Intellectual Property Protection and Technological Innovation of Chinese GEM Manufacturing Enterprise

based on research of Quantile regression model and Dynamic panel models

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Abstract—By considering Chinese GEM listed manufacturing enterprise as research object, this paper presents an analysis of panel data from 2009 to 2013 and examines the relationship between R&D capital investment, level of intellectual property protection and patent output based on the quantile regression model, dynamic panel model and least squares regression model. This paper also presents estimators for factors that affect R&D capital investment input. The research indicates that intellectual property protection level promotes R&D capital investment. The research also shows an inverted U-shaped relationship between intellectual property protection level and innovation output. R&D capital investment and labor input show facilitation on promoting innovation output. Taking effects of government subsidy, liabilities and some other factors into consideration, the results this paper obtained demonstrate what kind of behavior companies and government shall conduct, this paper find company's assets and government subsides can promote innovation input while company's age and scale impede innovation input.

Keywords- quantile regression model; dynamic panel models; intellectual property protection level; innovation input;innovation output

I. INTRODUCTION

Innovation is very important in modern society; Joseph Alois Schumpeter [1] had pointed out that innovation was the process of commercialization and industrialization of scientific research. The Chinese GEM listed companies are mostly engaged in high-tech business with high growth potential. Although sizes are small and performance is not outstanding, but there is a huge room for growth. In innovation-driven development background, the GEM listed companies meet with new opportunities and challenges. GEM listed companies' innovation output is affected by many factors. In addition to R&D capital investment, labor input and other factors, the level of intellectual property protection is also an important factor in affecting innovation output, what kind of effects has the current level of intellectual property rights protection brought to influence GEM companies innovation output? What factors constraint these effects?

Therefore, through researching macro data to analyze the impact of the current level of IPR protection on GEM listed companies' innovation output is impressive, it has important theoretical and practical significance to design further refinement of intellectual property protection policies and industrial policies which are beneficial to the development of small and medium innovative enterprises.

II. RESEARCH STATUS

A. Relationship between Innvation Input and Output

The most representative person who used patents to analyze the relationship between innovation inputs and outputs were Schmookler (1966), Scherer (1965), which Schmookler (1966) found positive patents and industrial investment relations. To analyze the innovation output using patent is actually relatively easy, patent data is easy to obtain, but other measures of innovation output data are difficult to obtain.

In China, Wu Yuming and He Jiankun [2] (2007) conducted econometric analysis based on data from R&D investment of the capital region research universities and patent output of the region, found that in the capital region R&D investment affecting patent output existed two lag relationship. Xu Xin, Tang Qingquan [3] (2012) conducted research based on Chinese manufacturing listed companies from 2002 to 2006, discovered the relationship between the R&D investment, the stock of knowledge and patent output. The study found that since 2000, the number of patents owned by listed manufacturing companies increased year by year. Corporations R&D investment, past accumulated stock of knowledge and patents created a significant positive correlation, the greater R&D investment intensity, the more the stock of knowledge, the more different types of patent output.

B. Relationship between Intellectual Property Protection and Innovation

Research on whether intellectual property protection could promote innovation, there are three kinds of views. The first view is that strengthening intellectual property rights protection can promote technological innovation. Leger [4] (2007) had researched panel data of developed countries and developing countries, the estimation results indicated that there was a significant positive correlation between intellectual property protection and innovation

output in developing countries and the developed countries. Hu Kai, Wu Qing et al. [5] (2012) found that in China, strengthening intellectual property protection could significantly promote technological innovation by studying the 1997-2008 provincial panel data.

The second view is that strengthening intellectual property protection impedes technological innovation. Hu and Matthew [6] (2005) found that the relationship between intellectual property protection and technology innovation was significantly negative through empirical study on five countries in East Asia. Xing Fei [7] (2009) found that with the enhancement of patent protection, the company's R&D investment would decline, but the patenting activity increases. This meant that strengthening intellectual property protection suppressed the short-term innovation from the perspective of short-term. Samaniego [8] (2013) found that the relationship between knowledge spillovers and innovation activities was significant, high levels of intellectual property protection would increase innovation expenditure.

