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Innovation of the mainland China

—— from the perspective of patents

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Introduction

Both economic theory and empirical facts show that technological progress and innovation are the keys to an economy's long-term sustainable economic growth. To measure innovation activity or technological progress, existing studies mainly use three types of indicators: TFP (total factor productivity), R&D investment (R&D expenditure), and patents.

TFP is the residual of the unaccountable term besides the labor, capital and factors. And it is widely used in macroeconomics analysis, especially in the analysis of economy growth. In a modern economy, the vast majority of innovation is the result of conscious investment by people. Therefore, R&D spending is a reasonable indicator of market incentives for innovation. *Hall (1988),Klette and Griliches (1996)*

But in an imperfectly competitive market, there is a large error in using TFP to measure the level of innovation. In addition, there are two main problems in the use of R&D expenditures in some areas like China. First, the availability of data is relatively poor. Second, because the accounting system is not perfect, false reporting of R&D expenditures is a widely existing issue.

However, there are many advantages to using patents to measure innovation activities. *Aghion et.al (2005); Griliches (1990); Griliches et al. (1986)* First, patent data is open and objective, and protected by law; second, patent information is updated Timely and accurately reflect technology trends; finally, patent data provides a lot of basic information related to the company, we can use patent data in combination with other company information to analyze the company's profitability, and even use patent data Compare the differences between different regions and different types of companies.

In this report, we first shed the light on the global innovation activities by looking at the patent production by different countries. And then we focus on the mainland of China to see the trend of patent production. Furthermore, we did some research to explore how can we use patent to predict firms' performance. And finally, related studies and future interesting work are given.

Database

We use the Amazon RDS to build database based on MySQL Community engine. We then created a MySQL database and constructed our data on it. (EndNode: database-2.csfxnbrvm18e.us-west-2.rds.amazonaws.com Port:3306) It can be easily connected by Dbeaver or other client software applications.

You can check Amazon RDS user guide to explore this cloud service.
https://docs.aws.amazon.com/zh_cn/AmazonRDS/latest/UserGuide/CHAP_GettingStarted.CreatingConnecting.MySQL.html

Patent analysis from the country level

PatentsView is a patent data visualization and analysis platform that increases the value, utility, and transparency of U.S. patent data. The initiative is supported by the Office of the Chief Economist in the United States Patent and Trademark Office (USPTO).

We use PatentsView annual data from 2011 to 2020 to explore patents from different countries or regions.
https://patentsview.org/data/annualized

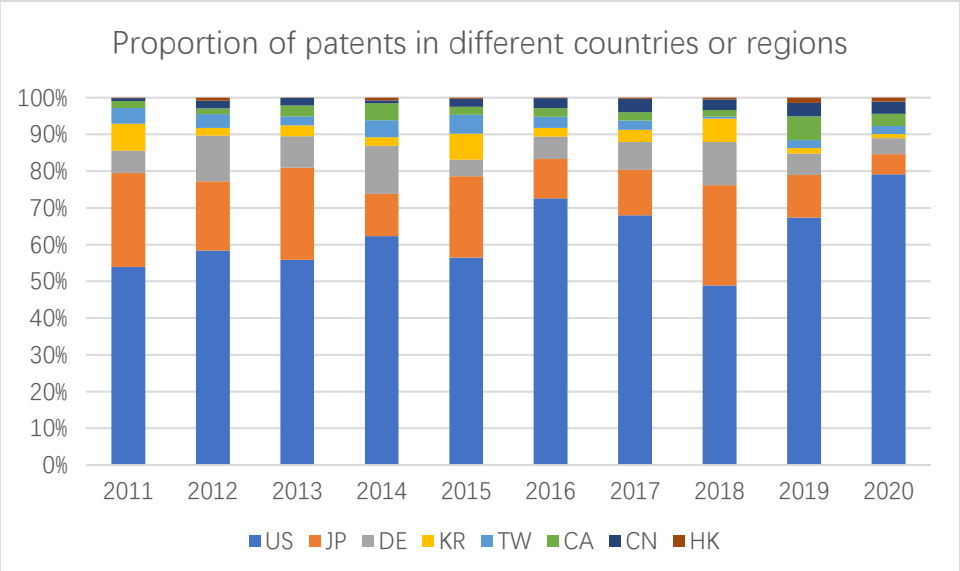

Figure 1

As can be seen from Figure 1, the number of patents in the United States is the largest every year, about 50%, followed by Japan.

