}{\alpha}\left[\frac{(1-L)}{r^*+p}\right]^{-1} TE^{-1}K^{1-\alpha}H^{-\beta} \qquad (5)$$

Where TP is a function of K_A, namely: $TP = f(K_A)$

$$f(K_A) = \frac{1}{\alpha}G^{-1}TE^{-1}K^{1-\alpha}H^{-\beta}, \mathrm{G} = \frac{(1-L)}{r^*+p} \qquad (6)$$

Corresponding to equation (6), the size of technology capital stock (K_A) has a positive relationship with the reciprocal of corporate governance level (G).Obviously, technological progress is directly proportional to the probability of per unit capital obtained by the rent-seeker (P), and inverse to the ratio (1-L) retained by the producer. For the index of shareholder governance, a higher level of shareholder governance indicates lower ownership concentration and more small investors' protection. Finally, it means that the probability (P) of which managers' "rent-seeking" behavior is found descends by the improvement of regional shareholder governance level, under the existence of small shareholders' free riding. Simultaneously, more incentive pay (L) is necessary for managers to ensure the effective implementation of technological innovation activities, and this is not conducive to the accumulation of technology capital (K_A).

Comparatively, the higher level of manager governance indicates that more attention should be paid to strict supervision and incentive compensation. Stricter supervision can directly reduce the incentive pay (L) to managers and the success probability (P) of managers' "rent-seeking" behavior, which is conducive to the accumulation of regional technical capital (K_A). In addition, the ultimate foothold of the manager governance is the risk preference (Huffman and Hegarty, 1993). Nevertheless, external economic factors which can influence the managers' risk appetite, such as economic policy, foreign investment level, economic growth (Li 2009), as well as the economic cycle (Wang 2005) and inflation (Shen 2011), etc., are conduced to intensify the effect of regional manager governance on technological progress.

Overall, inspired by above analyses, we formulate the following hypotheses in this paper:

Hypothesis 1: Ceteris paribus, the regional shareholder governance index has a negative correlation with the technological innovation.

Hypothesis 2: Ceteris paribus, the regional manager governance index is positively related to technological innovation.

Hypothesis 3: Ceteris paribus, the positive association between the regional manager governance index and technological innovation is stronger with better external economic environment (including the capital stock, human capital stock, output level, loan size, economic extroversion and foreign investment environment, etc.).

3. Specification of Empirical Models and Selection of Variables

Combined with the analysis of the basic model, this paper will establish the econometric model according to the formula (6) as follows:

$$\ln TP_{it} = \ln\alpha + \beta_1 \ln G_{it} + \beta_2 \ln x_{it} + \varepsilon_{it}, \ \left(i = 1,2,\dots,N; t = 1,2,\dots, \ T\right) \quad (7)$$

Among them, TP_{it} represents the regional technological innovation level, measured by the technology capital stock (K_A), and G_{it} stands for the Chinese regional corporate governance level, and other variables such as social average yield, regional capital stock (K), regional human capital stock (H), technical efficiency (Te), regional gross domestic product (GDP), economic openness (Open) and regional loan balance (Loan) and so on are substituted by x_{it}, the subscript i for the region and t for the time .Therefore, the specific measurement model is:

$$lnK_A = c_0 + (-c_1)lnG + c_2 lnK + (-c_3)lnH + (-c_4)lnTE + c_5 lnGDP + c_6 lnloan + c_7 lnopen + c_8 lnFDI + \varepsilon \quad (8)$$ [1]

The specific definitions of these variables are:

K_A: the value of regional R&D capital stock, measuring the level of regional science and technology development. It is obtained by the estimation of R&D investment in each period. We use $\ln K_A$ as the explained variable.

G: the level of provincial corporate governance, appraised by the corporate governance evolution index. The variables in the model are determined by the probability (P) of rent seekers' behavior on predation to get additional private profits and the producer retention ratio (1-L).

K: the Chinese provincial capital stock calculated by the perpetual inventory method.

H: the Chinese provincial human capital stock according to the method of years of education accumulation.

TE: technical efficiency. The total factor productivity is decomposed into technical innovation and technical efficiency by using random boundary analysis.

GDP, Open and Loan: system environment variables. Technological innovation is affected by the environment of local economic development and system. Hence, this paper assumes that the factors of system environment are economic openness, foreign capital utilization (measured by FDI) and regional debt level (measured by total loan).

