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Capital Supply Channel through Venture Capitals: Evidence from matched data*

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Abstract

This paper examines the impact of venture capital firms' (VCs) characteristics on their capital (i.e., fund) supply and how such an impact interacts with the dynamics of public equity markets. To this end, we use a unique dataset consisting of around 6,000 pairs of venture companies and VCs match-level dataset in Japan, which covers around 2,600 unlisted companies and 600 VCs. This match-level panel dataset allows us to control for companies' time-varying unobservable capital demand, so that we can identify the effects of VCs' characteristics on their capital supply and how such effects vary as public equity markets fluctuate. The estimation results indicate that VCs with larger past investment experiences tend to supply more capital to their portfolio companies. Furthermore, such positive impact of VCs' experience on the capital supply became larger (smaller) when public equity markets were in their downturn (upturn). We also confirm that omitting firms' fund demand leads to substantial overestimation of these impacts.

Keywords: Venture capital firms, Stock market, Time-variant venture company individual effects
JEL classification: E44, G24

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1. Introduction

Venture capital firms (VCs) are a class of financial intermediaries that finance venture companies through equity investment (Gompers and Lerner 2001) with intensive screening of investment targets. VCs also provide various strategic, management, marketing, and/or administrative advices to venture companies in their portfolio to add value to these portfolio firms. The objective of VCs is to exit from their investments with profit through, for example, an initial public offering (IPO) or selling the firm to other investors (trade sale). Toward this end, VCs employ their strategic, management, marketing, and administrative expertise to appropriately finance and provide advices to venture companies (Cumming et al. 2005).

The extant studies on banks has been presenting various mechanisms through which bank loan supply is constrained. As an example of theoretical illustrations, banks tend to reduce the supply of loan during economic downturn since the agency problems involved in banks' financing through uninsured debt become severer (Stein 1998). Furthermore, such an adverse impact originating from the economic downturn could be larger when banks have weaker balance sheets as such banks are more likely to incur larger agency costs. Given these empirical implications obtained from theoretical model, large numbers of empirical literature have been conducted to show the existence of the mechanism called as a bank balance sheet channel.

Following the large accumulation of empirical banking study in this direction, the pattern of VCs' capital provision has been also studied (Gompers and Lerner 1998; Jeng and Wells 2005; Kaplan and Schoar 2005; Rin et al. 2013). As an example, Gompers et al. (2008) found that VCs with larger investment experience tented to increase their fund provision when public market signal became more favorable, compared to VCs with smaller industry experience. Their finding suggests the existence of some mechanisms through which VCs' capital provision is interacted with market conditions.

As in the discussion with the bank balance sheet channel (Hosono and Miyakawa 2013, 2014), however, it is difficult to identify the mechanism through which VCs' capital supply is determined. This is mainly because it is necessary for identifying such a mechanism to employ shocks to VCs' capital supply disentangled from shocks to venture companies' capital demand.

Notably, it is also necessary to address various observable and unobservable characteristics associated with VCs and venture companies as well as to address the assortative matching mechanism that may arise if better-performing venture companies are more likely to acquire capitals from better-performing VCs (Sorensen 2007). As far as we understand, extant studies examining the patterns of VCs' capital provision have not fully addressed these identification concerns.

Against this background, we examine the impact of VCs' characteristics on capital supply and how such an impact is interacted with aggregate shocks by using a unique dataset that contains information on multiple VCs from which venture companies obtain capital. The data contain the amount of capital invested by multiple VCs to each venture companies as well as on the characteristics of each venture company and VC. Using this unique dataset, we examine, first, whether VCs' investment experience, which is measured in terms of VCs' age and their past investment experiences, and the scope of their collaboration with other VCs affects capital supply to venture companies. Second, we also study whether the fluctuation in public equity market strengthens or weakens the effects of these VCs' characteristics on capital supply. To disentangle VC capital supply from the capital demand of venture companies, we control for venture company-year fixed effects. Controlling for this time-variant firm-level unobservable effect, we study the variation in the amounts of invested capital across VCs for the same venture company over time. Since such a time-variant firm-level effect accounts for firms' capital demand as one component, we can identify the effects of VCs' characteristics on their capital supply and how such effects vary as public equity markets fluctuate. We also control for VC-venture company matching pattern up to some extent (if any) by including their match-level fixed effects.[1]

There are a few studies that successfully overcome the identification problems in empirical banking studies (e.g., Khwaja and Mian 2008; Jiménez et al. 2012; Hosono and Miyakawa 2014). For example, Jiménez et al. (2012) use Spanish data on loan applications and focus on whether banks accept firms' loan applications. To the best of our knowledge, however, there is no extant study specifically focusing on VCs' capital provision with taking into account the aforementioned

[1] Li and Prahala (2007) and Bottazzi et al. (2008) summarize other methodologies able to account for potential selection biases associated with assortative matching.

identification problems. Filling this gap is the goal of our study.

The findings of our analysis can be summarized as follows. First, VCs with larger investment experience in terms of their past investment volume tended to supply more capital. Second, the effects of VCs' investment experience on capital provision became stronger (weaker) when the stock market was in downturn (upturn). Third, the effects of VCs' experience mattered more largely in specific sector such as internet and pharmaceutical. Fourth, the effects of VCs' experience mattered only in early rounds of VC investment. Fifth and finally, omitting the demand control in the estimation leads to substantial overestimation of the effects of VCs' investment experience on capital provision, and its interaction with the dynamics of stock market.

The rest of the paper proceeds as follows. Section 2 briefly describes the Japanese venture capital industry to provide some background to the following analysis. Section 3 reviews the relevant literature and discusses the contribution of this study while Section 4 describes the dataset and the empirical methodology. Section 5 presents and discusses the results, and Section 6 concludes.

2. Background Information on the Japanese Venture Capital Industry

The dataset we use for our analysis covers the twelve years up to 2012 – a period of considerable change in the environment for start-up firms attempting to obtain capital and achieve IPO in Japan. The aim of this section is to provide brief background information on venture capital industry by specifically focusing on fund flow and IPO activity in Japan during this period.

Understanding the capital provision ultimately aiming at successful IPO is important, particularly when considering Japan's recent economic performance. Japan's "Two Lost Decades" and their causes have been the subject of considerable academic debate. One key issue on which consensus has been reached is that Japan's low growth is not only due to the decline in labor and capital input, but also to low productivity growth (Fukao 2012). This means that raising productivity growth is of vital importance and research on the sources of productivity growth suggests that the entry of innovative firms plays a major role. Partly reflecting this concern, the size of Japan's VC industry has been increasing and gradually started to function as an additional financing channel

throughout 1990s and 2000s. A wide range of governmental support measures, including the introduction of markets for young firms (e.g., Tokyo Stock Exchange-Mothers), have also encouraged the growth of the VC industry.

