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Effect of Venture Capitalists on Japanese Firms' Patent Applications in the Pre- and Post-IPO Periods

Zhang Jian Xiong*

Abstract

This paper examines the effect of venture capitalists (VCs) on the patent applications of Japanese firms in the pre- and post-IPO periods. We performed an empirical analysis using a Tobit model with endogenous regressors (IVTOBIT model) and firm- and industry-level variables. We found that shareholding by VCs has a positive effect on the patent applications of Japanese firms in the pre-IPO period and that this effect weakens in the post-IPO period.

***Keywords*:** Patent applications, IPO, Venture capitalists, Shareholding, Innovation and R&D expenditure

***JEL Classification*:** G32, G34, O32

1. Introduction

Recent years have witnessed a boom in the number of initial public offerings (IPOs) by venture capital firms in the Japanese stock markets. From 1999 to 2001, 488 Japanese firms issued equity to the public in the Tokyo Stock Exchange, the newly established Jasdaq, Mothers, and Hercules. During this period, VCs funded a large number of such firms, many of which were high-tech firms, owing to these firms' significant profit potential.

Previous studies have investigated the relationship between VCs and innovation. For instance, Kortum and Lerner (2000) find that VC firms have an incentive to perform R&D activities. Meanwhile, Sahlman (1990) show that VCs have the resources and ability to promote innovation in their portfolio firms through their industry experience and expertise.

While the literature on VCs' contribution to innovation is considerable, the literature on the effect of VCs on the patent application of Japanese firms in the pre- and post-IPO periods is relatively scarce.

In this paper, we analyse the effect of the shareholding of VCs on the patent applications of Japanese firms, focusing on the change in the role of VCs in the pre- and post-IPO periods. We determine whether shareholding by VCs has a positive effect on the number of patent applications fuelled by the R&D expenditures of firms in the pre- and post-IPO period.

The remainder of this paper is organised as follows. Section 2 discusses the effects of VCs on

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the patent applications of Japanese firms in the pre- and post-IPO periods. Section 3 explains the estimation model. Section 4 presents the data. Section 5 presents and discusses the empirical results. Finally, Section 6 presents the study's conclusions, limitations, and implications for further research.

2. Literature Review and Hypotheses

Innovation, Information Asymmetry, and a Firm's Market Valuation

Innovation is an important factor that helps firms grow and build and improve their market value. A firm's investment in R&D fuels the development of innovative products and services, improving the firm's market performance and, consequently, its market value. This positive correlation between innovation and a firm's market value has been established in previous studies (Griliches, 1981; Pakes, 1985).

During an IPO, information regarding the firm is disclosed to investors in order to inform them of the firm's current market value. At the time of the IPO, accurate information regarding the quantity and quality of innovation in a firm is crucial in gaining the confidence of the market and investors, as credible information regarding a firm's market value reduces information asymmetry and the undervaluation of firms (Rock, 1986).

Patent Applications and a Firm's Market Valuation

Innovation is an important element in the competition among firms. Lerner (1994) study the relationship between the stock of intellectual property and market valuation of firms and find that a patent holder for a single product effectively protects its intellectual property and enables it to establish a monopoly on the market. Meanwhile, Austin (1993) show that the number of patent applications of a firm also affects the firm's future in the market, while new patent applications can increase a firm's market valuation. Findings by Kogut and Zander (1996) concur with Austin's research, stating that if a firm has numerous patents, it implies that the firm has the ability to undertake future innovations and capitalise on scientific developments that is linked to potential future profits. Indeed, since patents contain direct information regarding the value of innovation and reflect the principal value-creation ability of a firm, a firm's patent applications can reduce its potential undervaluation.

VCs and Patent Applications

VCs have a significant incentive to fund the firms in their portfolio as they stand to gain large capital gains from the IPO of these firms. In order to establish a timely and successful IPO, therefore, VCs need to increase the market valuations of the firms that they are funding. VCs often have vast experiences in the management of innovative firms and possess a considerable amount of expertise in the areas of technology and patent application. To this end, they may support the R&D activities of these firms and help increase their patent applications using their industry experience and expertise.

There are a few studies that have previously examined the relationship between VCs and patent applications of firms. For instance, Sahlman (1990) find that VCs have incentives to promote innovation in their portfolio of firms through their industry experience and expertise. Meanwhile, Kortum and Lerner (2000) analyse the influence of venture capital on patented inventions in twenty industries in the U.S. including the manufacturing sector over three decades. Their results show that venture capital funding in an industry positively influences the number of patent

applications. Theirs do not focus on the VC's impact on patent applications in the pre- and post-IPO periods.