[1] From the equation (6), $f(K_A) = \frac{1}{\alpha} G^{-1} TE^{-1} K^{1-\alpha} H^{-\beta}$, corporate governance factors (G), human capital stock (H) and technical efficiency (TE) are for the reciprocal forms. To better explain our findings, we introduce these three variables with negative coefficients. That is, when the estimated value of the variable parameter is positive, there is a negative correlation between the explanatory variable and the dependent variables, a positive correlation otherwise.

3.1 The measurement of technological innovation

How to measure enterprise technological innovation level is still a difficult problem for researchers. Previous research mainly takes several flow indexes such as the current R&D investment (Baysinger, 1991) and the ratio of current R&D expenditure to sales income (Lee, 2003). Instead, in order to reflect the characteristics that the benefits of the current period investment in technological innovation will continue for some time in the future and the investment in technological innovation projects is carried out at some stages, we choose a new method. In this paper, we select the R&D capital stock formed by the accumulation of R&D technological expenditure in each period as a measure index.

Following the idea that Li (2007) takes for the estimation of China's R&D capital stock, the R&D capital stock in the stage t can be described by the sum of all present value of R&D expenditure $\{E_{t-i}\}$ in the past periods and present value of R&D capital stock in the stage (t-1) (Griliches, 1984; Suzuk and Goto 1989).The equation is as follows:

$$R_t = \sum_{i=1}^{n} \mu_i E_{t-i} + (1-\delta)R_{t-1} \qquad (9)$$

In Equation (9), R_t means the R&D capital stock in the stage t, *n* means the longest lag period, μ_i is the discount coefficient of the R&D expenditure lag, E_{t-i} is the R&D investment in the stage (t-i), and δ is the rate of obsolescence of R&D capital stock. Assuming that the rate of obsolescence does not change with the time, the average lag phase of R&D expenditure is equal to τ. When $i = \tau$, $\mu_i = 1$, and μ_i is zero if i is not equal to τ. As a result, we can summarize in the following equation:

$$E_{t-\tau} = \sum_{i=1}^{t} \mu_i E_{t-i} \qquad (10)$$

With reference to international practices, the rate of obsolescence δ about China's R&D capital stock is set for 15%, and the lag phase τ is for 0. Moreover, combined with equations (9) and (10), we can obtain:

$$R_t = E_t + (1-15\%)R_{t-1} \qquad (11)$$

Supposing that the average growth rate of R&D capital stock (R) and R&D expenditure (E) is equal and if t is equal to 1, we can draw some conclusions based on Equation (11):

$$R_1 = E_1 + (1-15\%)R_0\,, \quad R_0 = E_1/(g+15\%), \quad g = \sqrt[11]{E_{2011}/E_{2000} - 1},$$

where R_0 represents the R&D capital stock in the base period, G is the average growth rate of R&D expenditure (excluding the price factor) from the base year 2000 to 2001. In addition, in order to eliminate the impact of price factors, the amount of the current R&D expenditure will be reduced by the GDP deflator.

3.2 The measurement of corporate governance

This paper is based on Chinese listed Corporate Governance Evaluation Research Report issued by the research center of corporate governance in Nankai University. So far, the evaluation index system has been the most authoritative and comprehensive evaluation system of corporate governance. Specifically, it establishes six first class indexes and nineteen second class indexes from six dimensions of the shareholder equity ($CCGI_{SH}^{NK}$), "the board of directors" ($CCGI_{BOD}^{NK}$), "the board of supervisors" ($CCGI_{BOS}^{NK}$), "the manager layer " ($CCGI_{TOP}^{NK}$)," information disclosure "($CCGI_{ID}^{NK}$)and “the stakeholder equity "($CCGI_{STH}^{NK}$). Considering previous literature research, this paper mainly focuses on the indexes of corporate shareholder governance evaluation and the regional manager governance evaluation.

