Industry Technological Changes, Venture Capital Incubation, and Post-IPO Firm Innovation and Performance

Scott H.C. Hsu
University of Wisconsin Milwaukee

Abstract

This paper examines the determinants of the length of the venture capital incubation period and its impact on the post-IPO innovation and performance of investee firms. Venture capitalists (VCs) shorten incubation periods and take firms public when the industry shows rapid technological changes; further, firms with longer incubation periods earn more patents, are more likely to survive, and exhibit better performance after their IPOs. Incubation period effects on post-IPO firm performance are robust after controlling for incubation-period endogeneity. Finally, firms financed by more experienced VCs earn more post-IPO patents. The findings provide new evidence of interactions between financial and product markets, and support the value-creating role of VCs.

Venture capital has been the primary financing mode for startup firms in high-tech sectors and helps spur innovations in the economy (Kortum and Lerner (2000)). Yet similar to the risky nature of its investments, the venture capital (VC) industry is volatile in terms of its funding flows and the number of investments it initiates and exits (Gompers et al. (2008), Puri and Zarutskie (2008), Lerner (1994)). According to the literature, equity market conditions determine fluctuations of VC industries,[1] yet little is known about whether changes in industry fundamentals, such as technological changes, can explain fluctuations of VC activities.[2] VCs closely follow the technology and market developments in industries in which they specialize (Fenn, Liang, and Prowse (1995), Hellmann and Puri (2000)), so they may be aware of and adapt to changes in industries fundamentals by initiating or exiting their investments accordingly.

In this paper, I examine whether industry-specific technological change affects the timing of VC-backed initial public offerings (IPOs) by studying the effect on the length of time VCs remain invested before the IPO. I call this measure the VC incubation period. Technological changes provide a good setting for examining how changes in industry fundamentals affect the timing of VC-backed IPOs. First, technology constitutes an integral part of VC-backed firms that mostly cluster in high-tech industries (Kaplan, Sensoy, and Stromberg (2009)). Second, the timing and success of IPOs often depend on the industry technological environment (Maksimovic and Pichler (2001)). Technological changes may cause greater uncertainties and generate higher subsequent market returns (Pastor and Veronesi (2005), Hsu (2008)), so VCs may take firms public in response to high technological advances to realize higher gains.

[1] For example, Gompers et al. (2008) and Puri and Zarutskie (2008) find that VCs increase their investments, which create more new firms, when public market signals are favorable. Furthermore, VCs tend to exit their investments by taking firms public at stock market peaks (Lerner (1994), Cumming and McIntosh (2001), Giot and Schwienbacher (2007), Hochberg et al. (2008)).

[2] The notable exceptions are Gompers et al. (2008), who find that changing public market signals reflect changes in industry fundamentals. Gompers and Lerner (1998) also show that fund-raising activities depend on the level of R&D expenditures in some industries.

Technological changes also may indicate positive productivity shocks that cause firms to go public, whether because of the lower information production cost of going public (Chemmanur and Fulghieri (1999)) or to avoid a higher rent extracted by VCs (Michelacci and Suarez (2004)).

Using the annual change in industry patenting as a proxy for industry technological changes,[3] I study the length of the VC incubation period of a sample of 1,755 VC-backed firms that went public from 1980 to 2004. The length of the VC incubation period decreases when the industry shows more technological changes, and these results are robust even when I control for factors such as equity market conditions and other industry characteristics.

After investigating the effect of industry technological changes on the length of the incubation period, I consider whether going public earlier or later benefits VC-backed firms after their IPOs; that is, do firms with a longer incubation period enjoy better post-IPO performance? Existing literature suggests a link between an earlier or later IPO decision and post-IPO firm performance (Jovanovic and Rousseau (2001)). In the context of VC-backed firms, VCs engage in value-creating activities that help the businesses they finance, including active participation (Bottazzi, Da Rin, and Hellman (2008)), monitoring, capital infusion (Gompers (1995)), and membership on boards (Lerner (1995)). Therefore, firms with a longer incubation period may improve their post-IPO performance due to close monitoring and mentoring by VCs for a longer time. Alternatively, firms with shorter incubation times may represent better investment choices by VCs and thus achieve better post-IPO performance.