In addition, Kortum and Lerner's (2000) study use [firms receiving funding] and [venture disbursements] as explanatory variables. Other factors that may have an effect on the innovation of firms such as bank, bill, firm, foreigner and director shareholders are not considered.

However, although there has been a considerable focus on IPOs and VCs in existing literature, only a few studies have focused on (1) the patent applications of Japanese firms and (2) the change in the impact of VCs on patent applications in the pre- and post -IPO periods in Japan. Our paper analyse the effect of shareholding by VCs on the patent applications of Japanese firms taking into account the change in the role of VCs in the pre- and post-IPO periods as well as the role of bank, bill, firm, foreigner and director shareholders.

Syndicated VCs and Patent Applications

Moreover, VCs tend to invest in high-risk, high-return deals and as such, they select firms that have high potential for yielding high returns on investment. They use several methods of managing risk, one of which is the syndication of investments, also known as a 'syndicate'. A syndicate is established when two or more VC firms have a stake in an investment.

This paper analyses how a VC firm uses syndication to improve its overall portfolio performance through financial risk dispersion and monitoring innovation activity. This paper also analyses how syndication can improve the management of individual portfolio firms through R&D investment and patent applications.

By dispersing investments across a number of firms with little covariation, syndication can reduce risk considerably (Markowitz, 1952). Through syndication, a VC firm can also organise a portfolio with more VC-backed companies, thus increasing innovation activity and making the process of patent application easier for the funded firms.

In other words, VCs try to access as many high-quality opportunities as possible in order to be able to protect the results of innovation activities in their portfolio of firms. As the syndication network of a VC firm grows stronger, its status and visibility increases (Lerner, 1994), making it likelier for the VC firm to be invited into a new syndication network.

The relationship among VCs, syndicated VCs, and the patent applications of Japanese firms in the pre- and post-IPO periods have been inadequately addressed in previous studies. As such, this paper also examines these issues.

Based on the discussion above, we propose the following two hypotheses:

Hypothesis 1: Shareholding by VCs has a positive effect on the patent applications of firms in the pre-IPO period.

Hypothesis 2: The positive influence of VCs on the patent applications of firms decreases in the post-IPO period.

3. Estimation Model

We analyse our two hypotheses using the following model:

PAT = f (ownership structure, other firm-level factors, industry factors).

In this model, the dependent variables are the natural logarithm of the number of patent appli-

cations plus one (PAT) and the natural logarithm of the number of patent applications plus contraptions plus one (PAT1). The explanatory variables include ownership structure, firm-level factors, and industry-level factors. The definitions of the dependent and explanatory variables are provided in Table 1.

Table-1： Definitions of Variables

	Dependent variables
	Natural logarithm of (numbers of patent applications +1) (PAT)
	Natural logarithm of (numbers of patent applications + contraptions+1) (PAT1)
	Explanatory variables
Ownership Structure/Governance Factors	Shareholding ratio by all venture capitalists (VCSH)
	Shareholding ratio by syndicating venture capitalists (SVCSH)
	Bank-venture capitalist dummy (BA_VC)
	Bill-venture capitalist dummy (BI_VC)
	Firm-venture capitalist dummy (COM_VC)
	Independence-venture capitalist dummy (IND_VC)
	Foreign-venture capitalist dummy (FOR_VC)
	Shareholding ratio by top-10 shareholder (TOP10_SH)
	Shareholding ratio by banks (BASH)
	Shareholding ratio by bills (BISH)
	Shareholding ratio by firms (COMSH)
	Shareholding ratio by foreigners (FOCOMSH)
	Shareholding ratio by directors (DIRSH)
Firm-level Factors	Natural logarithm of R&D expenditures (RDE)
	Employee number (SIZE)
Industry Factors	Manufacturing industry dummy (D1)
	Software industry dummy (D2)
	Information-Communication industry dummy (D3)
	Wholesale-Retail industry dummy (D4)
Instrumental Variables	Dummy for the TOP shareholders that shareholding ratio is more than 1/3(TOPD)
	Ratio of 1 to the distance of the firms to Tokyo (DIS)

Meanwhile, the factors related to VCs include shareholding by all VCs (VCSH), shareholding by syndicated VCs (SVCSH). And, in the above-mentioned model, the factors relating to VCs include the bank-VC dummy (BA_VC), bill-VC dummy (BI_VC), firm-VC dummy (COM_VC), independent-VC dummy (IND_VC), and foreign-VC dummy (FOR_VC).