3.2.1 The evaluation of shareholder governance

Shareholder governance evaluation is to measure whether the allocation of profits among the

shareholders is fair, including three main factors: related transaction ($CCGI_{SH1}^{NK}$), independence ($CCGI_{SH2}^{NK}$) and protection for small shareholders' rights and interests ($CCGI_{SH3}^{NK}$).

$$(CCGI_{SH}^{NK} = W_1 \times CCGI_{SH1}^{NK} + W_2 \times CCGI_{SH2}^{NK} + W_3 \times CCGI_{SH3,}^{NK} \quad W_1 + W_2 + W_3 = 1$$

$CCGI_{SH1}^{NK}$ explains whether there is a competition between the corporate and related units , an analysis report about definite connection transaction pricing , the controlling shareholders' free possession of capital, the guarantee for controlling shareholders or other associated parties or not ; $CCGI_{SH2}^{NK}$ measures whether the corporate has a relation with its controlling shareholder in the aspects of personnel, business , finance and assets; $CCGI_{SH3}^{NK}$ is evaluated by answering a series of questions such as whether the shareholders' meeting allows the shareholders' participation as much as possible, whether the procedure of the shareholders' meeting is fair and standard, as well as whether the small shareholders have been given enough more concern, etc..

3.2.2 The evaluation of manager governance

Similarly, manager governance evaluation index consists of three dimensions: managers' appointment and removal system ($CCGI_{TOP1}^{NK}$), guarantee of managers' execution ($CCGI_{TOP2}^{NK}$) and managers' incentive and constraint mechanism ($CCGI_{TOP3}^{NK}$).

$$CCGI_{TOP}^{NK} = W_1 \times CCGI_{TOP1}^{NK} + W_2 \times CCGI_{TOP2}^{NK} + W_3 \times CCGI_{TOP3,}^{NK} \quad W_1 + W_2 + W_3 = 1$$

3.2.3 Other dimensions of corporate governance

The evaluation of the board of director's governance is aimed at measuring directors' sincerity and diligence consciousness from the perspective of financial creation and social responsibility. Simultaneously, the evaluation of the board of supervisor's governance is to appraise whether the regulation is effective on the principles of the enthusiasm and effectiveness of supervision, independence, completeness and objectivity. Besides, the information disclosure governance measures the quality and transparency of information according to the standard of reliability, timeliness and relevance about information disclosure. In addition, stakeholder governance evaluation measures the condition of enterprise stakeholders 'participation of corporate governance and protection of interests on the basis of scientificalness, feasibility and integrity.

3.3 The capital stock, human capital stock and technical efficiency

The perpetual inventory method (PIM) is applied to assess the value of capital stock K (Goldsmith 1951). Under the assumption of investment price index and efficiency model (Shan 2008), we determine the year 1952 as the base year, and fix the depreciation rate of all the regions at the level of 10.96%. Secondly, we choose the method of years of education accumulation to estimate the regional human capital stock (Jin and Duan 2007). In detail, we estimate the total human capital stock in each region by selecting the data between 2003 and 2008 from China's population statistics yearbook. Finally, this paper attempts to estimate technical efficiency (TE) in accordance with the stochastic frontier model $y_{i\tau} = f(x_{it}, t)\exp(-u_{i\tau})$ (Battese and Coelli, 1995).

4. Empirical Analysis

4.1 Descriptive statistics

Broadly, we can gain the systemic evaluation of corporate governance level between 2003 and 2008 from *Chinese Listed Corporate Governance Evaluation Report*. In this paper, we choose the data from 2003 to 2008, which covers a total of 186 samples from 31 provinces, municipalities and autonomous regions in China (excluding Taiwan province). The definition and basic statistics of main variables are showed in Table 1.

Table 1 Definition and Basic Statistics of Main Variables (2003~2008)

Variables	Definition	Sources	Samples	Mean	Std. Dev.	Min	Max
lnK_RD	R&D Capital stock (million RMB)	estimated	174	4.666	1.583	0.125	7.261
lnK	Real Capital stock (million RMB)	estimated	180	7.699	1.151	4.722	9.741
lnH	Human Capital(million)	estimated	186	0.032	0.903	-2.875	1.163
lnTE	Technical Efficiency	estimated	180	-0.058	0.021	-0.126	-0.02
lnGDP	Real GDP (million RMB)	NBS	186	8.457	1.055	5.221	10.513
lnLOAN	Loan size at provincial level (million RMB)	NBS	181	8.351	1.038	4.972	10.288
lnOPEN	total imports and exports (million RMB)	NBS	186	6.841	1.778	2.583	10.784
lnFDI	total amount of foreign investment (million RMB)	NBS	186	7.307	1.56	3.31	10.277

We establish the provincial corporate governance evaluation index system, one total index and six sub-indexes from different dimensions included. Particularly, the data of Guangdong province in 2003 is calculated by the weighted average listed corporate governance index of the Shenzhen municipal and Guangdong province (excluding Shenzhen). All the indexes are computed by centesimal system, and the greater index implies better corporate governance level. In detail, we display the basic descriptive statistics of corporate governance indicators in Table 2.