We start by looking at a representative data series accounting for the aggregate-level VC fund provision. Figure 1 depicts the aggregated annual investment flows by 101 Japanese VCs in each fiscal year from 1999.[2] The investment flow started from more than 2,000 million yen in the early 2000s, followed by the slowdown after the bust of IT bubble. Although it had again increased during the middle of 2000s, the number largely declined after the scandals including serious window dressing of a venture company in Japanese emerging market.

Along with such large swings in the aggregated investment flow, the number of IPOs in Japanese stock markets have been also largely varying. Figure 2 shows the number of IPOs in the Japanese stock market over the last two decades. The figure indicates that there were a considerable number of IPOs in the 2000s until the onset of the global financial crisis, which led to a large decline in IPOs.

The concomitant deterioration in the prospects for VC investors to exit from their investment in turn has made it difficult for firms to raise sufficient funds from VCs. It thus implies that the stock market environment is one of the main factors responsible for the dynamics of fund flows in recent years. Examining the microeconomic factors (i.e., VCs characteristics) as well as its interaction with stock market fluctuation may help to provide clues on how to achieve a more vibrant the environment surrounding venture companies.

3. Related Literature

A vast number of extant studies starting from Bernanke and Gertler (1989) have been examining the mechanism governing firms' borrowing and banks' loan provision as well as its consequences on firm activities (e.g., capital investments). While a large number of empirical literature has been specifically examining, for example, the role of bank net worth in loan supply

[2] The number is based on the survey study (fact book 2014) conducted by Venture Enterprise Center and covers 101 Japanese VCs investments regardless of the geographical location of target companies (http://www.vec.or.jp). Since the data we use in the present paper consists of the investments by both domestic and foreign VCs to the companies located in Japan, the coverages of the survey and our dataset are not necessarily overlapped.

(Kashyap et al. 1993; Hoshi et al. 1993; Ueda 1993; Peek and Rosengren 1997; Jayaratne and Morgan 2000; Kashyap and Stein 2000; Ito and Sasaki 2002; Hosono 2006) and reporting significant effects of bank balance sheet condition on lending and the interaction between such a mechanism and aggregate variables, the approach and data used in the extant studies cannot clearly disentangle fund supply and demand shocks.

Given such a discussion, recent studies have employed a number of empirical strategies to isolate loan supply shocks from loan demand shocks, ranging from event studies to the use of natural experiments and loan-level data.[3] As the most relevant to this paper is the use of loan-level information for firms with multiple bank relationships. Khwaja and Mian (2008) is the first paper to employ a strategy of identifying (bank-specific) loan supply shocks to the changes in loans after controlling for firm-level fixed effects that are assumed to reflect firm-specific loan demand shocks (as well as aggregate loan supply shocks). Using data on loan applications in Spain, Jiménez et al. (2012) extended the empirical strategy employed by Khwaja and Mian (2008) and controlled for the time-variant quality of potential borrowers by considering either firm-month or loan-level fixed effects. Hosono and Miyakawa (2014) applied the same empirical strategy employed in Jiménez et al. (2012) to Japanese firm-bank match-level data and study how the intensive margin of loan (i.e., the change in loan outstanding) is affected by banks' balance sheet characteristics and aggregate conditions including the change in monetary policy. We employ the same empirical strategy employed in these three papers to examine VCs' capital provision.

On VC characteristics potentially affecting their capital provision, Sorensen (2008) discussed the mechanism through which VCs can learn from their own investments. His discussion suggests that the past investment history matters for the ability of VCs' capital provision. Kanniainen and Keuschnigg (2004) as well as Fulghieri and Sevilir M. (2009) also developed theoretical models to illustrate the relationship between the size of VCs' portfolio and the fundamental conditions surrounding startups. In their model, under economic downturn where the risk associated with startups become higher, VCs with larger portfolio could provide mode funds since they can more easily diversify their portfolio. These studies suggest that accumulated investments of VCs positively

[3] See Hosono and Miyakawa (2013) for a survey.

contribute to fund provision through various mechanisms.

Among the related studies to the present paper in the field of VC finance (Rin et al. 2013), the most closely related paper is Gompers et al. (2008). Using the investment records of U.S. venture capitals between 1975 and 1998, they regressed the VC investments measured in each VC-level on the Tobin's Q measured for nine VC industry categories (Internet & Computer, Communications & Electronics, Business & Industrial, Consumer, Energy, Biotechnology & Healthcare, Financial Service, Business Service, and All Others), each VC's investment experience, VC industry-level fixed effect, and year-fixed effect. From this estimation, they found that more experienced VCs' investment were more sensitive to the VC industry-level Tobin's Q. This suggests that under market upturn (downturn), more experience VCs tended to increase (decrease) more than less experienced VCs.

While their finding certainly shows the existence of some mechanisms through which VCs' capital provision is interacted with market conditions, mainly because their estimation does not disentangle the variations in invested amounts associated with the fund-demand side (i.e., venture company) and that with the fund-supply side (i.e., VCs), it is difficult to obtain a precise picture of the fund flow. In the presenting paper, we take into account such a concern about the identification, and study how VCs' investment experience affect their capital provision and , if any, how aggregate shocks affect the pattern.

4. Data and Empirical Framework

4.1. Data and Hypotheses Construction

This section provides a description of the data we use for our empirical analysis and construct our hypotheses. We begin by describing our data. As the variable representing venture company-VC match-level investment amounts, we use data on VCs' capital provision obtained from Japan Venture Research (JVR database). The dataset contains the information for all the VC-backed venture companies establishing IPO since 2000 and a large number of VC-baked unlisted venture firms in Japan. The dataset accounts for the amount of capital invested in all investment rounds by each VC to each venture company since FY1991. We measure the flow amount of invested capital

from VC-*i* to venture company *j* during year *t* by taking the natural logarithm of the flow amount of invested capital *INV*(*i*,*j*,*t*). When venture firms obtain funds from multiple VCs, there is a set of {*i*} corresponding to the VCs investing on each (*j*,*t*). As detailed in the next subsection, we model the determination of the amount of invested capital *INV*(*i*,*j*,*t*) as a function of venture company characteristics, VC characteristics, and aggregate-level variables.

Information for most of the variables representing VCs' characteristics is taken from JVR database. Specifically, for VCs' age *VC_AGE*(*t*), we compute the difference between the year corresponding to each data point minus VC-*i*'s established year stored in JVR database.[4] VCs' experience in terms of their past investment *VC_PRE_INV*(*t*) is measured as the natural logarithm of the accumulated amount of capitals invested by VC-*i* prior to year *t*. To take into account VCs' scope of collaboration with other VCs *VC_PRE_COLL*(*t*), we use the natural logarithm of the number of VCs that VC-*i* had invested together with prior to year *t*. We treat all the VC characteristics as exogenous variables. In order to avoid the potential endogeneity bias originating from simultaneity, we employ the firm characteristics as of the beginning of each year.[5] The observation period is from 1991 to 2012.