To test the effect of a longer incubation period on VC-backed firm performance after their IPOs, I study the effect on firms' post-IPO patenting, performance, and survival. Patents represent the realization of firms' R&D activities and long-term investments (Lerner, Sorensen,

[3] Change in patenting is a measure that appears in other studies to proxy for technological changes. For example, Hsu (2008) uses annual log differences in patenting and finds that technological shocks help explain aggregate stock market premiums.

and Stromberg (2008)). Because most VC-backed firms engage in intensive R&D activities, patents should be considered in overall performance assessments. Moreover, patents appear increasingly important to the business of VC-backed firms (Kaplan, Sensoy, and Stromberg (2009)). Finally, more patents indicate greater stock market value (Hall, Jaffe, and Tratjenberg (2005), Rossi (2006)). I find that firms with a longer VC incubation period earn more patents, are more likely to survive, and exhibit better industry-adjusted operating performance and market-to-book ratios after IPO. These findings are robust, even when I control for incubation period endogeneity, different sources of survivorship bias, and the pre-VC-investment firm maturity,.

The incubation period effect also may depend on heterogeneity among VC investors. Experienced VCs benefit their portfolio firms (Hsu (2004), Gompers et al. (2008), Bottazzi, Da Rin, and Hellmann (2008), among others), but little is known about whether experienced VCs help these firms innovate. This study shows that VC experience positively affects post-IPO patented innovations, such that firms financed by more experienced VCs earn more patents after their IPO. Furthermore, I find a stronger incubation period effect on post-IPO patenting for firms receiving financing from more experienced VCs, but the incubation period effect per se is still robust to controlling for the experience of VCs.

This study therefore offers several key contributions. First, I shed light on the interactions between financial and product markets by presenting new evidence that the timing of VC-backed IPOs depends on changes in industry fundamentals, such as technological changes. Second, this article extends existing literature pertaining to the timing of IPOs by investigating the implications of an early versus a late IPO decision on firm performance after the IPO. In particular, I introduce an aspect of the potential trade-offs of an early versus late IPO decision, i.e., the length of time firms incubated by specialized investors such as VCs. This finding

provides an explanation for the cross-sectional differences in firm performance following IPOs. Third, this paper adds to research on the value-creation role of VCs (Gompers (1995), Lerner (1995), Casamatta (2003), Kaplan and Stromberg (2004)). Most literature in this vein examines the effect of VC heterogeneity (such as the experience of VCs) on the successful exits of their investments[4]. In contrast to these studies, using various performance measures, this study demonstrates the positive "duration effect" of VCs on their portfolio firms in addition to VC investor heterogeneities. This incubation period effect does not seem to result from underlying firm quality. Fourth, this study contributes to literature that links VCs to patented innovation. Prior literature finds that firms earning more patents are more likely to obtain VC funding (Hellmann and Puri (2000)) and that VCs spur patenting in the industry level (Kortum and Lerner (2000)). In contrast, the present study finds that firms with a longer VC incubation period and/or receiving financing from more experienced VCs earn more patents after their IPO.

The remainder of this paper is organized as follows: Section I briefly reviews related literature. Section II describes the data, sample, and main variables used in this study. In Section III, I discuss the empirical findings, including how industry technological changes affect the length of the VC incubation period and its effect on post-IPO firm performance. Section IV performs further robustness checks. Section V concludes the paper.

I. Literature Review

Theoretical research considers the best sequence of financing for startup firms. For example, Chemmanur and Fulghieri (1999), Myers (2000), and Maksimovic and Pichler (2001) show that firms with high research intensities should first obtain private financing, then go

[4] A notable exception is Ivanov et al. (2008), who investigates the effect of VC reputation on different post-IPO performance measures.

public. After obtaining VC financing, the timing of the IPO depends on various factors, including competitive risks (Maksimovic and Pichler (2001)), information production costs (Chemmanur and Fulghieri (1999)), and returns for the VCs (Inderst and Muller (2004), Michelacci and Suarez (2004)). Furthermore, stock markets and/or industry conditions can influence these factors and therefore the timing of IPOs.