The specific factors related to ownership structure include the shareholding ratio of the top 10 shareholders, banks, bills, firms, foreigners, and directors. The firm-level factors include the firm's size (SIZE) measured by the number of employees, and the natural logarithm of R&D expenditures (RDE).

In the analysis, industry-level factors are expressed in terms of the industry dummy variables for the manufacturing, software development, information-communication, and wholesale-retail industries.

We expect that the VCSH and SVCSH variables will have a positive effect on patent applications in the pre-IPO period. These variables are estimated interchangeably. Hypothesis 1 will be supported if the coefficients of these variables are shown to be positively and statistically significant.

If the BA_VC, COM_VC, IND_VC and FOR_VC variables have positively significant coef-

ficients in the pre-IPO period, it will be suggested that bank-VCs (BA_VC), firm-VCs (COM_VC), independent-VCs (IND_VC), and foreign-VCs have a positively significant effect on the patent applications of firms in the pre-IPO period.

TOP10_SH refers to shareholding ratio of the top 10 shareholders. TOP10_SH is a variable that measures the concentration of shareholding. In this paper, we use the variable to examine the effect of shareholding concentration on the patent applications. If a chief shareholder is positively related with innovation, the coefficients of these variables are shown to be positively and statistically significant.

In this model, if the estimated coefficients for the shareholdings of banks, bills, firms, foreign firms, and directors are positive and significant in the pre- and post-IPO periods, it is assumed that these financial institutions and non-financial business corporations have impact on the patent applications of the firms in these periods.

RDE is the natural logarithm for R&D expenditures. According to the hypothesis proposed by Hausman et al. (1984), the number of patent applications of a firm increases with an increase in R&D expenditures. Thus, it is reasonable to assume that firms with high R&D expenditures have more patents. In this paper, the explanatory variables are controlled by the R&D expenditures. If the coefficients of RDE are shown to be positively and statistically significant, it indicates that firms with high R&D expenditures are more innovative and thus have more patent applications.

Another firm-level variable used in the model is size (SIZE), measured by the number of employees. SIZE is used as an explanatory variable and proxy for firm size. According to the Schumpeterian hypothesis, large firms have more internal funds, more opportunities to procure external funds, a high ability to take risks, and more complementary resources for implementing innovation; thus, large firms have high R&D expenditures. The effect of the firm's size is therefore controlled for in our analysis.

Industry-level factors are represented in the estimation model by industry dummy variables which include: the manufacturing industry dummy: D1, software development industry dummy: D2, information-communication industry dummy: D3, and wholesale- retail industry dummy: D4. The data used in this study indicate that patent applications are higher in the manufacturing industry than in the software development, information- communication and wholesale-retail industries and as such, the effect of VCs may differ from one industry to another. We therefore analyse these industries separately in order to determine whether VCs have different effects on patent applications in the different industries.

If VCs select innovative firms for investment, the shareholding ratio of VCs is endogenous, thereby resulting in the problems of simultaneity and reverse causality. In order to avoid these problems, we employ a Tobit Model with endogenous regressors (IVTOBIT Model) in the empirical analysis.

If a firm has a chief shareholder who has stronger authority and influence than others in the firm, external intervention becomes difficult; as such, the firm becomes less attractive for investment by VCs. Therefore, the dummy for the top shareholders with a shareholding ratio of over 1/3 of the total shareholding of a firm (TOPD) is used as an instrumental variable. In addition, the farther the location of the firms in the VCs portfolio, the more difficult it is for the VCs to support and monitor the managers of these firms. VCs therefore prefer firms that are in their proximity. As such, the ratio of 1 to the distance of the firms to Tokyo (DIS) is considered as another instrumental variable. Here, the distance of the firms to Tokyo is measured as the geographical distance of the firms to the JR Tokyo station in kilometres. This information regarding distance was obtained from the public transportation tracking information of Yahoo Japan.

4. Description of Data

This paper analyses firms that issued an IPO in the years 1999 (52 firms), 2000 (19 firms), and 2001 (52 firms)—a total of 123 firms. The analysis periods are 1997–1998 and 2000–2001 for the firms that issued an IPO in 1999; 1998–1999 and 2001–2002 for the firms that issued an IPO in 2000; and 1999–2000 and 2002–2003 for the firms that issued an IPO in 2001.