As for aggregate-level variables *STOCK*(*t*), we use the growth rate of the end-of-the-year level of JASDAQ index and TOPIX, both of which represent the change in stock markets over each year. While TOPIX data series is available for all the periods from 1991 to 2012, JASDAX index is available only from 1993. The full data series accounting for *STOCK* is summarized in Table 1.[6]

Based on the theoretical discussion above regarding the VCs' investment experience, we hypothesize that VCs with larger investment experience tend to provide larger amounts of capitals. Thus, the first hypothesis we test is as follows:

[4] Since some of the VCs started their investment operations before the official established year, a small number of VC_AGE data show negative values.

[5] Still, there would be some concerns about the existence of omitted variables affecting both the VC characteristics (e.g., *VC_PRE_INV*) and *INV*. Unfortunately, the dataset used in this paper do not contain a comprehensive list of VC characteristics. Given this limitation, we control for VC-level unobservable fixed effect as mentioned later.

[6] Although we focus on the analysis associated with this *STOCK* variable accounting for the growth rate of stock indexes in this paper, it is a promising direction to employ other aggregate information including the volatility of *STOCK* to explicitly study the meaning of VC characteristics (e.g., the response of more experienced VCs to higher stock market uncertainty).

Hypothesis 1: VCs with a higher VC_PRE_INV provide larger amounts of capitals.

We also hypothesize that this mechanism is related to the condition of stock market, the dynamics of which is represented by JASDAQ index and TOPIX. On one hand, we presume that the mechanism hypothesized above is magnified (mitigated) when stock market is in downturn (upturn). This reflects the theoretical presumption that VCs with a smaller experience do not have sufficient funds to allocate to venture companies as macroeconomic conditions deteriorate. This could be the case, for example, if less experienced VCs' finance is adversely affected by macroeconomic condition as in the discussion for bank loan. On the other hand, according to the discussion in Gompers et al. (2008), exactly opposite result could be also predicted. In fact, if there is any chance that more experienced VCs crowd out less experienced VCs when observing positive (negative) signal from public equity market, more experienced VCs might increase (decrease) their investment than less experienced VCs. Thus, the second hypothesis could be as follows:

Hypothesis 2: The positive marginal impact of VC_PRE_INV becomes larger (smaller) when STOCK is lower (higher) if less experienced VCs' finance is adversely affected by macroeconomic condition. The positive marginal impact of VC_PRE_INV becomes smaller (larger) when STOCK is lower (higher) if more experienced VCs crowd out less experienced VCs.

A full list of variables used in our estimation, their definitions, and summary statistics is provided in Table 2.

4.2. Empirical Framework

The aim of our empirical study is to examine the marginal impact of (i) VC characteristics on VCs' capital supply and (ii) their interaction with the aggregate-level variables *STOCK*(*t*) while controlling for firm characteristics, including time-variant capital demand. For this purpose, we estimate equation (1) below. In this equation, we include unobservable time-variant individual effects $\eta(j,t)$ where subscript *j* denotes the venture company and *t* the year. Incorporating such a

time-variant individual effects into our analysis, we control for all venture company-year level variations, including, for example, venture companies' capital demand, changes in venture companies' investment opportunities, and changes in the availability of other financing measures (e.g., debt). $STOCK(t)$ denotes either (a) the growth rate of JASDAQ index or (b) that of TOPIX. To control for year-specific effects, we also include the yea-specific fixed-effect $YEAR(t)$ in this estimation. Since we include this year- effect, we cannot include $STOCK(t)$ on its own, but only in their interacted form.

$$\begin{aligned} INV(i,j,t) = \eta(j,t) + \beta_1 VC\_AGE(i,t) + \beta_2 VC\_PRE\_INV(i,t) + \beta_3 VC\_PRE\_COLL(i,t-1) \\ + \gamma_1 VC\_AGE(i,t) \times STOCK(t) + \gamma_2 VC\_PRE\_INV(i,t) \times STOCK(t) \\ + \gamma_3 VC\_PRE\_COLL(i,t-1) \times STOCK(t) + YEAR(t) + \varepsilon(i,j,t) \end{aligned} \quad (1)$$

For the last term in the equation $\varepsilon(i,j,t)$, we employ three alternative assumptions. The first is that $\varepsilon(i,j,t) \equiv \epsilon(t)$ is simply a random error. The second is that $\varepsilon(i,j,t) \equiv \delta(i) + \epsilon(t)$, where $\delta(i)$ is the VC-level fixed effect. This captures unobservable VC-specific time-invariant factors. As our data set contains limited information on VC characteristics, incorporating such factor might be preferable. Finally, as the most comprehensive model, we assume $\varepsilon(i,j,t) \equiv \delta(i,j) + \epsilon(t)$, where $\delta(i,j)$ is the venture company-VC match-level fixed effect. This captures unobservable venture company-VC relationship specific time-invariant factors. Controlling for such a match-level fixed effect is useful if some venture company and VCs have a special relationship that affects capital provision. An illustrative example includes the case that a venture company, which spins off from a larger listed firm, obtain capital from bank-dependent VCs, and the parent company of the VCs is the main lender bank for the listed firm. Note that when we control for $\delta(i,j)$, the VC-level fixed effect is automatically controlled for.

We include interaction terms between the aggregate-level variables (*STOCK*) and VCs' characteristics. The coefficients of these interaction terms capture how the marginal effects of VCs' characteristics vary as the aggregate-level variables change. For example, suppose the interaction term between *VC_PRE_INV* and *STOCK* has a negative coefficient, while *VC_PRE_INV* on its own

has a positive coefficient, which is actually the case we observe later. This means that VCs with a larger experience tend to provide more funds than VCs with a smaller experience, and this relationship is stronger when stock market is in its downturn.

To estimate this equation, we first eliminate the time-variant company-level individual effect $\eta(j,t)$ by taking the difference between *i*'s for the same *j* and *t*. Note that, in our analysis, we specifically focus on venture company obtaining capitals from multiple VCs. Suppose venture company *j* obtained capitals from a set of *I*(*j*,*t*) and a set of *I*(*j*,*t-1*) VCs at the end of year *t* and *t-1*, respectively. Then the number of VCs we use to estimate (1) for venture company i in year t is min{*I*(*j*,*t*), *I*(*j*,*t-1*)}. For these observations, we estimate the equation (2) below, which is indexed by (*i1*, *i2*, *j*, *t*). In this equation, $VC(i,t-1)$ represents the vector of VC *i*'s characteristics in year *t*. We estimate this equation under the three different assumptions for $\varepsilon(i,j,t)$ described above.

$$
\begin{aligned}
&INV(i1,j,t) - INV(i2,j,t) \\
&\quad = \boldsymbol{\beta}\{VC(i1,t) - VC(i2,t)\} \\
&\quad + \gamma_1\{VC\_AGE(i1,t) - VC\_AGE(i2,t)\} \times STOCK(t) \\
&\quad + \gamma_2\{VC\_PRE\_INV(i1,t) - VC\_PRE\_INV(i2,t)\} \times STOCK(t) \\
&\quad + \gamma_3\{VC\_PRE\_COLL(i1,t) - VC\_PRE\_COLL(i2,t)\} \times STOCK(t) \\
&\quad + \varepsilon(i1,j,t) + \varepsilon(i2,j,t) \qquad (2)
\end{aligned}
$$

In the next section, we show the estimation results based on the model and discuss the implication of the results. Our main interest is in the signs of $\boldsymbol{\beta}$ and $\{\gamma_1, \gamma_2, \gamma_3\}$.