Empirical literature shows strong evidence that stock market valuations affect the timing of VC-backed IPOs (Lerner (1994), Cumming and McIntosh (2001), Giot and Schwienbacher (2007), Hochberg et al. (2008)). Yet Chemmanur, Nandy, and He (2007) find that the time to an IPO decreases with industry total factor productivity (TFP). Technological innovations also may influence the timing of VC-backed IPOs, which could help explain previous findings that IPO timing depends on stock market conditions and TFP, because literature finds that technological changes could trigger fluctuations in both stock markets (Hsu (2008)) and TFP (Comin and Gertler (2006)).

The effect of shareholder investment horizons also receives some academic attention. For example, Gaspar, Massa, and Matos (2005) find that this horizon influences firms' performance during and after mergers. In the context of VC-backed firms, the investment duration effect may be stronger, because VCs are active investors that remain closely involved in the businesses they finance (Gompers (1995), Lerner (1995), Bottazzi, Da Rin, and Hellmann (2008)). In a management context, Napier, Thompson, and Williams (2001) investigate 133 VC-backed firms that went public in the second half of 1999 and find that a longer incubation period relates to higher post-IPO market returns. In contrast, by using a larger sample with more comprehensive performance measures including patented innovation, this paper provides more robust and comprehensive results related to the incubation period effect. This paper further investigates

factors that determines the length of the VC incubation period and addresses the potential endogeneity issue of the incubation period effect by conducting different robustness analyses.

II. Data and Variables

A. Description of Sample

The data pertaining to VC-backed firms and their VC investors come from the SDC Venture Xpert database. For each VC-backed firm, I obtain the investment date and amount of the VC investments in each financing round. I also include information about the VC firms, such as their founding dates, capital under management, and the cumulative firms in which they have invested. The accounting information for VC-backed firms comes from Compustat, whereas firms' delisting information, including the date of and reasons for delisting, comes from CRSP. Finally, the patent data for VC-backed firms come from the NBER Patent Citation Database (for details about this database, see Hall, Jaffe, and Tratjenberg (2001)).

To ensure the accuracy of the data, the sample includes only VC-backed firms for which I can obtain both CRSP and Compustat data. I also undertake a data verification process, verifying the founding and IPO dates of the VC-backed firms using the data set posted on Jay Ritter's Web site (http://bear.cba.ufl.edu/ritter/) and excluding any firms whose stage of development is "Buyout/Acquisition" during the initial VC investment, because they likely are more mature and developed firms.[5] Therefore, these firms may have different profiles than the typical VC-backed firms (Sorensen (2007)). Finally, I exclude firms that received VC financing after their IPO dates, because my focus is on the effect of VCs on private rather than public firms. The final sample therefore consists of 1,755 VC-backed firms that went public between 1980 and 2004.

[5] Cao and Lerner (2007) study the sample of 526 reverse leverage buyout firms that shows a longer average firm age at IPO and a shorter buyout holding period than the sample firms used in this study. They also find negative and not particularly significant effects of buyout holding periods on post-IPO stock returns.

By construction, the sample includes only VC-backed firms that eventually went public, because one of the goals of this study is to examine the potential causal relationship between the length of the pre-exit VC incubation period and the firm's post-exit performance. By studying only VC-backed IPOs, I can test this causal relationship with minimal noise. For VC-backed firms that eventually merge with another firm, positive or negative merger synergies may contaminate the results. As another robustness check, I control for the survivorship bias of IPOs, but the economic and statistical significance of the incubation period effect remains unchanged.

