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The Separating Effect of Venture Capital on Patents: Evidence from GEM Listed Companies in China

Xiao-Wei Li*
Ocean University of China, Qingdao, Shandong, P.R. China 266100
lixiaowei@ouc.edu.cn

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Abstract. Based on the dataset of the Growth Enterprise Market (GEM) listed companies in China, from 2009 to 2016, our analyses reveal the separating effect of venture capital investment on heterogeneous patents, as the supply of venture capital increases, there is a significantly negative linear relationship with the application number of low-quality non-invention patents, however there is an inverted U-shape relationship with the application number of high-quality invention patents. Our results remain robust for estimation with Heckman two-stage model to address the potential sample selection bias in the provision of venture capital. We further formulate an intermediary effect model and find that the mitigation of financial constraint completely functions as an intermediary variable. Our findings have implication for both policy makers and practitioners and provide evidence on the role of venture capital in improving the quality of innovation effectively.

1. Introduction

Patents can be generally divided into three categories: invention patent, utility model patent and design patent. Among all the patents, the invention patent is more demanding, original, high-quality, and hard to achieve. That is the reason why those companies who pursue long-term sustainable competence will maintain more invention patents, but those firms who seek short-term speed and quantity of innovation will rely less on the output of invention patents.

A substantial amount of studies have shown the important impact of venture capital on the numbers of patents (Gompers and Lerner, 2001; Lerner and Watson, 2008; Popov and Roosenboom, 2012) [1,2,3]. In china, a number of government schemes in support of the venture capital have been set up with the intention to improve firm growth and innovation, particularly for small high-tech start-ups. With the development of GEM initiated in 2009 in China, the big data increasingly becomes available, this allows researchers and policy-makers be able to study the potential influence of VC on business performance, innovation, IPO pricing and other related issues in China, but little is still known about the impact of venture capital on the quality difference of patents in China (Xu et al., 2017)[4].

In this paper we attempt to distinguish between invention and non-invention to shed more light on the separating effect of venture capital. Hence, our work goes beyond the existing literature by furthering the relation between quality difference of patents and venture capital investments.

2. Hypothesis Development

2.1. Patents and Venture Capital

Venture capital serves as a critical catalyst to fund the development of promising inventions to turn them into marketable innovations(Arqué,2012)[5]. Kortum and Lerner (2000) [6]found that increases in venture capital in the United States are associated with significantly higher patenting rates on an industry level. Mann and Sager(2007)[7]examined a significant and robust positive correlation between patenting practices and venture capital activities. Hellmann and Puri(2000)[8]found a strong association between patents and venture capital funding.

Before the investment, venture capital screens and detects the most promising companies involving patented product inventions that have the potential for penetrating new market demands. Once making an investment, venture capital tends to have a real incentive to nurture the patenting quality and foster the development of a prototype product. Whether for the pre-investment decision or for the post-investment supervision, the quality of patents matters. If one certain invention of a firm could successfully enter the market, venture capital obviously might obtain a considerable return of investment. Arqué(2012) points out the company patenting activity only increases the first two years following venture capital investments, patent trajectories follow an inverted U-shape over time.

Since venture capital involvement implies a sort of re-birth (Croce et al., 2013)[9], the sources provided by venture capital can help the investee company in modifying a new strategic behavior with long-lasting competence. In particular we assume that, once the expertise capability function of venture capital is absorbed, the company will decrease the creation of low-quality non-invention patents but increase the generation of high-quality invention patents. Therefore, we propose the following hypotheses to test.

Hypothesis 1. Venture capital investments are negatively with non-invention patents creation.

Hypothesis 2. Venture capital investments are partially positively associated with the application numbers of invention patents.

2.2. Financial Constraint in the Relationship between Patents Creation and Venture Capital Investment

High-tech new start-ups are particularly exposed to financial constraints(Denis, 2004)[10]. The high uncertainty and R&D intensive nature make it difficult for external investor to provide sufficient financing, but the investment behavior of venute capital signals the potential of the investee companies to third parties, thereby the presence of venture capital could reduce information asymmetries and increase the willingness of more capital providers to fund the process of company patenting as well.