Table 2 Descriptive Statistics of Corporate Governance Indicators at Provincial Level

Variables	Sample	Mean	Var	Min	Max
Corporate governance evaluation total index（score）	186	54.84	2.791	47.47	59.23
Shareholder governance evaluation index（holder）	155	56.43	3.437	44.30	64.28
Board of director governance evaluation index（board）	186	52.96	5.153	36.00	60.29
Board of supervisor governance evaluation index (supervisor）	186	50.95	3.363	36.99	57.75
Manager governance evaluation index（manager）	186	54.36	3.175	45.42	59.63
Stakeholder governance evaluation index（stakeholder）	186	52.95	3.227	45.50	62.30
Information disclosure evaluation index (information）	180	61.72	2.902	49.93	67.91

4.2 Results of panel data regressions

To investigate the relationship between corporate governance and technological innovation at regional level, we attempt to select the best method to evaluate the panel data .Consequently, this paper utilizes F test to identify the Pooled Regression model and Fixed Effects Regression model. Furthermore, the recognition of the Pooled Regression model and Random Effects Regression model is tested by LM statistic after we perform the BP test in Table 3. Finally, we make a choice between Fixed Effects Regression model and Random Effects model by the Hausman test. According to the equation (8), the test results show that the Fixed Effects model is superior to the other two estimation models. Therefore, this paper selects the Fixed Effects model as the estimation method to equation (8).

To avoid the noise of heteroskedasticity, sequence correlation and cross-sectional dependence, etc., we adopt to the method proposed by Kraay and Driscoll (1998)[2]. Columns 1-7 of the panel in table 4 report the results of the corporate governance evaluation index and the six sub-indexes as the

[2] Driscoll& Kraay (1998) put forward to a kind of nonparametric covariance matrix estimation method, which is asymptotic efficiency when N tends to infinity and provides the consistent standard error with eliminating the consequences of heteroskedasticity and self-correlation.

explanatory variables respectively. The R^2-wald value is significant, which indicates that goodness of fit of the model is perfect.

Table 3 Results of tests to Pooled OLS Model, Fixed Effects Model and Random Effects Model

	Pooled Regression Model	Fixed Effects Regression Model	Random Effects Regression Model
F-test（Prob. > F）		185.98(0.0000)	
BP-test（Prob. > chi2）			310.91(0.0000)
Hausman-test（Prob. > chi2）		16.65(0.0198)[3]	
Adjusted R^2	0.9287	—	—
R^2 Within	—	0.9458	0.9429

Table 4 Empirical results of the relation between corporate governance and technological innovation

Dependent Variables	R&D Capital Stock（K_rd）						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
lnK	0.206***	0.182**	0.201***	0.194***	0.200***	0.196***	0.113***
	(0.046)	(0.084)	(0.046)	(0.038)	(0.045)	(0.056)	(0.031)
lnH	0.0210	0.0710	0.0250	0.0210	0.0350	0.0220	0.0200
	(0.102)	(0.094)	(0.103)	(0.095)	(0.100)	(0.101)	(0.081)
lnTE	-13.474***	-14.840***	-13.524***	-13.699***	-13.732***	-13.588***	-14.925***
	(1.038)	(2.251)	(1.033)	(0.869)	(1.016)	(1.152)	(0.830)
lnGDP	-0.155*	-0.152	-0.147	-0.135	-0.134	-0.143	-0.101
	(0.087)	(0.098)	(0.089)	(0.089)	(0.094)	(0.092)	(0.068)
lnloan	0.225***	0.195***	0.224***	0.218***	0.211***	0.228***	0.209***
	(0.064)	(0.060)	(0.065)	(0.066)	(0.065)	(0.062)	(0.058)
lnopen	0.210***	0.226***	0.215***	0.219***	0.224***	0.213***	0.211***
	(0.033)	(0.040)	(0.029)	(0.029)	(0.030)	(0.030)	(0.025)
lnFDI	0.0240	-0.0130	0.0250	0.0240	0.0260	0.0240	0.0160
	(0.029)	(0.015)	(0.029)	(0.027)	(0.029)	(0.030)	(0.025)
lnscore	0.103						
	(0.076)						
lnholder		0.191***					
		(0.068)					
lnboard			0.0120				
			(0.052)				
lnsupervisor				-0.0490			
				(0.073)			
lnmanager					-0.109***		