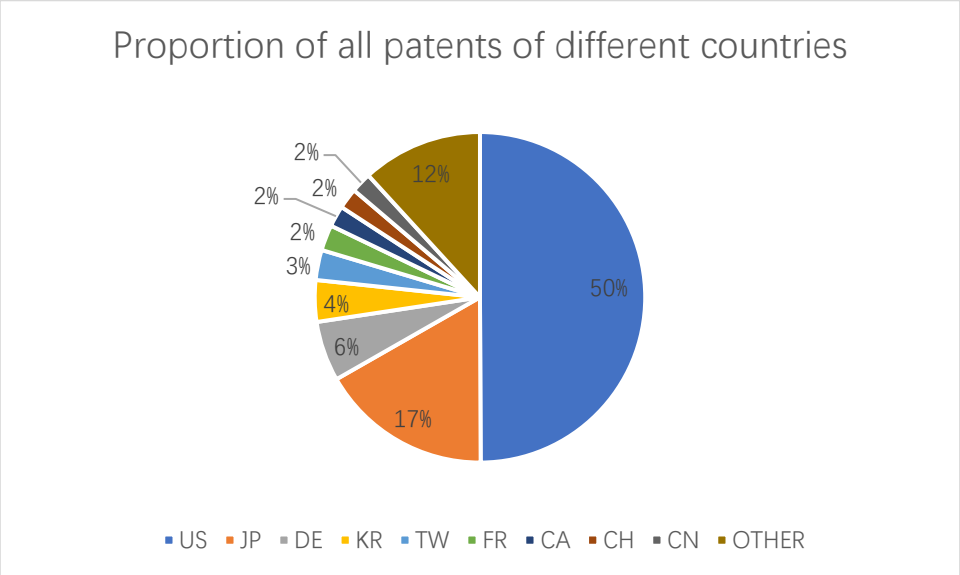

Figure 2

As can be seen from Figure 2, the United States has the largest number of total patents in the past ten years, accounting for 50%, followed by Japan, accounting for 17%

This is an overview, then we use the Chinese data to study in detail.

Patent analysis from China level

- **Data**

1. CIRD

The Chinese Innovation Research Database (CIRD) is a professional database mainly developed based on the patent applications and grants of different listed companies, unlisted companies and different regions. CIRD not only considers patent data filed or granted by different subjects, which distinguish three categories of patents for invention, utility model, and design, but also includes important information such as independent or joint applications, summary of patent classification numbers.

The patent application and acquisition module of listed companies provides the patent application and authorization status of all listed companies in China. This module includes the number of patents applied for and authorized each year since 1991; it is divided into the number of independent and joint applications and authorized patents each year. It includes the number of patent applications and granted patents for the company itself, subsidiaries, associates and joint ventures.

The patent application and acquisition module includes stock code, fiscal year, company type, application time, the number of inventions independently applied for in the year, the number of utility models independently applied for in the year, the number of designs independently applied for in the year, the number of inventions jointly applied for in the year, the number of utility models jointly applied for in the year, the number of designs filed jointly in the year.

2. CSMAR

China Listed Company Database CSMAR includes the main financial indicators, balance sheet, income statement, cash flow statement, domestic and foreign patent application status of listed companies and Tobin's Q.

Tobin's Q is the market value of all public companies in the US divided by their replacement cost. Many macroeconomists consider the market overvalued when Tobin's Q is above its long term mean and undervalued when it is below the long-term mean.

We also use some other data, including property rights, company industry data. The company industry data can help to further subdivide state-owned enterprises, private enterprises and the industries the companies belong to.