5. Estimation Results

5.1. Baseline Estimation Results

The baseline results of our empirical analysis are presented in Tables 3 and 4. Each table has three columns corresponding to the three alternative assumptions for $\varepsilon(i,j,t)$. The results in column (i) are for the assumption that $\varepsilon(i,j,t) \equiv \epsilon(t)$, those in column (ii) for the assumption that $\varepsilon(i,j,t) \equiv \delta(i) + \epsilon(t)$, and those in column (iii) for the assumption that $\varepsilon(i,j,t) \equiv \delta(i,j) + \epsilon(t)$.

In all the estimations, we run the regression using the equation (2) introduced above. More specifically, when we assume $\varepsilon(i,j,t) \equiv \epsilon(t)$, we run a pooled ordinary least squares (OLS) regression, while we include the two bank-level fixed effects for banks *i1* and *i2* in the case of $\varepsilon(i,j,t) \equiv \delta(i) + \epsilon(t)$. When we assume $\varepsilon(i,j,t) \equiv \delta(i,j) + \epsilon(t)$, we employ a fixed-effect panel estimation with (*i1, i2, j*)-level fixed effects.

Table 3 shows the results when using the growth rate of JASDAQ index for $STOCK(t)$. First, consistent with Hypothesis 1, VCs with a larger investment experience tend to provide larger amounts of capitals to their portfolio companies. In particular, the results in column (ii) and (iii) imply that even after taking into account VC-level or venture company-VC relationship-specific factors such as the pre-investment relationship between the parent firms of the venture company and the bank from which the VC obtain the source of funds, we find the same systematic pattern that VCs with a large investment experience tend to provide more than VCs with a smaller experience. We also find that VCs that had worked with a larger number of other VCs in previous investments tend to provide smaller amounts of loans. The latter result implies that working with various VCs is not necessarily leads to larger fund provision but rather reflect the tendency for the VCs to diversify their investments through co-investments.

Second, the results for the coefficients on the interaction term between VC characteristics and *STOCK* indicate that the positive marginal impact of VCs' experience (*VC_PRE_INV*) becomes smaller when *STOCK* is higher, suggesting that the first part of Hypothesis 2 is supported. In other words, the marginal impact of VCs' experience on capital supply becomes larger when stock market is in downturn. This may reflect the fact that VCs with a smaller experience do not have sufficient funds to allocate to venture companies when stock market is in downturn. Note that as we can observe from the results in Tables 4, which corresponds to the case using the growth rate of TOPIX for $STOCK(t)$, these results are fairly robust to the use of alternative measures of $STOCK(t)$.

Figure 3 depicts this pattern by using the results of subsample period analyses. To construct this figure, we split the sample into eight subsamples consisting of 1995-97, 1998-99, 2000-02, 2003-05, 2006-08, 2009-10, 2011, and 2012 each of that corresponds to the set of consecutive year(s) experiencing all the positive or negative growth in JASDAQ index. Then, we

estimate the equation (2) with the assumption (i) on the error term without the cross term between VC characteristics and STOCK, and depict the estimated coefficient associated with *VC_PRE_INV* with its 95% confidence band. The bar chart measured in the right axis shows the growth rate of JASDAQ index corresponding to each period. The figure shows, first, during the so-called "dotcom bubble" around 1998-99, the marginal impact associated with VC_PRE_IV became substantially smaller than the previous period 1995-97, which was followed by the large hike in 2000-02 after the bust of the bubble. Second, during the expansion period during the early 2000s, the marginal impact again decline. Third, after market participants observed so-called "Livedoor shock" in 2006, which is one of the biggest scandal issue in Japanese emerging market, the coefficient associated with *VC_PRE_INC* has been constantly increasing. All of these results are consistent with the ones we presented in the previous section.[7]

Let us consider the quantitative implications of these results. Specifically, let us focus on the results for the baseline model (i.e., the third column in Table 3). The coefficient on *VC_PRE_INV* in this estimation is 0.5824 and that on the interaction term of *VC_PRE_INV* and *STOCK* is -0.0012. Suppose that the hypothetical past investment experience of *VC i* for venture company *j* increases by one standard deviation (i.e., 2.01) in year *t* and that stock market it in zero growth in year *t*. Given the estimated parameters, the model predicts that $INV(i,j,t)$ will increase by $0.5824 \times (2.01) = 1.17$ than in the case that VC experience stays in a same level as before. Considering that the standard deviation of $INV(i,j,t)$ is 1.64, this implies that VC experience has an economically sizable impact on capital provision. Next, suppose that the stock market is in boom (i.e., *STOCK*=213.1 as in 1999) in year *t*. Assuming again a one-standard deviation decline in *VC_PRE_INV*, $INV(i,j,t)$ will increase by $0.5824 \times (2.01) + (-0.0012) \times (2.01) \times (213.1) = 0.66$ compared to the absence of an increase in VC experience. Thus, the impact of VC experience becomes around half when stock market is in boom when compared with the case of zero growth in stock market. This means that under a great upturn (downturn) in stock market, the impact of VCs'

[7] The change in *STOCK* might be somehow correlated with the investment rounds. If investment rounds under market downturn are, for example, concentrated on the later stage where only the VCs with previous investments in the early rounds can invest, we might have a positive coefficient of the interaction between *VC_PRE_INV* and *STOCK*. If this is the case, the obtained results are not necessarily supporting our theoretical explanation. But, since the correlation coefficient between the growth rate of JASDAQ index and the investment rounds of each observation is -0.0095, we assume that we can ignore such a concern.

investment experience becomes smaller (larger).

5.2. Subsample Analysis

In this section, we apply the same model as in the previous section to various subsamples. The purpose of this additional analysis is to compare the magnitude of the estimated coefficients between two sets of venture companies with different characteristics and investment rounds hence consider the mechanisms governing capital provision in more detail.