[3] According to the Hanuman-test, chi^2 value is negative. The variance-covariance matrixes both are replaced by Fe model and Re Model, and results are shown separately as 17.81（0.0129, 16.65（0.0198）,we choose the model with greater P-value .

					(0.039)		
lnstakeholder						-0.0300	
						(0.071)	
lninformation							-0.0520
							(0.099)
cons	-0.305	-0.156	0.00200	0.220	0.415	0.156	0.713
	(0.347)	(1.111)	(0.408)	(0.313)	(0.452)	(0.717)	(0.530)
N	163	135	163	163	163	163	158
R^2-wald	0.946	0.947	0.946	0.946	0.946	0.946	0.946

Notes: (1) The results are estimated on the basis of the standard errors measured by Driscoll& Kraay, and the value in parentheses is the standard deviation of the coefficient in the table;

(2) The data are processed by Stata 12.0. ***, **, and * represent the 1%, 5%, and 10% levels of statistical significance, respectively.

Moreover, we concentrate on the relation between the regional corporate governance level and the R&D capital stock. From the results (table 4), with the size of human capital and loans, capital stock and regional GDP, the degree of opening up as well as the foreign investment environment and technical efficiency constant, the coefficient of the total corporate governance evaluation index at provincial level is positive, which illustrates that R&D capital stock has a negative correlation with the total corporate governance evaluation index[4]. Nevertheless, the effect is not significant.

However, when it comes to six sub-indexes, we can conclude that only the coefficients of regional shareholder governance evaluation index and manager governance evaluation index are significant to R&D capital stock (at 1% level), other indexes not. Overall, only the regional shareholder governance and manager governance can impact the accumulation of technological innovation capital among the six aspects used to measure corporate governance. These findings are consistent with the view that the focus point of the relevant studies is to discuss the mechanism how the shareholder and manager governance contribute to corporate governance and technological innovation.

In addition, the coefficient of regional governance evaluation index is positive; inversely the coefficient of regional manager governance evaluation index is negative. By the formula (8), we argue that the regional governance index negatively correlates with the accumulation of technological innovation capital, while the regional manager governance index is on the contrary. In other words, the improvement of regional shareholder governance is not conducive to technological innovation, while higher level of regional manager governance can promote the accumulation of technological innovation capital. Consequently, hypothesis 1 and 2 are strongly supported.

4.3 Robustness checks

In this paper, we adopt the indicator of R&D capital stock rather than the current R&D expenditure to measure technological progress, which is different from most prior literature. Hence we perform several robustness checks of our main results by selecting current R&D expenditure as the independent variable. Table 5 shows that the sign and significance of coefficients of main independent variables and control variables keep consistent with the results in table 4. Regional shareholder governance index and regional manager governance index both are significant at the 5% level. On the whole, it demonstrates that the estimation results are robust to the equation (8).

[4] In equation (8), the coefficient of the corporate governance level (G) is $-c_1$.It means that R&D capital stock has a negative correlation with the corporate governance level when the coefficient is positive.

Table 5 Robustness Checks results of the relation between corporate governance and R&D expenditure