Moreover, venture captial complements the financial resources with a number of coaching functions, such as administrative, strategic, mentoring and monitorting support (Bottazzi and Da Rin, 2002)[11]. The invovlement of venture capital acts as a stamp of approval, facilitate investee companies find innovation partners and increases the probability of receiving external financing in the future. Thus, we posit Hypothesis 3.

Hypothesis 3. Financial constraints negatively intermediate the relationship between venture capital investments and heterogeneous patents creation.

3. Data

3.1. Data Source

Using the GEM public information, a dataset of 569 listed companies was created. Following the venture capital recognition standard set by Wu et al.(2012)[12], we hand-collected the dynamic ratio of venture capital among the top 10 shareholders from the prospectus and equity status statements via the Cninf website.

Patent data come from the Baiten database, and the annual firm-level accounting data come from CSMAR database. All the matched data period covers 2009-2016 in the analysis.

3.2. Sample Characteristics

Table 1 presents the characteristics of patent applications. In this paper we allow utility patent and design patent, with regard to quality totally different from invention patent, have been fallen into one category, we define them as non-invention patent. As shown in Table 1, about 67.06% companies are involved into activities of invention application, in contrast, 60.04% companies solely or simultaneously carry out non-invention applications. Considering the right-side skewed distribution of patent counts, we take the logarithm after handling the original number of patent application plus

one. Table 1 shows that the number of invention applications are less than the number of non-invention applications, which implies non-invention patent remains the domination over the invention patent.

Table 1. The characteristics of patent applications

	N	Mean	Std. Dev	Min	Max
Non-invention	3418	7.1252	16.8691	0	341
Invention	3418	5.6989	13.4005	0	378
Non-invention_dummy	3418	0.6004	0.4899	0	1
Invention_dummy	3418	0.6706	0.4701	0	1

4. Empirical Findings

4.1. The Separating Effect of Venture Capital on Heterogeneous Patents

During the observation period, Table 1 also shows that 32.94% of the samples do not have any invention patent output, 39.96% of the samples do have any non-invention patent output. In this case the dependent variable indicated a probability distribution combining a discrete point and a continuous distribution, so a Tobit model is used to examine the relationship between the venture capital investment and the patent output of the firm.The basic model is shown in model (1).

$$Patent_{i,t} = \beta_0 + \beta_1 VC_{i,t} + \beta_2 Controls_{i,t} + \beta_3 \sum Year + \beta_4 \sum Region + \varepsilon_{i,t} \quad (1)$$

Where *Patent* represents the two categories of patents, that is either non-invention or invention , *VC* measures the equity ratio of venture capital investment, *Controls* denotes the other characteristics that may affect the patent creation. The subscript *i* refers to the individual company sample, *t* refers to the time difference. We consider the variances of year and region among the samples in the model (1), in particular, we include year dummies and region dummies which allow us to control for cross-sectional differences among regions and across time respectively.

The Tobit model estimation results are presented in Table 2. In order to measure the non-linear relation, *VC2,* the square item of venture capital, is present. After controlling for other variables, column (1) and (2) show the venture capital investments are strongly and negatively associated with the number of non-invention patent applications. Obtaining venture capital is associated with a decrease in the number of non-invention patent application, hence Hypothesis 1 is supported.

Column (3) and (4) in Table 2 indicate that the percentage of venture capital among all the shareholders is not always in proportion to the number of the application of invention patent, the regression coefficient of the square item of venture capital share is statistically significant at the 0.01 level. As the venture capital investment journey progresses, the invention patent application significantly increases but to a turning trend begins to decrease due to the risk aversion. This provides evidence to support Hypothesis 2.

Overall, the results in Table 2 suggest that venture capital investment strongly and significantly separate between the number of non-invention patent appplication and the number of invention patent application. Venture capital distincts the quality difference among heterogeneous patent creation, on the one side, the participation of venture capital helps to decrease the low-quality non-invention patent creation, and on the other side, there is an increase in the high-quality invention patent if the venture capital still remains at a level below the control ratio of investment.Hence, the venture capital investment presents an inverted U shaped relationship with invention patent creation.