The dataset used in this paper includes data on patent applications, contraptions, R&D expenditures, number of employees, and shareholding by VCs. The shareholding data includes the shareholding ratio of the top 10 shareholders, banks, bills, firms, foreigners, and directors. Data on R&D expenditure, number of employees, shareholding by VCs, and ownership structure for the pre- and post-IPO periods were collected from the *Annual Corporate Financial Data* of the Development Bank of Japan for the years 1997–2003. Meanwhile, the patent application and contraption data were obtained from the Japanese Patent Office's electronic patent library for the years 1997–2003. Information pertaining to VCs was obtained from the *Nihon Benntya Kyapitaru Youran* (Compendium of Venture Capital in Japan). Last but not least, information on IPOs was obtained from the *Kabusiki Tenntou Jyoujyou Hakasyo* (White Papers of Initial Public Offerings) from the years 2000, 2001, and 2002.

Out of the 123 firms, the number of firms in the pre-IPO period with patent applications is 58 while that of firms without any patent applications is 65. In the post-IPO period, the number of firms with patent applications is 57 while that of firms without any patent applications is 66. These figures indicate that compared to the post-IPO period, majority of the firms in our sample were financed by VCs in the pre-IPO period.

In our sample, there were 56 VC firms in the pre-IPO period and 28 VC firms in the post-IPO period (Table 2). There were 27 syndicating VC firms in the pre-IPO period and 7 syndicating VC firms in the post-IPO period. Based on the data, the mean values of the shareholding ratio of all VCs in the pre-IPO period are significantly higher than those of VCs in the post-IPO period.

Table 3 presents the breakdown of VC firms in our data. As the table shows, there were nine bank-VCs, nine bill-VCs, five firm-VCs, 12 independent-VCs, and 21 foreign-VCs in the pre-IPO period. Meanwhile, there were seven bank-VCs, three bill-VCs, three firm-VCs, five independent-VCs, and 10 foreign-VCs in the post-IPO period.

Table-2: VC and Patent Applications

	Pre-IPO		Post-IPO	
	VC	NO-VC	VC	NO-VC
Number of Firms	56	67	28	95
PAT	39	19	20	37
NO-PAT	17	48	8	58

Table-3: Attribution of VC

Number of Firms	Bank-VC	Bill-VC	Firm-VC	Independence-VC	Foreign-VC
Pre-IPO	9	9	5	12	21
Post-IPO	7	3	3	5	10

Table 4 presents the change in other shareholding ratios of banks, bills, firms, foreigners, and directors. Based on the data, the mean values of the shareholding ratios of bills, firms, and directors of firms in the pre-IPO period are higher than those of firms in the post-IPO period. In contrast, the mean value of the shareholding ratio of banks in the post-IPO period is higher than that in the pre-IPO period.

Table-4: Ownership Structure
(Shareholding Ratio)

Mean(%)	Bill	Firm	Foreign	Directors	VC	Bank
Pre-IPO	0.64	27.86	5.53	24.79	2.03	3.85
Post-IPO	0.56	23.98	6.03	22.3	0.5	4.43

In the pre-IPO period, the mean value of the natural logarithm (number of patent applications) of the firms is 0.279 and the median is 0. In the post-IPO period, the mean is 0.205 and the median is 0. In addition, the number of patent applications is higher in the manufacturing industry than in the software development, information-communication and wholesale-retail industries.

5. Empirical Results and Discussion

Tables 5 and 6 present the estimations for the pre- and post-IPO periods. These tables include the results for the industry dummy variables for the manufacturing, software development, information-communication, and wholesale-retail industries.

The VC shareholding variables (VCSH and SVCSH) are included interchangeably in the estimation. The variables pertaining to ownership structure, including VCSH and SVCSH all display positively significant coefficients in the pre-IPO period, supporting our first hypothesis. These results suggest that VCs have a positively significant effect on the patent applications of firms in the pre-IPO period.

In the above-mentioned model, the factors relating to VCs include the bank-VC dummy (BA_VC), bill-VC dummy (BI_VC), firm-VC dummy (COM_VC), independent-VC dummy (IND_VC), and foreign-VC dummy (FOR_VC).