The third view is that there is a complex relationship between intellectual property protection and technology innovation. Futagami & Iwaisako [9] (2007) found that too strong intellectual property protection would hinder technological innovation; there was inverted U-shaped relationship between IPP and technical innovation. Dong Yu and Sun He [10] (2012) considered that the relationship between intellectual property protection and industrial innovation depended on the industry's development level and technical level. For industry with high level of technology and development, the level of intellectual property protection promoted industrial innovation; but for industry of low level, the level of intellectual property protection and industrial technology innovation correlated negatively.

Many researches investigating relationship between intellectual property protection, R&D investment and innovative outputs from domestic and international scholars are carried out at the national level, there are little research related to the company level. Researches on the GEM listed companies are seldom so far. In this paper, the GEM companies are chosen as the research objects, through quantitative analysis, research intends to find out constraints that may exist in the innovation process of new high-tech listed companies and whether intellectual property protection, R&D investment and other factors are truly effective in promoting innovation.

III. RESEARCH DESIGN

A. Innovative investment model design

Innovative investment is not only influenced by the level of protection of intellectual property rights, but also affected by firm size, liabilities, profitability and other factors, so in order to verify and analysis the impact of intellectual property protection on innovative investment. In this paper, the econometric model is constructed as follows:

$$\ln RD_{it} = \alpha + \beta \ln IPP_{it} + \gamma Z_{it} + \varepsilon_{it} \qquad (1)$$

RD variable is R&D expenditure, which expresses the company's actual annual research and development expenditures; IPP is the horizontal area of intellectual property protection where the companies locate in, Z is a set of control variables; ε is a random disturbance term. The following table (1) shows the control variable Z:

TABLE I. THE CONTROL VARIABLES SELECTED

Variables	*Meanings*	*Variables selection*
HC	Labor input	university education employees
AST	Company's scale	Company's total assets at the end of year
LEV	Liabilities	asset-liability ratio at the end of year
AGE	Company's age	Considering the age of the newly established enterprise company, ages plus 1
SUB	Governmen t subsides	Government subsides related to income
ROA	Profitability	the ratio of net profit before interest and tax to total assets

B. Innovative output model

There are many indicators measuring innovation output, mainly are patents. The granted patents will be affected by government agencies and other subjective factors, and intervals between patents granted and patent applications are long, so this paper chooses patent application as explanatory variables. In addition to intellectual property protection and development of capital investment, but also R&D labor input, preliminary patent applications (Dong Xuebing and Shi Jinchuan, 2006 [11]) and so on affect patent applications. Therefore, this model can be established as below:

$$\ln PAT_{it} = \alpha + \beta_1 \ln PAT_{it-1} + \beta_2 \ln IPP_{it} + \beta_3 \ln RD_{it} \qquad (2)$$

Wherein, i is the provinces; t is the year; PAT is the explanatory variables of patent applications; RD is the capital investment; A is a constant term, ε is a random disturbance term.

For analyzing of area level of intellectual property protection, this paper is established on the basis work of Xu Chunming and Chen Min (2008) [12], meanwhile integrates with research results of Yao Limin, Rao Yan (2009) [13]. This paper selects judicial protection indicators, administration and protection indicators, the level of economic development indicators, social awareness indicators for intellectual property protection as well as the international community monitoring indicators to measure regional intellectual property enforcement.

- Judicial protection indicators are measured by the proportion of the total population of attorneys, when the actual value is greater than or equal to five ten thousandths, the judicial protection index score takes 1, if the actual value is less than 1, the index score is equal to the ratio of the proportion of the lawyers proportion and five ten thousandths.
- Administration and protection indicators are measured by legislative time, when legislative time

is greater than or equal to 100 years, the index score takes 1, when legislative time is insufficient, the index score is equal to the ratio of legislative time and 100 years.

- For the level of economic development indicators, the benchmarks of middle-income countries are set to GDP 2,000 per capita one year, when reach or exceed, the score is 1, when insufficient, the score is the ratio of real GDP per capita and GDP 2000.
- For social awareness indicators for intellectual property protection, this paper uses patent applications per capita to represent. Set it to, when regional patent applications reach ten or more per ten thousand people, the score takes 1, when insufficient, the score takes the actual number of patents per ten thousand persons divided by 10 patent applications.
- In this paper, the WTO member country is taken as a measure of international community monitoring indicators. This article assumes that, from 2001 to 2015, the international community monitoring index increases gradually from 0 to 1.