3. Our Database

We built a new database based on the above. The database includes patents held by the parent company under the existing name, and we also take into account the company's renaming history. Patents held by subsidiaries, associates, joint ventures are attributed to the parent company. Using this data, the rigor of its collection can increase the credibility of the conclusions of this study.

- **Analysis**

1. Rank of patents

Here we listed the TOP 10 firm that owned patent independently and jointly from 1990 to 2020. We find that the top ten companies are mostly manufacturing companies, which may be because they accumulated more patents at the beginning of our statistical period. And Internet companies such as Alibaba and Tencent are not listed on A-shares in mainland China, so we did not observe them here. In addition, we do not find any obvious dominant tendency of private company or state-owned company that dominates the list when looking at the equity nature of firms.

Table 1: TOP 10 listed firms that independently own patents

Scode	ShortName	EquityNature	Indpatent
000063	中兴通讯	private	111676
000333	美的集团	private	70944
000100	TCL集团	private	60268
000157	中联重科	state-owned	22852
000338	潍柴动力	state-owned	21128
000425	徐工机械	state-owned	19744
000016	深康佳A	state-owned	15652
000418	小天鹅A	private	12888
000039	中集集团	state-owned	8520
000521	美菱电器	state-owned	5880

Table 2: TOP 10 listed firms that independently and jointly own patents

Scode	ShortName	EquityNature	totalpatent
000333	美的集团	private	159780
000063	中兴通讯	private	112708
000100	TCL集团	private	62920
000157	中联重科	state-owned	26228
000338	潍柴动力	state-owned	21432
000039	中集集团	state-owned	20116
000425	徐工机械	state-owned	20020
000016	深康佳A	state-owned	15952
000418	小天鹅A	private	12888
000050	深天马A	other	9184

2. Trend of patents

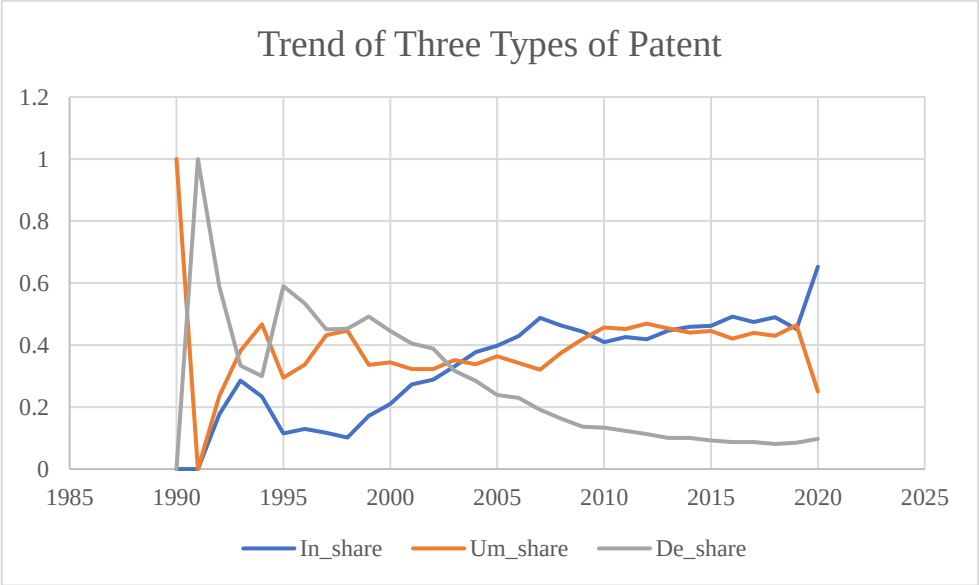

Figure 3

Figure 3 shows the proportion of the three kinds of patents obtained by all companies over time. The three kinds of patents are innovative patents, practical patents, design type patents. We can clearly see that the proportion of innovative patents is growing steadily; the proportion of design type patents is gradually decreasing, while the proportion of practical patents remains stable. The data fluctuations in the 1990s were caused by the low number of patents themselves, and small changes can cause dramatic changes in proportions.