Our results show that the BA_VC, COM_VC, IND_VC and FOR_VC variables have positively significant coefficients in the pre-IPO period, suggest that bank-VCs (BA_VC), firm-VCs (COM_VC), independent-VCs (IND_VC), and foreign-VCs have a positively significant effect on the patent applications of firms in the pre-IPO period. It supports our first hypothesis. However, the coefficients of BI_VC are not shown to be positively significant in the pre-IPO period.

Kutsuna, Hasegawa, and Yamamoto (2006) point out that major Japanese bill-VCs is a balanced type of VCs in that it they see potential for growth in firms at all stages in the firm life-cycle, while other types of Japanese VCs prefer to invest in firms in the start-up and early growth stage. This paper's finding that bill-VCs do not have a positive effect on patent applications in the pre- and post-IPO period therefore supports that of Kutsuna, Hasegawa, and Yamamoto (2006).

Meanwhile, the coefficients for VCSH, SVCSH, BA_VC, BI_VC, COM_VC, IND_VC and FOR_VC variables were not found to be positive and significant in the post-IPO period, supporting our second hypothesis. These results indicate that the effect of VCs weakens in the post-IPO period.

Table-5： Estimation Results

Method of Estimation: IVTOBIT (Tobit Model with Endogenous Regressors)

	Dependent variable Natural logarithm of numbers of patent applications (PAT)							
	PRE-IPO				POST-IPO			
Explanatory variables	①	②	③	④	①	②	③	④
VCSH	**0.0911**				**0.398**			
	(1.81)c				**(0.74)**			
SVCSH		**0.129**	**0.148**			**0.0268**	**0.022**	
		(2.24)b	**(2.05)b**			**(0.05)**	**(0.05)**	
BA_VC				**0.629**				**0.285**
				(4.12)a				**(1.56)**
BI_VC				**0.0242**				**-0.248**
				(0.14)				**(-0.88)**
COM_VC				**0.539**				**0.179**
				(2.94)a				**(0.63)**
IND_VC				**0.387**				**-0.167**
				(2.76)a				**(-0.72)**
FOR_VC				**0.522**				**0.252**
				(4.56)a				**(1.52)**
BASH	-0.0032	0.0072	0.01	-0.00064	0.0017	0.000075	-0.00002	0.0029
	(-0.29)	(0.59)	(0.73)	(-0.07)	(0.14)	(0.01)	(-0.001)	(0.28)
BISH	-0.0231	-0.0089	-0.0063	-0.0101	0.0948	0.0426	0.0351	0.0454
	(-0.72)	(-0.28)	(-0.19)	(-0.36)	(0.97)	(0.72)	(0.61)	(0.9)
COMSH	-0.0012	-0.00029	-0.0018	-0.0016	-0.00559	-0.0025	-0.00082	-0.0032
	(-0.35)	(-0.09)	(-0.43)	(-0.62)	(-1.01)	(-0.69)	(-0.21)	(-1.10)
FORCOMSH	-0.00099	0.0018	0.00099	-0.0058	0.00015	-0.00018	0.00137	-0.00013
	(-0.23)	(0.4)	(0.21)	(-1.38)	(0.03)	(-0.04)	(0.28)	(-0.03)
DIRSH	0.00044	0.00053	-0.00079	0.00016	-0.0028	-0.00006	0.0014	-0.0001
	(0.14)	(0.17)	(-0.20)	(0.06)	(-0.53)	(-0.01)	(0.31)	(-0.03)
TOP10_SH			0.0032				-0.0033	
			(0.6)				(-0.77)	
RDE	**0.0783**	**0.091**	**0.092**	**0.063**	**0.0922**	**0.128**	**0.126**	**0.121**
	(3.07)a	**(3.54)a**	**(3.47)a**	**(2.84)a**	**(1.62)**	**(4.27)a**	**(4.30)a**	**(4.77)a**
SIZE	0.00025	0.00027	0.0003	0.00022	0.00026	0.00016	0.00015	0.00017
	(1.94)c	(2.15)b	(2.11)b	(2.26)b	(1.34)	(1.17)	(1.2)	(1.67)c
D1	0.196	0.37	0.375	0.262	0.101	0.275	0.279	0.308
	(1.71)c	(2.25)b	(2.21)b	(1.83)c	(1.66)c	(1.67)c	(1.70)c	(1.92)c
D2	-0.116	-0.187	-0.216	-0.0033	-0.289	-0.095	-0.0982	-0.153
	(-0.58)	(-0.90)	(-0.97)	(-0.02)	(-0.84)	(-0.52)	(-0.54)	(-0.85)
D3	0.0085	0.0824	0.0863	0.052	0.0374	0.0313	0.0185	0.148
	(0.04)	(0.41)	(0.401)	(0.30)	(0.02)	(0.15)	(0.09)	(0.07)
D4	-0.152	-0.105	-0.0857	-0.0759	-0.159	-0.239	-0.31	-0.0093
	(-0.97)	(-0.65)	(-0.51)	(-0.54)	(-0.58)	(-0.12)	(-0.16)	(-0.06)
Constant	-0.452	-0.622	-0.806	-0.427	-0.555	-0.639	-0.504	-0.643
	(-1.94)c	(-2.46)b	(-1.94)c	(-2.05)b	(-1.95)c	(-2.77)a	(-1.72)c	(-3.02)a
Log likelihood	-821	-745	-744	-158	-554	-472	-472	-145
Number of observations	246	246	246	246	246	246	246	246