Other characteristics of the firm may affect the patent output, such as size of firm, R&D activity, political connection, leverage, firm performance, research staff and others. The coefficient of size in Table 2 is found to be statistically different from zero, the development of firm size will decrease the low-quality non-invention patents and increase the high-quality invention patents. The coefficient of

R&D intensity is significantly negatively related to the non-invention patent but is significantly positively related to the invention patent, which indicates that the firm will emphasize more invention patent instead of non-invention patent. The coefficient of political connection shows that the firms with some certain political connections present fewer non-invention patent and more invention patent than the firms without any political connections. The leverage, return on assets, research staff, market competition are all taken into consideration, they all show significantly positive relationship with patent creation.

Table 2. Modelling the heterogeneous patents using a tobit estimation model

	Non-invention		*Invention*	
	(1)	(2)	(3)	(4)
VC	-0.0116***	-0.0031*	0.0091***	0.0205***
	(-11.0240)	(-1.6940)	(11.4508)	(17.0870)
VC2		-0.0003***		-0.0004***
		(-6.1863)		(-12.9618)
Size	-0.1413***	-0.1414***	0.3118***	0.3116***
	(-1.0e+02)	(-1.0e+02)	(294.6204)	(294.7996)
Lev	0.0163***	0.0163***	0.0039***	0.0038***
	(24.9946)	(24.8382)	(7.7692)	(7.5374)
Dual	0.3139***	0.3138***	-0.0761***	-0.0752***
	(14.9757)	(14.9787)	(-4.8065)	(-4.7511)
Turnover	-0.8799***	-0.8678***	-0.4795***	-0.4609***
	(-21.4984)	(-21.1969)	(-15.4578)	(-14.8728)
ROA	0.0280***	0.0277***	0.0300***	0.0296***
	(14.4058)	(14.2550)	(20.5936)	(20.3240)
RD	-0.1133***	-0.1137***	0.0969***	0.0960***
	(-21.4468)	(-21.4806)	(25.0155)	(24.7922)
RS	0.2109***	0.2147***	0.0724***	0.0780***
	(37.3998)	(38.0581)	(16.7888)	(18.1082)
PC	-0.0317*	-0.0319*	0.0936***	0.0936***
	(-1.7706)	(-1.7824)	(6.8051)	(6.8074)
HHI	0.7720***	0.7705***	0.5401***	0.5382***
	(54.8079)	(54.7022)	(49.8093)	(49.6871)
Year/Region	Y	Y	Y	Y
_cons	-9.6438***	-9.6565***	-15.7867***	-15.8361***
	(-3.3e+02)	(-3.4e+02)	(-7.1e+02)	(-7.2e+02)
N	2634	2634	2634	2634

4.2. Robustness Checks

In order to control for the sample selection caused by the reverse causality, 2-stage Heckman estimation model is used as a robustness check. In the first stage, the Probit estimation is made to obtain the inverse Mills ratio, then it is added to the Tobit regression model in the second stage. The model (2) and model (3) are formulated.

$$\Pr(Z_i = 1 \mid Patent_{i,t} > Median) = \phi(VC_{i,t}, Controls_{i,t}, \sum Year, \sum Region) \tag{2}$$

$$Patent_{i,t} = \theta_0 + \theta_1 VC_{i,t} + \theta_2 Controls_{i,t} + \theta_3 Mills_{i,t} + \theta_4 \sum Year + \theta_5 \sum Region + \varepsilon_{i,t} \tag{3}$$

Table 3. Robustness check

	(1)	(2)	(3)	(4)	(5)	(6)
	z	*Non-invention*	*Non-invention*	*z*	*Invention*	*Invention*
VC	-0.0091**	-0.0078***	-0.0027	0.0082**	-0.0170***	0.0514***
	(-2.5596)	(-7.2345)	(-1.4487)	(2.3576)	(-21.2763)	(42.6592)
VC2			-0.0003***			-0.0003***
			(-5.9396)			(-10.4193)
Mills		-0.6490***	-0.1220***		-5.1220***	-5.6378***
		(-19.4080)	(-3.6425)		(-2.2e+02)	(-2.2e+02)
Controls	Y	Y	Y	Y	Y	Y
Year /Region	Y	Y	Y	Y	Y	Y
_cons	1.0011	-9.5591***	-9.6419***	-5.5828***	5.8780***	-15.1001***
	(1.0059)	(-3.2e+02)	(-3.3e+02)	(-5.6648)	(259.8590)	(-6.7e+02)
N	2631	2634	2634	2631	2634	2634

Note: Column(1) , (4)is the estimation of the first-stage selection model.
Column(2), (3), (5), (6)refers to the estimation of the second-stage model.