In our first subsample analysis summarized in Table 5, we divide venture companies by four industry focuses, which consist of internet, financial, electronics, and pharmaceutical, based on the industry classification of venture companies stored in JVR database. The results that all the results support Hypothesis 1 while the first statement of Hypothesis 2 is supported only by the sample of internet and pharmaceutical. Given that *VC_PRE_INV* proxies for VCs' investment experience, this result implies that such an experience matters more in some specific industries.

Next, we divide our observations into two subsamples based on the investment rounds (i.e., 1st to 3rd round vs. the latter stages). The results are shown in Table 6. We find that the results in the baseline estimation are obtained only for the early rounds. Again, this result implies that VCs' experience matters more in the phase under some specific environment. More precisely, the financial constraints faced by less experienced VCs under market downturn seems to matter more for the investment in the early round where the investment is more risky than the later rounds.

5.3. Endogeneity Bias

The central motivation of this paper is to examine the role of VCs' investment experience and its interaction with the dynamics of public equity market through the empirical analysis properly controlling for venture companies' capital demand by incorporating firm-level time-variant individual effect in our estimation. This approach reflects a premise that omitting such a demand factor leads to biased estimates.

Given this motivation, we estimate the following equation (3), which does *NOT* include the venture company-level time-variant individual effect $\eta(j,t)$ used in the equation (1). Since our

dataset contains only a limited number of company characteristics, omitting the time-variant effect is expected to inevitably generate bias to our estimation. The purpose of this section is to compare the estimates obtained from this "false" model with that in Table 3 so that we can discuss the consequence of not properly controlling for fund demand.

$$\begin{aligned} INV(i,j,t) = {} & \beta_1 VC\_AGE(i,t) + \beta_2 VC\_PRE\_INV(i,t) + \beta_3 VC\_PRE\_COLL(i,t-1) \\ & + \gamma_1 VC\_AGE(i,t) \times STOCK(t) + \gamma_2 VC\_PRE\_INV(i,t) \times STOCK(t) \\ & + \gamma_3 VC\_PRE\_COLL(i,t-1) \times STOCK(t) \\ & + YEAR(t) + \tilde{\varepsilon}(i,j,t) \end{aligned} \quad (3)$$

For the last term in the equation, $\tilde{\varepsilon}(i,j,t)$, we employ four alternative assumptions. The first is that $\tilde{\varepsilon}(i,j,t) \equiv \epsilon(t)$ is a random error. The second is that $\tilde{\varepsilon}(i,j,t) \equiv \eta(j) + \epsilon(t)$, where $\eta(j)$ is the venture company-level fixed effect. This captures unobservable company-specific time-invariant factors. Since we do not have a set of precise company characteristics, which we can use to control for companies' observable as in, for example, Hosono and Miyakawa (2014), it is crucial to control for this unobservable factor. The third is that $\tilde{\varepsilon}(i,j,t) \equiv \delta(i) + \epsilon(t)$, where $\delta(i)$ is the VC-level fixed effect. Fourth and finally, for the most comprehensive model, we assume $\tilde{\varepsilon}(i,j,t) \equiv \delta(i,j) + \epsilon(t)$, where $\delta(i,j)$ is the venture company-VC match fixed effect. As we mentioned above, when we control for $\delta(i,j)$, the VC-level fixed effect is automatically controlled for.

Table 7 summarizes the estimate results. First, the positive impact associated with VCs' investment experience on their fund provision are obtained as in Table 3. However, the size of the coefficient is almost double to that in Table 3. This means that the bias gives rise to a substantial overestimation of the economic impact of the VCs' investment experience. This could be the case, for example, when the impact of missed fund demand is positively correlated with the dependent variable $INV(i,j,t)$ and the correlation between such fund demand and VCs' investment experience is indeed positive. While the first condition is easily expected to be met since higher fund demand naturally leads to larger realized VC investment, the plausibility of the second condition

rests on an additional discussion. Suppose more experienced VCs can more easily access to deal flows than VCs with smaller experience due to, for example, their broader network (Hochberg et al. 2007). Under this environment, venture companies' fund demand could be positively correlated with VCs' investment experience. The comparison between the results in Table 7 and our baseline results (Table 3) suggest that such a correlation might actually exist.

Second, as more important result, unlike the results in Table 3, the coefficient associated with the interaction term between VCs' investment experience and the growth rate of stock index is not statistically different from zero in Table 7. This means, again, the bias gives rise to a substantial overestimation of the economic impact associated with the interaction term between VCs' investment experience and the dynamics of public equity market. This could be the case, for example, when the fund demand, which is omitted in the estimation of (3), is positively correlated with the dependent variable $INV(i,j,t)$ and the correlation between such fund demand and the interaction term (i.e., $VC\_PRE\_INV \times STOCK$) is positive. The latter condition could be met if the tendency of more experienced VCs easily accessing to venture companies with larger fund demand becomes higher during the boom in stock market.

The latter result is somewhat consistent with the finding in Gompers et al. (2008) that "*…the industry investment activity of more experienced venture capital firms is more sensitive to Q (Tobin's Q measured in industry-level) than it is for less experienced venture capital firms*" (pp. 13). One important implication obtained in the present paper is, however, that once we properly control for fund demand by incorporating the venture company-level time-variant individual effect, such a pattern is reversed. This difference tells that although venture companies with higher fund demand are likely to be funded by more experienced VCs when stock market is in boom, VCs with less investment experience in fact increase their fund supply more than VCs with more experience under such a boom in stock market. Presumably, higher funding availability faced by low experienced VCs generates the latter result.

These results provide a complemental view to that in Gompers et al. (2008). Namely, under the boom in stock market, not only the experienced VCs increase their fund provision due to the larger deal flows (i.e., demand-driven), which generates the positive correlation between higher

fund demand and the more experience VCs, but also the less experienced VCs increase fund provision due to less financial constraint (i.e., supply-driven), both of which result in the observed high volatility in the aggregated venture capital investments. Suppose, contrary to the case mentioned above, public equity market is in downturn. Then, both the more and less experienced VCs decrease their fund provision. An important implication obtained in the present paper is that the sources of the declines in fund provision by more and less experienced VCs should be treated differently.

The abovementioned result has an important policy implication. First, fostering more experienced VCs could lead to more stable VC investments. In fact, the decline of investment by more experienced VCs under market downturn is not the consequence of financial friction but natural reaction to smaller fund demand. According to our empirical results, it is less experienced VCs which magnify the investment fluctuation under market upturn and downturn. This also means that inducing more experienced VCs to provide larger amount of funds under market downturn, for example through policy supports, could lead to substantial resource misallocation. Second, contrary to such an implication associated with more experienced VCs, it could be effective from policy perspective to provide financial supports to less experienced VCs under market downturn. This is because the reason such less experienced VCs reduce investment under market downturn is mainly financial constraint faced by these VCs.