Dependent Variables	R&D expenditure（R_d）						
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
lnK	0.551***	0.462***	0.552***	0.545***	0.561***	0.568***	0.491***
	(0.107)	(0.120)	(0.112)	(0.112)	(0.115)	(0.119)	(0.083)
lnH	0.374*	0.198	0.401**	0.357*	0.394*	0.405*	0.365*
	(0.216)	(0.137)	(0.191)	(0.176)	(0.204)	(0.203)	(0.195)
lnTE	-4.621***	-5.204*	-4.554***	-4.859***	-4.949***	-4.279***	-4.565***
	(0.606)	(2.908)	(0.689)	(0.682)	(0.655)	(0.837)	(0.773)
lnGDP	-0.016	0.124	-0.003	0.003	0.005	-0.022	0.073
	(0.134)	(0.154)	(0.146)	(0.149)	(0.142)	(0.156)	(0.115)
lnloan	0.235***	0.128	0.229***	0.234***	0.205***	0.207***	0.185**
	(0.067)	(0.134)	(0.066)	(0.070)	(0.059)	(0.057)	(0.069)
lnopen	0.425***	0.452***	0.431***	0.430***	0.440***	0.442***	0.422***
	(0.040)	(0.055)	(0.041)	(0.035)	(0.036)	(0.041)	(0.032)
lnFDI	-0.011	-0.054***	-0.010	-0.012	-0.007	-0.007	-0.010
	(0.025)	(0.006)	(0.024)	(0.023)	(0.027)	(0.026)	(0.024)
lnscore	-0.070						
	(0.213)						
lnholder		0.346***					
		(0.100)					
lnboard			-0.086				
			(0.083)				
lnsupervisor				-0.222*			
				(0.129)			
lnmanager					-0.309**		
					(0.150)		
lnstakeholder						0.193*	
						(0.103)	
lninformation							-0.020
							(0.112)
cons	-5.251***	-6.435***	-5.308***	-4.805***	-4.448***	-6.263***	-5.300***
	(0.507)	(1.374)	(0.256)	(0.318)	(0.483)	(0.725)	(0.427)
Obs.	175	145	175	175	175	175	169
R^2-wald	0.940	0.929	0.940	0.940	0.940	0.940	0.938

Notes: (1) The results are estimated on the basis of the standard errors measured by Driscoll& Kraay, and the value in parentheses is the standard deviation of the coefficient in the table;

(2) The data are processed by Stata 12.0. ***, **, and * represent the 1%, 5%, and 10% levels of statistical significance, respectively.

Secondly, as a consequence of the lack of regional R&D expenditure data from 2003 to 2008, we calculate the R&D capital stock based on the total R&D expenditure at provincial level (including expenditures of enterprises, research institutions, universities and other relevant

agencies)[5]. Additionally, in order to investigate the effect of the statistical deviation on the results, this paper substitutes the R&D capital stock for the internal R&D expenditure of regional industrial enterprises, and conducts robust tests. Naturally we can draw a conclusion from Table 6 that the results of the equation (8) are consistently robust. Besides, the board of director's governance, stakeholder governance and information disclosure are also significant at 5% level in table 6.

Table 6 Industry- level: results of the relation between corporate governance and R&D expenditure

Independent Variables	R&D expenditure(R_d2)						
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
lnK	0.642***	0.585***	0.643***	0.648***	0.674***	0.658***	0.653***
	(0.073)	(0.118)	(0.078)	(0.067)	(0.077)	(0.071)	(0.082)
lnH	0.357**	0.392***	0.450***	0.296*	0.390***	0.367**	0.214
	(0.136)	(0.121)	(0.116)	(0.159)	(0.136)	(0.140)	(0.128)
lnTE	-1.580	-1.753	-1.375	-1.661	-2.626	-0.840	-2.337*
	(1.274)	(1.897)	(1.127)	(1.564)	(1.548)	(1.275)	(1.153)
lnGDP	-0.400***	-0.334**	-0.355***	-0.435***	-0.358***	-0.418***	-0.366***
	(0.100)	(0.129)	(0.111)	(0.092)	(0.107)	(0.102)	(0.119)
lnloan	0.384***	0.327***	0.361***	0.392***	0.296***	0.327***	0.282***
	(0.028)	(0.045)	(0.031)	(0.031)	(0.076)	(0.053)	(0.051)
lnopen	0.286***	0.334***	0.302***	0.253***	0.314***	0.298***	0.239***
	(0.025)	(0.044)	(0.024)	(0.022)	(0.028)	(0.028)	(0.031)
lnFDI	-0.059*	-0.096***	-0.058	-0.065**	-0.053	-0.054	-0.041
	(0.033)	(0.020)	(0.038)	(0.030)	(0.037)	(0.038)	(0.038)
lnscore	-0.494**						
	(0.188)						
lnholder		0.408**					
		(0.199)					
lnboard			-0.380***				
			(0.105)				
lnsupervisor				-0.038			
				(0.193)			
lnmanager					-0.946***		
					(0.164)		
lnstakeholder						0.427**	
						(0.172)	
lninformation							-0.252**

[5] Following previous literature, R&D expenditure measured by the amount of enterprises' R&D investment rather than the total society R&D expenditure is more accurate. However, the missing values of enterprises' R&D investment data at provincial level are considerable, and the internal R&D expenditure of industry enterprises cannot contain technological innovation level of non-industry enterprises. Fortunately, a large proportion of the total society R&D expenditure is enterprises' R&D investment (73.4% in 2010). Thus we consider the indicator of the total society R&D expenditure as a measure of technological innovation level.