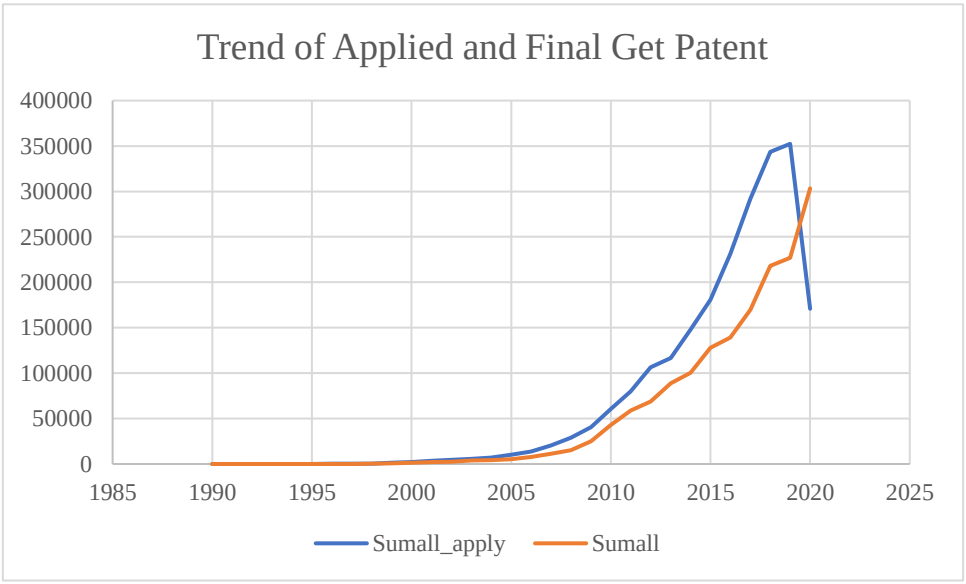

Figure 4

As can be seen from Figure 4, the number of patent applications and the number of patent grants were basically similar before 2007, but the gap between the two became

larger after 2008. Moreover, according to Figure 3, the proportion of applications for invention patents has increased since 2007, and enterprises have paid more and more attention to invention patents with high technology. This may also lead to a longer approval time for some patents and a low patent approval rate. In addition, the number of patent applications in 2020 has dropped sharply, which may be caused by the reduction of companies' investment in this area due to COVID-19.

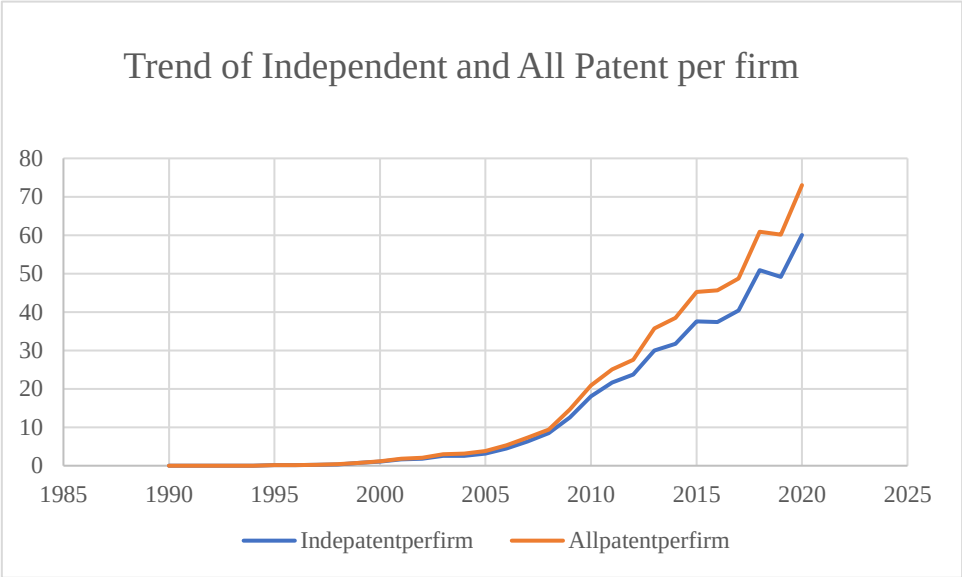

Figure 5

As can be seen from Figure 5, the number of authorized patents of Chinese listed companies has continued to grow, especially after 2006, showing a linear upward trend, and the number of authorized independent patents and joint patents has grown by leaps and bounds.