6. Conclusion

This paper examines the impact of VCs' characteristics on their capital supply and how such an impact is interacted with aggregate shocks. The estimation results indicate that VCs with more investment experiences tend to supply more capital to their portfolio companies. Furthermore, the quantitative impact of VCs' experience on the capital supply became larger when stock market was in its downturn. Overall, these results imply that past investment experience is one important measure of VCs' ability to provide capital and the magnitudes are interacted with the stock market condition.

The research presented in this study could be expanded in a number of directions. One such direction would be to extend our analysis to examine various firm dynamics such as capital investments, R&D activities, and productivity. Second, complementing the discussion in the present study by including the explicit evaluation of the consequences of VCs' investment would be a promising direction of future research. For this purpose, it is also important to measure VC characteristics by using other metrics including the number of investments, the number of established IPOs and M&A, and the amounts or numbers of investments in early stage of venture companies' financing. A further potentially interesting extension would be to model not only the capital supply but also the capital demand. Since the dataset used in our study contain the price information of each investment (i.e., purchased share price for each investment), it is potentially possible to estimate the fund demand and supply system. We believe all of these extensions would provide further insights to gain a better understanding of the venture companies' financing and VCs' capital provision mechanism.

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Figure 1: VC Investment Flows in Japan

The horizontal axis represents the corresponding fiscal year to each data point, while the vertical axis shows the aggregate value of 101 Japanese VCs investments. The data is taken from the survey result summarized in the “Fact Book” 2014 publsihed by Venture Enterprise Center (http://www.vec.or.jp).

Figure 2: Number of IPOs in Japan

The figure shows the annual number of IPOs in Japan from 1996 to 2011. From 2001, IPOs are broken down into those with and without the backing of VC firms.

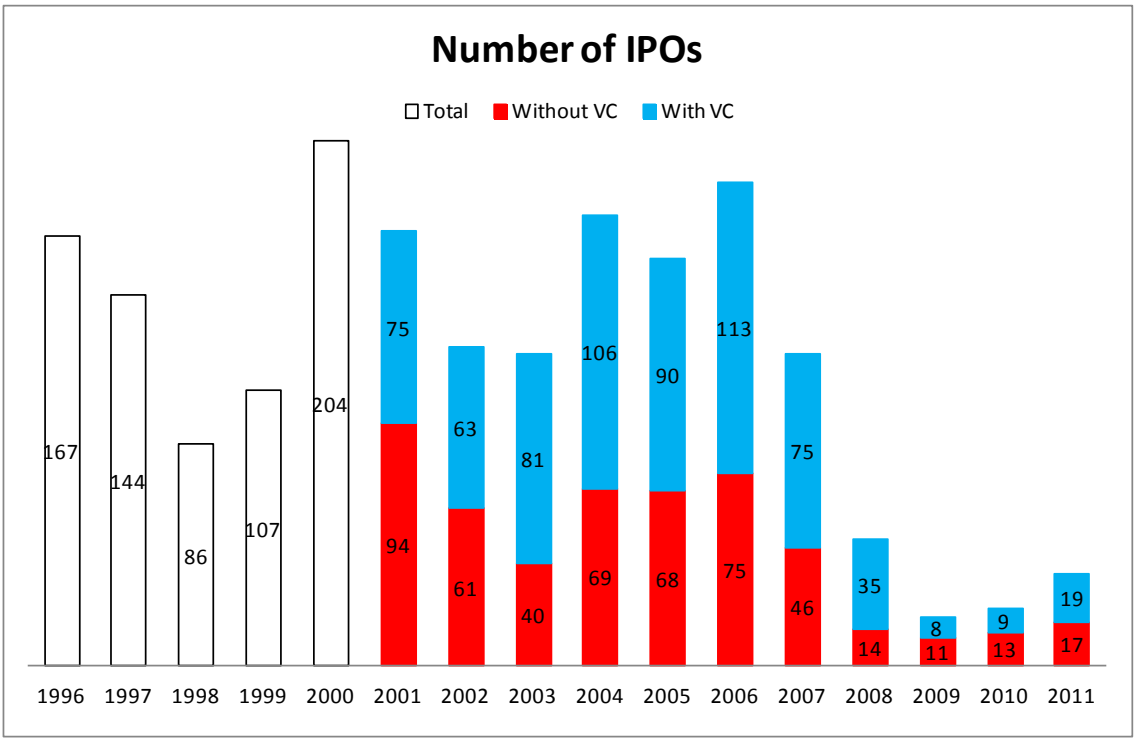

Figure 3. Estimated Coefficient of VC_PRE_INV over Sub-Periods

The figure shows the change in the coefficient associated with VC_PRE_INV over sub-periods.

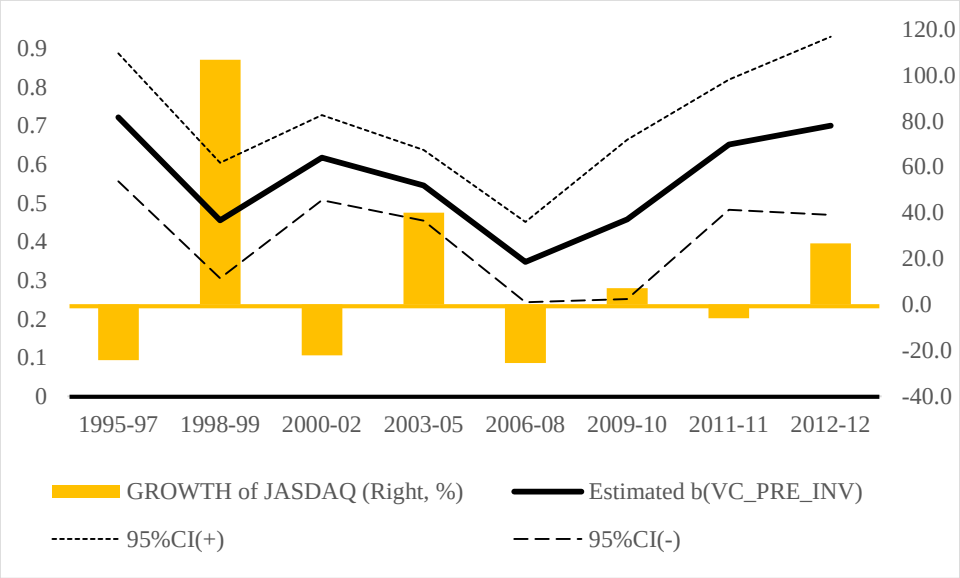

Table. 1 Aggregate-Level Variables (STOCK)

FY	Growth Rate of JASDAQ Index (%)	Growth Rate of TOPIX (%)
1991	n.a.	-3.6
1992	n.a.	-26.4
1993	n.a.	2.9
1994	22.7	13.2
1995	-16.2	0.7
1996	-10.6	-2.6
1997	-45.8	-21.2
1998	0.5	-9.3
1999	213.1	36.8
2000	-45.3	-27.2
2001	-8.4	-23.5
2002	-12.9	-18.6
2003	42.9	24.5
2004	22.6	7.6
2005	54.9	40.2
2006	-21.0	6.9
2007	-18.6	-11.1
2008	-36.9	-42.1
2009	7.8	19.0
2010	6.6	-3.0
2011	-6.0	-17.3
2012	19.8	22.9
2013	45.3	56.7
2014	15.1	6.6

Table 2. Summary Statistics

This table shows the summary statistics for the variables we use in the regression analysis.