Taking the possible presence of inverted U shaped relationship between the level of intellectual property protection and innovation output into consideration, the paper adds level of squared IPR protection into model (2), namely:

$$\ln PAT_{it} = \alpha \ln A + \beta_1 \ln PAT_{it-1} + \beta_2 \ln IPP_{it} + \beta_3 \ln IPPSQ_{it} + \beta_4 \ln RD_{it} + \beta_5 \ln HC_{it} + \varepsilon_{it} \quad (3)$$

C. Estimation Methods

This paper uses quantile regression to analyze model (1), quantile regression is linear regression method based on the distribution of the dependent variables. Compared with the least squares method, it has unique advantages. Quantile regression uses bootstrap methods in this paper.

Model (2) and models (3) include patent applications first order lag PATit-1, therefore this paper uses the dynamic panel model, so the results of the fixed effect estimation method is biased because of the presence of endogenous problems. In this paper, the system GMM model is established to analyze model (1) - (4), while adding year dummies to overcome endogenous problem, individual heterogeneity and time effect issues.

D. Data Sources and Descriptive Statistics

This paper takes China's Shenzhen Stock Exchange GEM listed manufacturing companies from 2009 to 2013 as samples, R&D capital input data is located in R&D investment part of the financial report, patent applications come from the company's annual report and the state intellectual property office inquiry order. The index data of regional level of IPR protection comes from the China economic statistical yearbook and statistical regional yearbook of the economy and development. This article excludes data that there is no patent application and data which labor capital investment is incomplete and continuous year is less than 2 years. Finally, the article gets 217 company's data, 679 samples. Table 2 below is the descriptive statistics of key variables after logarithmic.

TABLE II. KEY VARIABLES DESCRIPTIVE STATISTICS

	Mean	*Standard Deviation*	*Maximum*	*Minimum*	*Number of Samples*
lnPAT	2.3621	1.0879	5.8493	0	679
lnRD	16.8848	0.7318	19.1825	14.2794	679
lnHC	4.9460	0.7112	7.0817	2.9957	679
lnIPP	1.2099	0.1205	1.3957	0.8230	679
lnAST	20.7594	0.5635	22.6383	18.9169	679
lnLEV	-1.8680	0.7047	-0.4161	-4.5008	679
lnAGE	2.1872	0.5608	3.2958	0	679
lnSUB	15.4255	1.1159	18.8518	11.0821	679
lnROA	-2.7629	0.7342	-1.2758	-7.0131	679

IV. DATA RESULTS AND ANALYSIS

A. Innovative Investment Model Regression Results

To verify the model (1) regression results, this paper also presents OLS regression models compared to quantile regression. When the sample data uses quantile regression, five quantile points are chosen by 10%, 25%, 50%, 75% and 90%. The results show in the table (3) below.

TABLE III. QUANTILE MODEL TEST RESULTS

	10%	*25%*	*50%*	*75%*	*90%*	*OLS*
IPP	0.4411** (1.97)	0.8598* (4.60)	0.7348* (3.21)	1.0320* (6.35)	1.0373* (3.44)	0.7803* (5.27)
HC	0.4158* (8.02)	0.4546* (4.60)	0.4314* (8.60)	0.4246* (13.41)	0.3939* (8.76)	0.4459* (15.95)
AST	0.4877* (8.12)	0.5228* (11.16)	0.5493* (9.57)	0.5611* (12.41)	0.6194* (8.51)	0.5403* (14.95)
AGE	-0.0038 (-0.08)	-0.0077 (-0.18)	-0.0312 (-0.67)	-0.0975** (-2.00)	-0.1262*** (-1.88)	-0.0304 (-0.94)
LEV	0.1538* (3.12)	0.1250* (2.83)	0.1383* (3.96)	0.1215* (3.30)	0.1300* (3.34)	0.1177* (4.64)
SUB	0.0183 (0.56)	0.0177 (0.78)	0.0254 (1.03)	0.0508* (2.84)	0.0963* (3.41)	0.4167** (2.46)
ROA	0.1044** (2.00)	0.1061* (3.11)	0.0799** (2.22)	0.0319 (0.97)	-0.0066 (-0.12)	0.0526** (2.19)
Constant	3.9429* (3.08)	2.7432* (2.82)	2.6136* (2.69)	1.9159** (2.22)	0.3795 (0.28)	2.3067* (3.34)
R^2	0.3129	0.3750	0.4131	0.4597	0.4612	0.6304