1) The level of significance: a 1%, b 5%, c 10%.

2) T-statistics in parentheses.

3) Industry dummies are included in the estimation, but not shown in the table.

4) TOBIT Model is used in the ⑤.

Table-6： Estimation Results

Method of Estimation: IVTOBIT (Tobit Model with Endogenous Regressors)

Dependent variable

Natural logarithm of numbers of (patent applications + contraption)(PAT1)

Explanatory variables	①	②	③	④	①	②	③	④
VCSH	**0.091**				**0.373**			
	(1.79)c				**(0.71)**			
SVCSH		**0.129**	**0.15**			**0.038**	**0.0481**	
		(2.22)b	**(2.06)b**			**(0.08)**	**(0.1)**	
BA_VC				**0.627**				**0.273**
				(4.05)a				**(1.49)**
BI_VC				**0.014**				**-0.263**
				(0.08)				**(-0.93)**
COM_VC				**0.536**				**0.172**
				(2.88)a				**(0.6)**
IND_VC				**0.389**				**-0.18**
				(2.74)a				**(-0.78)**
FOR_VC				**0.517**				**0.24**
				(4.44)a				**(1.44)**
BASH	-0.0036	0.0068	0.0099	-0.00116	0.00071	-0.00089	-0.00103	0.0018
	(-0.33)	(0.55)	(0.71)	(-0.12)	(0.06)	(-0.09)	(-0.10)	(0.18)
BISH	-0.0241	-0.01	-0.007	-0.0107	0.0884	0.0401	0.0361	0.0423
	(-0.75)	(-0.31)	(-0.21)	(-0.38)	(0.929)	(0.68)	(0.62)	(0.83)
COMSH	-0.0012	-0.00032	-0.00196	-0.0016	-0.0054	-0.0026	-0.0016	-0.0032
	(-0.36)	(-0.10)	(-0.47)	(-0.61)	(-1.00)	(-0.71)	(-0.40)	(-1.09)
FORCOMSH	-0.00104	0.0018	0.00087	-0.0058	-0.00019	-0.00049	0.00051	-0.00046
	(-0.23)	(0.39)	(0.18)	(-1.37)	(-0.04)	(-0.11)	(0.1)	(-0.10)
DIRSH	0.00053	0.00061	-0.00084	0.0003	-0.0028	-0.00036	0.00049	-0.0003
	(0.17)	(0.2)	(-0.21)	(0.11)	(-0.55)	(-0.08)	(0.11)	(-0.10)
TOP10_SH			0.0035				-0.0021	
			(0.66)				(-0.50)	
RDE	**0.0809**	**0.0936**	**0.0944**	**0.0665**	**0.0948**	**0.128**	**0.126**	**0.122**
	(3.15)a	**(3.61)a**	**(3.53)a**	**(2.93)a**	**(1.69)c**	**(4.27)a**	**(4.26)a**	**(4.77)a**
SIZE	0.00025	0.00028	0.0003	0.00022	0.00026	0.00016	0.00017	0.00018
	(1.94)c	(2.15)b	(2.12)b	(2.24)b	(1.36)	(1.23)	(1.27)	(1.70)c
D1	0.192	0.365	0.371	0.258	0.124	0.285	0.287	0.321
	(1.07)	(2.19)b	(2.16)b	(1.77)c	(0.40)	(1.72)c	(1.74)c	(1.97)c
D2	-0.128	-0.199	-0.232	-0.0145	-0.271	-0.0906	-0.0939	-0.145
	(-0.64)	(-0.95)	(-1.02)	(-0.09)	(-0.80)	(-0.49)	(-0.521)	(-0.80)
D3	0.0143	0.0879	0.0921	0.0461	0.0046	0.0324	0.0267	0.0158
	(0.07)	(0.43)	(0.44)	(0.27)	(0.02)	(0.15)	(0.12)	(0.08)
D4	-0.159	-0.112	-0.0906	-0.0826	-0.139	-0.0153	-0.224	0.0029
	(-1.00)	(-0.68)	(-0.58)	(-0.58)	(-0.52)	(-0.08)	(-0.12)	(0.02)
Constant	-0.454	-0.624	-0.627	-0.432	-0.552	-0.629	-0.539	-0.635
	(-1.93)c	(-2.45)b	(-1.97)b	(-2.04)b	(-1.98)b	(-2.73)a	(-1.82)c	(-2.98)a
Log likelihood	-822	-747	-746	-159	-555	-473	-473	-146
Number of observations	246	246	246	246	246	246	246	246