B. Description of Variables

B1. VC Incubation Period

The *VC Incubation Period* is the length of time between the date of the initial VC financing round and the date of the firm's IPO. Table 1 presents the industry distribution of VC incubation periods for the sample, for which the mean VC incubation period is 4.489 years. Both industry characteristics and stock market valuations appear to affect the length of the incubation period; for example, firms in the semiconductors and biotechnology industries experience longer incubation periods (5.984 and 5.369 years, respectively), possibly due to their higher research intensities and longer time-to-market for their products. Firms in Internet-specific industries instead have a shorter incubation period (2.86 years), a possible reflection of the Internet bubble of 1999–2000, during which many Internet-related firms went public very quickly.

B2. Industry Technological Innovation Changes

Among the determinants and (aggregate and firm-level) effects of technological innovations, patents offer a rich and fruitful source for studying innovation and technical

change.[6] I use them to construct measures of technological innovations, as follows: First, following Hou and Robinson (2006), I define the industries of the sample of VC-backed IPOs on the basis of the three-digit standard industrial classification (SIC) codes. Second, from the NBER Patent Citation Database, I obtain the annual patent counts of a given three-digit SIC industry from 1963 to 2002. Third, I take the change in the annual three-digit SIC industry patent counts (in hundreds) between the observation year and the previous year as a measure of technological change by industry.

In addition to these simple patent counts, I take into account the number of citations each patent receives, because Aghion et al. (2005) and Hall, Jaffe, and Tratjenberg (2005) indicate that patent citations provide a good measure of the value of innovations. Because the importance of a patent can be measured by the number of citations it receives, I construct two additional measures of industry technological changes that are based on the annual change in citation-weighted patents, as I describe in detail in the Appendix.

C. Summary Statistics

Table II reports the characteristics of the 1,755 VC-backed firms before and after their IPOs. On average, these firms earn 3.14 patents within three years following their IPO, and 34.3% have at least one patent within the three-year post-IPO period. Their post-IPO operating performance falls below the industry median (mean industry adjusted return on assets is -11.9%) but moves above the industry median market value (industry-adjusted Tobin's Q ratio is 0.865). These numbers suggest that the typical performance profile of these firms features growth.

[6] For further discussions, see Hall, Jaffe, and Tratjenberg (2001), Kortum and Lerner (2000), Hall, Jaffe, and Tratjenberg (2005), and Lerner, Sorenson, and Stromberg (2008).

Finally, despite the below median operating performance, only 11.5% of the sample firms failed to survive within five years of their IPOs.

The pre-IPO features of these sample firms indicate they are relatively small in size (mean assets three years before the IPO = $127.09 million) and have low leverage ratios (0.06) but high mean market value (Tobin's Q ratio = 3.937). Before the VC investment, only 17.5% have earned at least one patent (average of 0.635 patents for each firm). Compared with their post-IPO characteristics, the sample firms grow more innovative as measured by patenting, which is somewhat consistent with Kaplan, Sensoy, and Stromberg's (2009) finding that patenting becomes more important for a VC-backed firm over time. In the next section, I further examine whether the length of the VC incubation period actually explains the cross-sectional variations of post-IPO patenting.

III. Empirical Results

A. Univariate Analysis

Table III contains the univariate analysis of post-IPO firm performance and its relationship to VC incubation period and VC experience. I split the sample into long and short VC incubation period groups, on the basis of whether the incubation period is above or below the median, then compare five post-IPO performance measures for the two groups. For example, as presented in Panel A of Table III, firms in the long incubation period group earn an average of 4.016 patents within three years of their IPO, whereas firms in the short incubation period group only have 2.321 patents. The difference of the mean (1.695) is statistically significant at the 1% level. The percentage of firms with patents before VC participation is lesser among the long incubation period group compared with the short incubation period group (15.8% versus 19.1%),

but within three years after their IPO, 38.5% of firms in the long incubation period group have patents, whereas only 26.7% of those in the short incubation period group have earned them. These findings suggest an effect of the incubation period on post-IPO patenting that is not driven by the level of innovativeness of the firms before the VC investments.