Variable		Definition	Obs.	Mean	Std. Dev.	Min.	Max.
INV	(i) Computed over all company-VC matches and years	Amount of funds invested by VC-i to Company-j in yeat t (log value)	6,135	9.90	1.64	0.00	17.40
VC_AGE		Each year minus VC-i's established year	5,560	15.41	11.88	-12	83
VC_PRE_INV		Accumulated amount of funds invested by VC-i prior to year t (log value)	6,160	14.13	2.01	4.61	17.84
VC_PRE_COLL		Accumulated number of collaborated VCs for VC-i prior to year t (log value)	6,161	3.88	1.77	0.00	6.86
VC_AGE ×STOCK(t)	(ii) Computed over the matches with JASDAQ Index data available	VC_AGE times the growth rate of JASDAQ index	5,553	246.99	1214.75	-2,344.00	7,672.00
VC_PRE_INV ×STOCK(t)		VC_PRE_INV times the growth rate of JASDAQ index	6,153	191.69	882.16	-745.00	3,521.00
VC_PRE_COLL ×STOCK(t)		VC_PRE_COLL times the growth rate of JASDAQ index	6,154	49.38	244.82	-263.00	1,104.00
VC_AGE ×STOCK(t)	(iii) Computed over the matches with MOTHERS Index data available	VC_AGE times the growth rate of TOPIX	5,560	30.25	508.60	-1,896.00	1,690.00
VC_PRE_INV ×STOCK(t)		VC_PRE_INV times the growth rate of TOPIX	6,160	0.93	371.50	-748.00	708.00
VC_PRE_COLL ×STOCK(t)		VC_PRE_COLL times the growth rate of TOPIX	6,161	1.31	111.14	-286.00	266.00

Table 3. Baseline Estimation Results

This table shows the estimation results for equation (2). ***, **, and * indicate significance at the 1, 5, and 10% level, respectively.

	All Sample with respect to Growth Rate of JASDAQ Index					
	STOCK = Growth Rate of JASDAQ Index					
Dependent Variable:	(i)		(ii)		(iii)	
INV(t)	Coef.	SD	Coef.	SD	Coef.	SD
VC_AGE(t)	-0.0002	0.0018	-0.0018	0.0025	-0.0038	0.0028
VC_PRE_INV(t)	0.5425	0.0267 ***	0.5337	0.0335 ***	0.5824	0.0396 ***
VC_PRE_COLL(t)	-0.5836	0.0310 ***	-0.5789	0.0407 ***	-0.6506	0.0482 ***
VC_AGE×STOCK(t)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
VC_PRE_INV×STOCK(t)	-0.0007	0.0004 *	-0.0009	0.0004 **	-0.0012	0.0005 **
VC_PRE_COLL×STOCK(t)	0.0007	0.0005	0.0011	0.0006 *	0.0014	0.0006 **
CONSTANT	0.2510	0.1565	2.0759	5.0220	3.0257	11.8345
Number of Obs.	5,158					
F-Value	76.51		2.07		0.87	
Prob > F	0.0000		0.0000		0.9985	
R-Squared	0.0818		0.1413		0.1943	
Year Effect	Yes		Yes		Yes	
Company Time-Variant FE	Yes		Yes		Yes	
VC-Level Time-Invariant FE	No		Yes		Yes	
Match-Level Time-Invariant FE	No		No		Yes	

Table 4. Alternative Measure for STOCK(t)

This table shows the estimation results for equation (2). ***, **, and * indicate significance at the 1, 5, and 10% level, respectively.

	All Sample with respect to Growth Rate of TOPIX					
	STOCK = Growth Rate of TOPIX					
Dependent Variable:	(i)		(ii)		(iii)	
INV(t)	Coef.	SD	Coef.	SD	Coef.	SD
VC_AGE(t)	0.0003	0.0017	-0.0014	0.0025	-0.0034	0.0028
VC_PRE_INV(t)	0.5332	0.0260 ***	0.5207	0.0327 ***	0.5641	0.0386 ***
VC_PRE_COLL(t)	-0.5760	0.0302 ***	-0.5664	0.0401 ***	-0.6316	0.0472 ***
VC_AGE×STOCK(t)	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001
VC_PRE_INV×STOCK(t)	-0.0023	0.0010 **	-0.0021	0.0011 *	-0.0032	0.0013 **
VC_PRE_COLL×STOCK(t)	0.0022	0.0012 *	0.0024	0.0013 *	0.0034	0.0015 **
CONSTANT	0.2589	0.1563 *	2.0444	5.0208	3.0257	11.8279
Number of Obs.	5,167					
F-Value	76.1		2.06		0.86	
Prob > F	0.0000		0.0000		0.9987	
R-Squared	0.0813		0.1404		0.1936	
Year Effect	Yes		Yes		Yes	
Company Time-Variant FE	Yes		Yes		Yes	
VC-Level Time-Invariant FE	No		Yes		Yes	
Match-Level Time-Invariant FE	No		No		Yes	

Table 5. Subsample Analysis: Venture Company Focus

This table shows the estimation results for equation (2). ***, **, and * indicate significance at the 1, 5, and 10% level, respectively.