1) The level of significance: a 1%, b 5%, c 10%.

2) T-statistics in parentheses.

3) Industry dummies are included in the estimation, but not shown in the table.

4) TOBIT Model is used in the ⑤.

TOP10_SH is a variable that measures the concentration of shareholding. In this paper, we use the variable to examine the effect of shareholding concentration on the patent applications. The coefficients of TOP10_SH are not significant in all periods. As such, we cannot state that the concentration of shareholding has an encouraging effect on the patent applications.

The estimated coefficients for the shareholdings of banks, bills, firms, foreign firms, and directors are not positive and significant in the pre- and post-IPO periods, it is assumed that these financial institutions and non-financial business corporations have little impact on the patent applications of the firms in these periods.

Moreover, compared to these other shareholders, VCs are more experienced in managing innovative firms and possess expert knowledge in many technological fields and in patent applications in the pre-IPO period. It is no surprise, then, that they have a more significant impact on patent applications than the other shareholders.

The coefficient of the RDE variable (natural logarithm of R&D expenditures) is positive and significant in the model, showing that the number of patents increases with an increase in R&D expenditures in the pre- and post-IPO periods. It inspected the hypothesis proposed by Hausman et al. (1984), the number of patent applications increases with an increase in R&D expenditures; hence, it is reasonable to assume that firms with higher R&D expenditures will apply for more patents.

The coefficient of SIZE is also significant in the pre-IPO period. VCs have vast experience in mentoring the firm's employees and possess expert knowledge in many technological fields. Therefore, they can support innovation efforts in a firm and lead patent applications using their industry experience and expertise in the pre-IPO periods. However, the impact of VCs dissipates in the post-IPO period, and as such, support and resources for innovation and patent application also weakens. Therefore, the number of employees (SIZE) has a significant impact on patent applications in the pre-IPO periods, but not in the post-IPO periods.

The coefficients of the manufacturing industry dummy variables are positively significant, while those of the software, information-communication, and wholesale-retail industries dummy variables are not.

This suggests that the manufacturing industry has higher patent applications. Meanwhile, the coefficients of the software and information-communication industries dummy variables do not indicate a positive effect on patent applications owing to the higher copyright privileges in these industries.

Overall, the results from our estimation show that shareholding by VCs has a positive effect on the patent applications of firms in the pre-IPO period. However, this effect weakens in the post-IPO period.

6. Conclusion

This paper examined the role of VCs in the patent applications of firms and analysed the relationship between ownership structure and patent applications. Results from our estimation show that shareholding by VCs is positively correlated with the patent applications of firms in the pre-IPO period, but that this effect weakens in the post-IPO period. Based on these finding, we conclude that VCs play a positive role in the increase of patent applications of Japanese firms in the pre-IPO period.

It is important to note that our study, like others, has its limitations. The sample is small, comprising only of 123 firms that had issued an IPO in 1999, 2000 and 2001, and as such, may be

biased. Data for the shareholding ratio and R&D expenditure are not available for all firms that issued an IPO. As such, only firms that published such data were selected for the analysis.

Nevertheless, existing empirical studies on the effect of VCs on the patent applications of Japanese firms is relatively scarce. We hope that through this paper, we can encourage further research in this area.

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