							(0.113)
cons	-0.219	-3.576***	-1.016***	-1.582*	1.404	-3.454***	-0.499
	(0.665)	(1.208)	(0.208)	(0.890)	(0.828)	(0.598)	(0.534)
Obs	169	140	169	169	169	169	163
R^2-wald	0.779	0.839	0.782	0.776	0.793	0.782	0.793

Notes: (1) The results are estimated on the basis of the standard errors measured by Driscoll& Kraay, and the value in parentheses is the standard deviation of the coefficient in the table;

(2) The data are processed by Stata 12.0. ***, **, and * represent the 1%, 5%, and 10% levels of statistical significance, respectively.

4.4 Results on the influence of regional manager governance

This section is aimed to figure out how the regional manager governance affects the accumulation of technological innovation capital. One more step, the multiplications of the manager governance evaluation index and main control variables are introduced in the basic model. From the results displayed in table 7, we find that most multiplications are significant at 1% level (except the multiplication of the regional manager governance evaluation index and the regional loan balance).

Table 7 The impact of multiplications of the regional manager governance and the main variables on the technological innovation

Dependent Variables	R&D expenditure(K_rd)							
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
lnH	-1.180***	-0.057	0.038	-0.043	-0.004	0.073	0.065	0.058
	(0.085)	(0.092)	(0.108)	(0.097)	(0.099)	(0.123)	(0.114)	(0.088)
lnK	0.287***	-1.202***	0.329***	0.298***	0.261***	0.215***	0.289***	0.210***
	(0.070)	(0.251)	(0.088)	(0.077)	(0.071)	(0.048)	(0.080)	(0.042)
lnloan	0.195***	0.190**	-1.138***	0.201***	0.196***	0.216***	0.190**	0.223***
	(0.064)	(0.073)	(0.034)	(0.064)	(0.062)	(0.065)	(0.070)	(0.056)
lnopen	0.228***	0.219***	0.232***	-0.612***	0.242***	0.221***	0.227***	0.226***
	(0.033)	(0.030)	(0.034)	(0.029)	(0.035)	(0.026)	(0.033)	(0.030)
lnFDI	0.031	0.026	0.032	0.033	-0.876***	0.021	0.031	0.026
	(0.030)	(0.026)	(0.029)	(0.028)	(0.025)	(0.031)	(0.029)	(0.029)
lnTE	-13.766***	-14.870***	-12.132***	-10.867***	-11.517***	-56.880	-12.382***	-13.784***
	(1.296)	(1.241)	(1.579)	(1.715)	(1.755)	(38.365)	(1.561)	(1.016)
lnGDP	-0.202**	-0.272**	-0.191*	-0.123	-0.120	-0.244	-1.474***	-0.147
	(0.097)	(0.104)	(0.094)	(0.086)	(0.086)	(0.159)	(0.161)	(0.090)
lnmanager	-0.166***	-2.967***	-2.912***	-1.537***	-1.804***	0.369	-2.828***	6.720
	(0.052)	(0.427)	(0.175)	(0.089)	(0.090)	(0.423)	(0.212)	(5.633)
lnmanager*lnH	0.340***							
	(0.026)							
lnmanager*lnK		0.382***						
		(0.050)						
lnmanager*lnGDP			0.334***					
			(0.017)					
lnmanager*lnopen				0.211***				

				(0.007)				
lnmanager*lnFDI					0.227***			
					(0.006)			
lnmanager*lnloan						10.010		
						(8.828)		
lnmanager*lnTE							0.328***	
							(0.020)	
lnmanager2								-0.866
								(0.713)
cons	0.603	12.201***	11.216***	5.428***	6.677***	-0.848	11.017***	-13.130
	(0.474)	(2.009)	(0.372)	(0.649)	(0.663)	(0.998)	(0.991)	(11.044)
Obs	163	163	163	163	163	163	163	163
R^2-wald	0.949	0.953	0.951	0.951	0.951	0.946	0.951	0.946

Notes: (1) the results are estimated on the basis of the standard errors measured by Driscoll& Kraay, and the value in parentheses is the standard deviation of the coefficient in the table;

(2) The data are processed by Stata 12.0. ***, **, and * represent the 1%, 5%, and 10% levels of statistical significance, respectively.