	Panel A: All Sample with respect to Growth Rate of JASDAQ Index							
	STOCK = Growth Rate of JASDAQ Index							
Dependent Variable:	(i) Internet		(ii) Financial		(iii) Electronics		(iv) pharmaceutical	
INV(t)	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD
VC_AGE(t)	-0.0002	0.0032	-0.0178	0.0146	-0.0076	0.0055	-0.0119	0.0070 *
VC_PRE_INV(t)	0.6381	0.0519 ***	0.4927	0.1727 ***	0.4772	0.0914 ***	0.5288	0.0912 ***
VC_PRE_COLL(t)	-0.6826	0.0599 ***	-0.4729	0.2104 **	-0.5104	0.0968 ***	-0.5013	0.1016 ***
VC_AGE×STOCK(t)	0.0000	0.0000	0.0007	0.0004	0.0001	0.0001 *	0.0001	0.0001
VC_PRE_INV×STOCK(t)	-0.0013	0.0006 **	-0.0075	0.0046	-0.0017	0.0018	-0.0025	0.0013 *
VC_PRE_COLL×STOCK(t)	0.0014	0.0008 *	0.0086	0.0057	0.0025	0.0022	0.0015	0.0019
CONSTANT	0.0727	0.2959	0.7779	0.8610	0.5130	0.4980	0.0607	0.6013
Number of Obs.	1,761		182		264		491	
F-Value	27.81		2.88		7.22		8.21	
Prob > F	0.0000		0.0107		0.0000		0.0000	
R-Squared	0.0869		0.0898		0.1443		0.0924	
	Panel B: All Sample with respect to Growth Rate of TOPIX							
	STOCK = Growth Rate of TOPIX							
Dependent Variable:	(i) Internet		(ii) Financial		(iii) Electronics		(iv) pharmaceutical	
INV(t)	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD
VC_AGE(t)	0.0003	0.0034	-0.0093	0.0128	-0.0048	0.0054	-0.0119	0.0069 *
VC_PRE_INV(t)	0.6109	0.0511 ***	0.4743	0.1730 ***	0.4900	0.0917 ***	0.5139	0.0933 ***
VC_PRE_COLL(t)	-0.6531	0.0603 ***	-0.4842	0.2112 **	-0.5291	0.0983 ***	-0.4948	0.0989 ***
VC_AGE×STOCK(t)	0.0000	0.0001	0.0007	0.0006	-0.0001	0.0002	0.0002	0.0003
VC_PRE_INV×STOCK(t)	-0.0014	0.0019	-0.0136	0.0073 *	0.0010	0.0043	-0.0049	0.0032
VC_PRE_COLL×STOCK(t)	0.0018	0.0022	0.0151	0.0090 *	0.0003	0.0043	0.0037	0.0033
CONSTANT	0.0880	0.2955	0.8083	0.8629	0.5727	0.5017	0.0623	0.6022
Number of Obs.	1,767		182		264		491	
F-Value	26.79		2.72		6.42		7.97	
Prob > F	0.0000		0.015		0.0000		0.0000	
R-Squared	0.0837		0.0853		0.1303		0.090	
Year Effect	Yes		Yes		Yes		Yes	
Company Time-Variant FE	Yes		Yes		Yes		Yes	
VC-Level Time-Invariant FE	No		No		No		No	
Match-Level Time-Invariant FE	No		No		No		No	

Table 6. Subsample Analysis: Investment Rounds

This table shows the estimation results for equation (2). ***, **, and * indicate significance at the 1, 5, and 10% level, respectively.

	Panel A: All Sample with respect to Growth Rate of JASDAQ Index			
	STOCK = Growth Rate of JASDAQ Index			
Dependent Variable:	(i) Invest Round <= 3		(ii) Invest Round > 3	
INV(t)	Coef.	SD	Coef.	SD
VC_AGE(t)	-0.0009	0.0019	0.0003	0.0033
VC_PRE_INV(t)	0.5446	0.0321 ***	0.5444	0.0437 ***
VC_PRE_COLL(t)	-0.6353	0.0369 ***	-0.5390	0.0518 ***
VC_AGE×STOCK(t)	0.0000	0.0000	0.0001	0.0001 *
VC_PRE_INV×STOCK(t)	-0.0013	0.0004 ***	0.0009	0.0008
VC_PRE_COLL×STOCK(t)	0.0015	0.0005 ***	-0.0009	0.0010
CONSTANT	0.6563	0.1777 ***	-0.1957	0.2718
Number of Obs.	2,854		2,304	
F-Value	58.04		29.77	
Prob > F	0.0000		0.0000	
R-Squared	0.1090		0.0721	

	Panel B: All Sample with respect to Growth Rate of TOPIX			
	STOCK = Growth Rate of TOPIX			
Dependent Variable:	(i) Invest Round <= 3		(ii) Invest Round > 3	
INV(t)	Coef.	SD	Coef.	SD
VC_AGE(t)	-0.0005	0.0018	0.0011	0.0033
VC_PRE_INV(t)	0.5225	0.0308 ***	0.5529	0.0430 ***
VC_PRE_COLL(t)	-0.6110	0.0357 ***	-0.5513	0.0508 ***
VC_AGE×STOCK(t)	-0.0001	0.0001	0.0001	0.0001
VC_PRE_INV×STOCK(t)	-0.0044	0.0012 ***	0.0008	0.0017
VC_PRE_COLL×STOCK(t)	0.0043	0.0014 ***	-0.0007	0.0019
CONSTANT	0.6615	0.1772 ***	-0.1897	0.2718
Number of Obs.	2,862		2,305	
F-Value	58.29		29.16	
Prob > F	0.0000		0.0000	
R-Squared	0.1091		0.0708	
Year Effect	Yes		Yes	
Company Time-Variant FE	Yes		Yes	
VC-Level Time-Invariant FE	No		No	
Match-Level Time-Invariant FE	No		No	

Table 7. Endogeneity Bias

This table shows the estimation results for equation (3). ***, **, and * indicate significance at the 1, 5, and 10% level, respectively.

	All Sample with respect to Growth Rate of JASDAQ Index							
	STOCK = Growth Rate of JASDAQ Index Without controlling form time-variant firm individual effect							
Dependent Variable:	(i)		(ii)		(iii)		(iv)	
INV(t)	Coef.	SD	Coef.	SD	Coef.	SD	Coef.	SD
VC_AGE(t)	0.0020	0.0022	0.0000	0.0021	-0.0021	0.0196	-0.0044	0.0242
VC_PRE_INV(t)	0.6838	0.0280 ***	0.5656	0.0294 ***	1.0048	0.0808 ***	1.0284	0.0956 ***
VC_PRE_COLL(t)	-0.7292	0.0346 ***	-0.5741	0.0351 ***	-1.2021	0.1103 ***	-1.1906	0.1325 ***
VC_AGE×STOCK(t)	0.0001	0.0000 *	0.0001	0.0000 *	0.0001	0.0000 *	0.0001	0.0000
VC_PRE_INV×STOCK(t)	0.0005	0.0004	0.0000	0.0004	0.0008	0.0005	0.0008	0.0005
VC_PRE_COLL×STOCK(t)	-0.0005	0.0006	0.0000	0.0005	-0.0006	0.0006	-0.0006	0.0007
CONSTANT	1.3995	0.8902	4.1342	0.8786 ***	-0.6094	1.0607	-2.4314	1.6123
Number of Obs.	5,523							
F-Value	46.26		6.47		4.93		1.62	
Prob > F	0.0000		0.0000		0.0000		0.0000	
R-Squared	0.1619		0.5177		0.2074		0.2711	
Year Effect	Yes		Yes		Yes		Yes	
Company Time-Invariant FE	No		Yes		No		Yes	
VC-Level Time-Invariant FE	No		No		Yes		Yes	
Match-Level Time-Invariant FE	No		No		No		Yes	