3. Patents with macroeconomic indicators

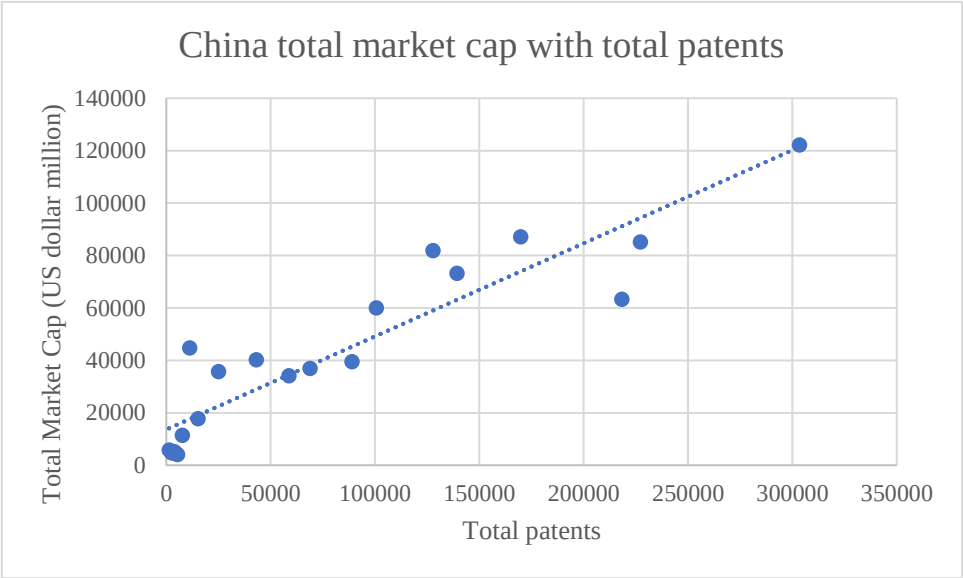

Figure 6

As can be seen from Figure 6, the number of patents and the total market cap show a positive linear relationship.

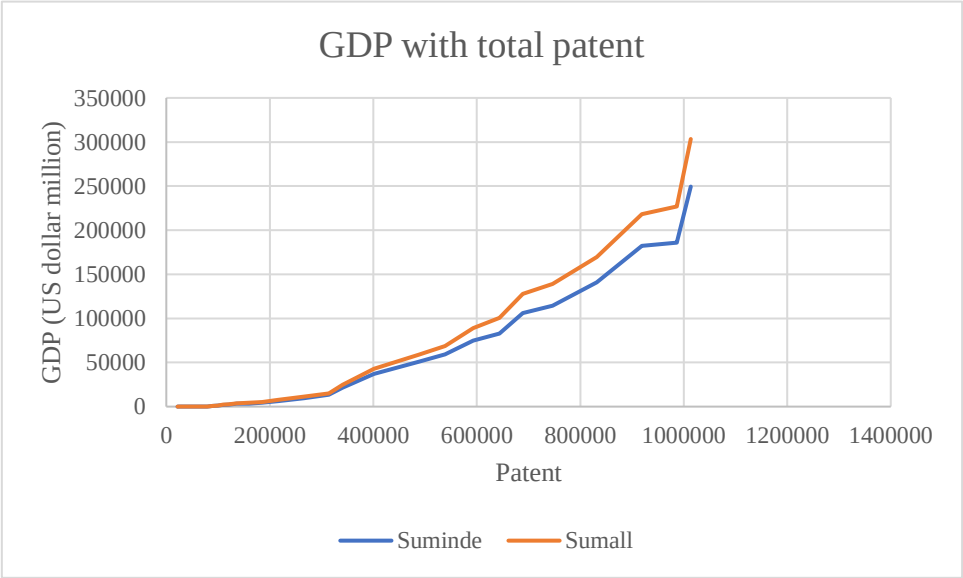

Figure 7

It can be seen from Figure 7 that the relationship between the total number of patents and GDP is a quadratic curve with positive relationship when the number of patents is below 1,000,000, and when the number of patents is around 1,000,000, the relationship between the total number of patents and GDP approximates an exponential growth.