Note: *, **, *** represent the 1%, 5%, 10% significance level, the number of brackets mean t value of bootstrapping 1000 times.

a) Firstly, concentrating on the impact of regional intellectual property protection on innovation investment, we can find that elasticities of regional IPP are positive both the method of least squares regression and each quantile regression, and most pass the 1% significant test. By observing changing trends on different quantile level of regional intellectual property protection, it can be found the elastic coefficient of IPP has always been rising, the elastic coefficient ranges from 0.4411-1.0373. Combined with the condition that the eastern coastal provinces have higher levels of intellectual property rights, the degree of

intellectual property rights protection influencing the eastern coastal provinces innovation investment is deeper than the central and western provinces. The enforcement degree of judicial protection and administration and protection indicators of the eastern coastal provinces are higher with higher level of economic development, they are also influenced by the competitive pressures, traffic location and many other factors, leading to the inconsistencies of regional IPP affecting coastal provinces in eastern and western provinces.

b) For other control variables, coefficients of labor input affecting innovation investment pass 1% significance test, it means selecting university academic staff numbers as a measure of corporate labor input is appropriate, this is consistent to the development trend of China's innovation enterprises, highly educated employees of enterprises play an increasingly important role in corporates' research and development activities and other fields.

c) The degree of enterprise scale affecting innovation investment also has passed 1% significance test, and it can be found there is a rising trend in the elastic coefficient of firm size, indicating that the scale of enterprises has significant role in promoting innovation investment. At the same time, for large-scale enterprises this promotion effect is larger than the small-scale enterprises.

d) The coefficients of company's age change from -0.0038 at the lower level of quantile point to -0.1262 at the higher level of quantile point, and only coefficients at high levels get through the significant test, which mean that for companies which set up for a long time, firm age produces inhibition effect on innovation investment. For enterprises established for a long time, companies are likely at a low tide, the industry is in recession or maturity, the important business goal is steady growth in cash flow, etc., bringing about low levels of research and development, leading to negative effect of company's age impacting on innovation investment. This conclusion has important instructive, solving related problems caused by firm age have became an important breakthrough in the development of innovative enterprises of China.

e) Liabilities elasticity coefficients in each quantile levels are all positive and passed the 1% significance test. It is conceivable that debt levels have significant role in promoting innovation investment, the purpose of corporates issuing bonds, taking bank loans or other financing behaviors is to address the plight of operating, conduct business investment activities such as research and development investment, but high debt levels may result in financial distress, endangering enterprise operations.

f) Government subsidies elasticity coefficients for innovation investment have been rising, but only at 75% and 90% of the quantile levels go through the significance test, which mean that low-level government subsidies do not promote research and development investment. This may be because government subsidies related to income are used to the operational behavior at a low level, but at a high level of government subsidies, enterprises can have abundance of grant funds to conduct research and development activities.

g) The influence coefficients of profitability on innovation investment vary from 0.1044 at low level to -0.0066 at high level, only in 10%, 25% and 50% of the quantile levels pass the significant test and the elastic coefficients are decremented. For companies with the low level of profitability, companies will be more focus on capital being applied to research and development expenditures up to seek technological advances in order to promote the level of earnings growth, leading to profitability promoting innovation investment; for companies with high level of profitability, enterprises formulate R&D expenditure levels based on the specific strategies, companies may use capital for R&D expenditure, it may also be used for other purposes such as developing marketing channels.

B. Innovative Output model regression results

For model (2) and models (3), this paper uses GMM estimation method, patent applications are chosen as explained variable to measure the estimation results of innovation output model. The results are showed in table (4), besides the eastern part of the GEM companies are also subjected to the above model analysis.