Table 3 shows the coefficient of adverse Mills ratio is statistically significant at the 1% level, the sample selection bias exists according to the evaluation standard made by Wooldridge (2010)[13]. After controlling the sample selection bias, the venture capital investment still functions as the determinant of the number of heterogeneous patents. The results are similar, the selection bias does disturb the separating effect of venture capital on patents. Hypothesis 1 and hypothesis 2 are confirmed. For reasons of brevity, the controlling vectors that affect the number of patent application are not reported and not discussed here.

Furthermore, all the continous variables are winsorized, the result remain similar, then additional variables such as tax is put into the model to repeat the above modelling estimation, the result is still robust. Even the scope of the non-invention patent is changed, the hypothesis 1 and hypothesis 2 can be affirmed. All these robustness checks are not discussed here due to the space limitation.

4.3. Further Analysis of the Intermediary Mechanism

Venture capital investment plays the role of separating effect for the patent quality, since it promotes the high-quality invention patent and restricts the low-quality non-invention patent, but how venture capital affects the patent requires further exploration. Based on the model (1), the intermediary effect model are constructed in model (4) and model (5), where SA refers to the financial constraint, we adopt the SA index made by Hadlock and Pierce(2010)[14].

$$SA_{i,t} = \alpha_0 + \alpha_1 VC_{i,t} + \alpha_2 Controls_{i,t} + \alpha_3 \sum Year + \alpha_4 \sum Region + \varepsilon_{i,t} \tag{4}$$

$$Patent_{i,t} = \gamma_0 + \gamma_1 VC_{i,t} + \gamma_2 SA_{i,t} + \gamma_3 Controls_{i,t} + \gamma_4 \sum Year + \gamma_5 \sum Region + \varepsilon_{i,t} \tag{5}$$

Table 4 reports the intermediary results. In the interest of simplicity, we have therefore not reported the controlling vectors in Table 4. Column (1) in table 4 shows that venture capital mitigates the company financial constraint, either column (2) or column (3) indicates that financial constraint functions as the intermedairy variable completely, the coefficient of SA is statistically negative, hypothesis 3 is supported.Venture capital investment contributes to the separating effect of heterogeneous patents creation through the decline of financial constraint.

Table 4. Intermediary mechanism

	(1) SA	*(2) Non-invention*	*(3) Invention*
VC	-0.0016***	-0.0035	0.0028
	(-7.0402)	(-0.7523)	(0.7844)
SA		-0.8405*	-1.4475***
		(-1.7528)	(-3.3629)
Controls	Y	Y	Y
Year/Region	Y	Y	Y
_cons	0.0039	-0.5735	-7.1674***
	(0.0583)	(-0.4960)	(-6.6677)
N	1986	1986	1986

5. Conclusions

Our results, based on the evidence from GEM companies in mainland China, confirm that venture capital investment matters for the innovaiton quality improvement. Venture capital investment has efficiently recognized the heterogeneous patents during the post-investment supervision, in this sense, venture capital stimulates innovation effectively, the government indirect and direct measures related to promoting venture capital in China are proved to be affirmative.

The long-term investment attribute of venture capital matches the long-term high intensity, high quality, and high revenue of invention patent creation, but mismatches the low intensity, relatively low quality, and low anticipated revenue of non-invention patent creation. Only within the participation instead of controlling scope, the more proportion of venture capital, the more invention patent may be promoted, whereas the more non-invention patent has always been restricted. Hence, venture capital play a quality separating effect on patent output. After we control the bias of sample selection, the results are similar.

We further investigate how the separating effect of venture capital investment funtions in China. The financial constraints are found to be a complete intermediary variable, the creation of an invention patent requires more resources allocation than the production of non-invention patents, the participation of venture capital helps to overcome the uncertainty of R&D externalities and high information asymmetry.

Finally it is worth noting that this study has some limitations. Especially, due to the date limitation in China, we only focus on evidence from the emgering GEM, even though venture capital constitute a quite heterogeneous crowd, the effect of venure capital on patents should differ according to the specific characteristics of investors, we did not examine these interesting issues yet. The limitations of our study suggest starting points for further research.

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