Further analysis: Does the owned Patents of Chinese Listed Companies Affect Company Value?

We selects A-share listed companies in Shenzhen and Shanghai from 2001 to 2020 as the research sample, and deletes companies with a total number of patent applications (independent and joint) less than 1 during the period, and the final sample has 3,625 companies. The patent data comes from the patent database of China A-share listed companies, and the corporate financial data and government subsidy data come from the CSMAR data.

Using the patent and company financial information database of mainland Chinese listed companies we constructed, we first calculated the patent stock

$$k_{it} = (1-\delta)k_{i,t-1} + r_{i,t}$$

k_{it} is the patent stock at the end of year t, $r_{i,t}$ is the number of new patents in year t, and the depreciation rate δ is set as 15%. In addition, we also calculated the case where the depreciation rate is zero. We then use the calculated ratio of the patent stock to the firm's total assets as the main explanatory variable.

In fact, there are many other factors which might affect company value, such as the debt to equity and the sales revenue of the company. To control variables, we also added the debt-to-equity ratio and the logarithmic growth rate of the sales revenue of the company, trying to remove the effects of these variables.

To eliminate the effect of extreme values, we did the 99% trim for the patent stock variable. And the following regressions are based on this process. The industry categories are followed by the China SEC firm code from A to S, totally 19 categories.

We did the pooled OLS regression with industry and year fixed effect to estimate the effect of the patent stock. And the following tables show the: all patent stock with 0.15 depreciation, all patent stock with 0 depreciation, independent patent stock with 0.15 depreciation and independent patent stock with 0 depreciation. The main regression formula is as follows.
(Note: after the difference of lnsales and the calculation of patent stock, the data is from 2002 to 2020)

$$\ln(Q_{i,t}) = \alpha + \beta_1 \frac{\text{Patent stock}_{i,t}}{\text{Asset}_{i,t}} + \beta_2 \frac{\text{Debt}_{i,t}}{\text{Equity}_{i,t}} + \beta_3 d\ln(\text{Sale}_{i,t}) + \beta_4 \text{Industry dummies} + \beta_5 \text{Year dummies} + \varepsilon_{i,t}$$

Table 3: Impact of All Patent Stock (0.15 depreciation) on Tobin's Q

	1	2	3	4	5
Patent	3.47***	3.50***	3.52***	2.79***	2.92***
	(0.11)	(0.11)	(0.11)	(0.12)	(0.11)
Debt/Equity	N	-0.00075***	-0.00061***	-0.00069***	-0.00054***
dlnSales	N	0.035***	0.023***	0.034***	0.021***
YearDummy	N	N	Y	N	Y
IndustryDummy	N	N	N	Y	Y
Obs	37,169	37,169	37,169	37,169	37,169

Robust S.e. in parenthesis
***$p < 0.01$,** $p < 0.05$, * $p < 0.1$.

Table 4: Impact of All Patent Stock (0.0 depreciation) on Tobin's Q

	1	2	3	4	5
Patent	2.03***	2.06***	2.06***	1.58***	1.66***
	(0.075)	(0.075)	(0.072)	(0.076)	(0.072)
Debt/Equity	N	-0.00075***	-0.00061***	-0.00068***	-0.00054***
dlnSales	N	0.037***	0.025***	0.035***	0.022***
YearDummy	N	N	Y	N	Y
IndustryDummy	N	N	N	Y	Y
Obs	37,169	37,169	37,169	37,169	37,169

Robust S.e. in parenthesis
***$p < 0.01$,** $p < 0.05$, * $p < 0.1$.