TABLE IV. GMM MODEL ESTIMATION RESULTS

	(1)Model (2)	***(2) Model (3)***	***(3) Model (2) of Eastern Region***	***(4) Model (3) of Eastern Region***
L.PAT	0.3269* (3.93)	0.3290* (3.93)	0.3265* (3.76)	0.3274* (3.76)
IPP	-0.0271 (-0.06)	11.4996*** (1.76)	-0.7467 (-1.04)	3.0026 (0.32)
IPPSQ		-4.8535*** (-1.79)		-1.4943 (-0.39)
RD	0.2054** (2.22)	0.2051** (2.19)	0.2626* (2.61)	0.2616** (2.59)
HC	0.1922** (2.09)	0.1924** (2.08)	0.1331 (1.34)	0.1352 (1.36)
Constant	-2.9528 (-2.08)	-9.7330 (-2.36)	-2.4419 (-1.55)	-4.7786 (-0.79)
Year effect	controlled	controlled	controlled	controlled
AR(1) P value	0.000	0.000	0.001	0.001
AR(2) P value	0.908	0.955	0.232	0.235
SarganP value	0.570	0.575	0.568	0.575
Number of Observations	679	679	527	527

Note: (1) *, **, *** represent parameter estimates at 1%, 5% 10% significant level; (2) the estimated amount of all the parameters in brackets below is t value; (3) AR (1) P value and AR (2) P value come from the first-order and second-order serial correlation test conducting on first order difference of residuals; (4) Sargan P comes from excessive identification test instrumental variables' rationality; (5) the system GMM models are estimated using xtabond2 command;

(6) The amount of central and western part data is too small to carry out the above analysis.

Column (1) (2) and (3) (4), respectively mean results of the entire and eastern GEM manufacturing enterprises of model (2) and model (3) by means of quantitative analysis, GMM analysis shows AR (1) rejects the null hypothesis and AR (2) accepts the null hypothesis that the model has a first-order serial correlation, there is no second-order serial correlation. P values of the Sargan test show that model selection tool variables are reasonable.

From column (1) - (4), lag coefficients of patent applications are significantly positive, indicating that the previous period of patent applications has a role in promoting current innovation output. IPP elastic coefficients of column (1) and (3) are not statistically significant, indicating that the regional level of intellectual property protection and innovation output have complex relationship. Through measurement of column (2), we can find the level of intellectual property protection coefficient IPP is positive, IPPSQ coefficient is negative, and they all pass the significance test, which mean that the level of protection of intellectual property and patent applications exist inverted U-shaped relationship.

Through the above analysis, intellectual property protection promoting patent applications has critical point, when exceeds the point; intellectual property protection will hinder technological innovation. With strengthening of the actual level of intellectual property protection enforcement, the actual region intellectual property rights will become increasingly high, which will lead to the protection of intellectual property rights hindering technological innovation.

Elasticities of innovation investment in column (1) - (4) are positive and pass the test of significance. It can be seen that strengthening research and development spending facilitates innovation output. Comparing all model estimation results, most significances and sign of variables coefficients are consistent. At the same time, we note that investment in labor input promoting innovation output only in column (1) and (2) show significant, this may be due to insufficient sample of the eastern region.

V. CONCLUSIONS

In this paper, the GEM manufacturing companies are chosen as the object to study the relationship between intellectual property protection, innovation input and innovation output, such conclusions are arrived at:

- Strengthening intellectual property protection has a significant role in promoting R&D expenditure. The level of intellectual property protection and innovation output exists inverted U-shaped relationship. Therefore, enterprises shall strengthen independent innovation capability, regional intellectual property protection policies shall be combined with the actual development to avoid forming a negative impact on innovation.
- R&D expenditures and R&D labor input can promote innovation output both, enterprises shall combine practical strategies with business strategies to choose appropriate level of R&D investment. On positive correlation between debt levels and innovation input, companies shall select appropriate level of debt to avoid financial difficulties.
- Past knowledge accumulation and current innovation output have a significant positive correlation, according to the law, enterprises shall increase research and development expenditure, enhance innovation capability in order to further enhance the future innovation productive capacity and create a virtuous cycle.
- Established for a long time will be impediments for R&D spending, furthermore inhibiting innovation. Enterprises shall develop new business point, complete process of transferring the business to high-tech business and enhance their competitiveness. Government shall introduce relevant policies to promote innovation, avoid firm age to become an innovation resistance.
- Low government subsidies do not promote corporate R&D expenditure; companies will first use subsides for operations. In order to promote innovation, research and development subsidies shall be increased.

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