From the results, the impact of regional manager governance on technological capital accumulation is enhanced with the improvement of regional capital stock and human capital. Furthermore, the improvement of the macro economic conditions functions in the same way including regional GDP, total imports and exports, total foreign investment and technical efficiency as well as other macroeconomic conditions. Actually, managers participate in the decision-making and implementation of enterprise technical activities during the whole process from application to technological achievement. Therefore, different from shareholders with the supervision power, managers are easily disturbed by the external business environment of technological innovation activities when they make decisions. On the whole, the empirical conclusions are identical with our expectations.

5. Conclusions

Inspired by the view of the model of Production, Protection and Predation, we conduct this empirical research to examine the relationship between regional corporate governance and technological progress based on Chinese provincial panel data. The results show that the factors which affect the corporate governance including regional shareholder governance and manager governance have different effects on technological innovation. On one hand, there is a significant negative correlation between the regional index of the shareholder governance and technological innovation. Because regional shareholder governance evaluation index emphasizes the balance interests of large shareholders and small shareholders, which is to prevent large shareholders from infringing the interests of small shareholders, it has limited the large shareholders to obtain additional benefits from technological innovation, which reduces their motivation to monitor the managers' behaviors in the process of technological innovation. Therefore, it is more convenient for the managers to avoid more active participation in technological innovation activities.

On the other hand, there is a significant positive correlation between the regional index of the manager governance and technological innovation. The higher level of manager governance means smaller discrepant risk appetites between the shareholders and the managers and smaller additional

incentive compensation paid to the managers. Undoubtedly, more capital put into the technological innovation activities can promote the accumulation of technological innovation capital. In addition, the empirical results also suggest that, with the increase of resources inputs and regional GDP, and improvement of openness and technical efficiency, the manager governance can better promote the accumulation of technological innovation capital. The policy implication is that even if we do not directly take measures to change the level of regional manager governance, the influence of corporate governance on technological innovation still can be reflected by improving the external economic environment. In other words, improvement of regional investment and openness and technical efficiency can magnify the impact of the regional manager governance to technology innovation even in the original area of the same manager governance level. In general, regional manager governance plays a role in the accumulation of technological capital through some channels such as the resources inputs, openness and technical efficiency, etc..

Finally, from the perspective of policy-making, most preventative policies to accelerate the technological innovation are usually set in the light of the cost-benefit analysis. Simply, the government has issued several policies such as the introduction of technology innovation tax incentives and increase of financial support to provide credit facilities for the enterprise technology innovation and so on. However, these policies support for the enterprises are seldom attached to the requirements of corporate governance, which often makes it difficult for enterprises to get effective supervision. Actually, many enterprises that enjoy preferential policies would rather invest the real estate, stocks and other popular assets than practical technological innovation. This paper argues that the managers will still tend to avoid invest in the highly uncertain technological innovation activities if there is no fundamental change on managers ‘attitudes to the risk appetites for technological innovation. In contrast, if the technical promotion policies are attached to the corporate governance requirements, such as the responsibility of the shareholders' supervision and the managers' incentive compensation, the managers’ personal benefits is directly linked with the technological innovation, so that the financial resources can be fully utilized to achieve its policy intentions.

In summary, this paper argues that corporate governance factors should deserve more attention in the promotion of technological innovation. We can improve corporate governance level through allocating the interests between shareholders and managers to achieve the purpose of changing the risk appetites of managers. Moreover, the improvement of risk appetites of managers is beneficial to technical innovation investment enhancing the accumulation of the regional technological innovation capital, which can finally realize the regional economic development. Under the background of current Chinese economic slowdown and the problem of industrial upgrading, the impact of corporate governance on technological innovation can provide a new way for policymakers to boost the development of regional technological progress.

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