Table 5: Impact of Independent Patent Stock (0.15 depreciation) on Tobin's Q

	1	2	3	4	5
Patent	3.79***	3.82***	3.85***	3.08***	3.22***
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
Debt/Equity	N	-0.00075***	-0.00062***	-0.00069***	-0.00054***
dlnSales	N	0.035***	0.023***	0.034***	0.021***
YearDummy	N	N	Y	N	Y
IndustryDummy	N	N	N	Y	Y
Obs	37,169	37,169	37,169	37,169	37,169

Robust S.e. in parenthesis
***$p < 0.01$,** $p < 0.05$, * $p < 0.1$.

Table 6: Impact of Independent Patent Stock (0.0 depreciation) on Tobin's Q

	1	2	3	4	5
Patent	2.24***	2.27***	2.27***	1.78***	1.86***
	(0.080)	(0.080)	(0.077)	(0.081)	(0.077)
Debt/Equity	N	-0.00075***	-0.00061***	-0.00068***	-0.00054***
dlnSales	N	0.038***	0.025***	0.035***	0.023***
YearDummy	N	N	Y	N	Y
IndustryDummy	N	N	N	Y	Y
Obs	37,169	37,169	37,169	37,169	37,169

Robust S.e. in parenthesis
***$p < 0.01$,** $p < 0.05$, * $p < 0.1$.

From the four tables above, we can see that the effect of patent stock to the performance of firms is positive and significant. And the effect is robust whether we control other factors (Debt to equity, dlnsales) or not. Moreover, it is also stable when we add year dummies, industry dummies and both.

Besides the main independent variable, we can see that the debt-to-equity ratio is negatively related with the firm's performance, which is suitable with our intuition. And the growth of sales positively affects the firm's tobin's Q.

Table 7: Impact of Three kinds of Patent Stock (0.15 depreciation) on Tobin's Q

	Innovative			Practical			Design		
	1	2	3	1	2	3	1	2	3
Patent	18.01***	18.09***	14.47***	4.17***	4.20***	3.26***	7.72***	7.78***	5.91***
	(0.54)	(0.54)	(0.52)	(0.19)	(0.19)	(0.18)	(0.37)	(0.37)	(0.34)
Debt/Equity	N	Y	Y	N	Y	Y	N	Y	Y
dlnSales	N	Y	Y	N	Y	Y	N	Y	Y
YearDummy	N	N	Y	N	N	Y	N	N	Y
IndustryDummy	N	N	Y	N	N	Y	N	N	Y
Obs	37,169	37,169	37,169	37,169	37,169	37,169	37,169	37,169	37,169

From table 7, we show the impact of three different types of patent stock on firm's performance. They are innovative patents, practical patents and design type patents. Either controlling other factors including industry and year fix effect or not, the patent stock factor is positive and significant in p-value 0.01 level.

Also, the table tells us that innovative patent is most valuable among the three. The following one is the design type patent, and the least valuable one to predict the performance is the practical use patent stock factor. It may be a little bit counterintuitive.

Conclusion and Future Study

Based on the database of patent and company value we built and the result of regression, we were able to conclude that there is a clear positive correlation between a Chinese Listed firm's patent stock and its company value, which is relatively robust. Also, we found that innovative patent is of most value among the three kinds of patents: innovative patent, practical patent and design patent.

There is much more to discuss in depth about the relationship between patent stock and company value. Many Chinese Internet companies such as Tencent, Meituan, Alibaba have been listed in the United States or Hong Kong in recent years, we should include these data.

For future study, we can combine patents and other data to explore the following three aspects. First, uncertainty in economic policies often affects a company's innovation activities and further affects its patent development. It will be interesting to discuss the relation between uncertainty in economic policies and company value. Second, due to the different policies and procedures for patent protection in different provinces, the location of the company might also affect its patent stock. Third, A company's ability to innovate is judged not only by the number of patents the company has applied for, but also other patents purchased and cited by the company. The purchase of patents from developed countries by a developing country like China leads to a deficit in relation to the use of intellectual property, and a developed country like the United States countries, every year other countries buy their patents, they can make a lot of money from them, so the number of purchases and citations also should be considered.