Furthermore, according to Panel A in Table III, firms in the long incubation period group achieve significantly higher median industry-adjusted returns on assets (ROA) than do firms in the short incubation period group, though the difference in the industry-adjusted Tobin's Q ratio is not statistically significant. Finally, firms in the long incubation period group are half as likely (7.4% versus 15.8%) to be delisted in the five years after their IPO. Overall, these results provide evidence that firms with longer incubation periods enjoy better post-IPO performance.

Experienced VCs help the businesses they finance in many ways, including professionalization (Hellmann and Puri (2002)), business referrals, extensive mentoring, and financial assistance (Hsu (2004)). However, it remains unclear whether firms financed by more experienced VCs are more innovative. Therefore, I split the sample into high and low VC experience groups on the basis of whether the lead VC is older or younger than the median (Table III, Panel B). Firms financed by more experienced VCs earn more patents after their IPO than do firms financed by less experienced VCs (3.857 versus 2.54), consistent with a positive relation between VC experience and post-IPO patenting. Otherwise, VC experience does not seem to have a significant effect on performance measures.

The univariate analysis therefore suggests that firms with a longer incubation period achieve more patents, better performance, and higher survival rates after their IPO.

B. Industry Technological Changes and the Length of the VC Incubation Period

In this section, I investigate whether industry technological changes affect the length of the VC incubation period and, if so, in what direction. Researchers ordinarily employ a hazard model to deal with duration data,[7] specifying the hazard function and conditioning it on particular explanatory variables. I assume a firm has a certain probability of going public, so the hazard rate is the probability that the firm will go public between time t and Δt, divided by the probability that the firm hasn't gone public before t. I use the Cox proportional hazard model, which can include time-varying explanatory variables and thus provides reliable estimates.

Three measures of annual change in industry patenting, as described in Section II, provide the main explanatory variables for the purpose of studying the effect of technological changes on the length of the incubation period. In addition to these main explanatory variables, firms tend to go public when stock markets show signs of overvaluation, because doing so enables them to take advantage of the windows of opportunity. Moreover, Baker and Wurgler (2006) find that investor sentiment is associated with lower subsequent returns on small, young, and high-volatility stocks; that is, these categories of stocks appear relatively overvalued in high-sentiment states. Because VC-backed firms typically fall into all three of these groups, I use Baker and Wurgler's (2006) investor sentiment index to proxy for stock market overvaluation.

Other factors also might determine the length of the VC incubation period. *Early Stage Dummy* is equal to 1 if the firm is in an early investment stage when it first receives financing from VCs and 0 otherwise. *Hightech Dummy* equals 1 if the firm is in a high-tech industry as defined in Loughran and Ritter (2004), and 0 otherwise. *Invested between 1995 and 2000* is a dummy variable equal to 1 if the firm receives investments from VCs between 1995 and 2000 and 0 otherwise, because investments in these years around the Internet bubble likely led to

[7] The duration model appears extensively in prior literature; see Gompers (1995), Hellman and Puri (2000), Cumming and McIntosh (2001), Giot and Schwienbacher (2007), and Hochberg et al. (2008).

shorter incubation periods. Finally, *Log(Total Firm investment*) is the natural logarithm of the total amount of investment made by VCs in the firm.

The results of the Cox proportional hazard regression appear in Table IV. A positive coefficient on *x* suggests that an increase in *x* results in a higher hazard rate—here, a higher probability of going public and a shorter expected incubation period. From Model 1 to Model 3, the positive and significant coefficients for all three measures suggest that the length of the VC incubation period significantly decreases when the industry experiences technological advances, after I control for investor sentiment in the stock markets and other explanatory variables.

The technological change effect could be confounded by other industry characteristics. For example, technological advances likely depend on the degree of competition in the industry (Schumpeter (1942)). Thus, the effect on the incubation period may result from the degree of industry competition, not technological changes per se. I include several variables to proxy for industry characteristics: industry market-to-book ratio, industry ROA, industry concentration ratio (Herfindahl index), and industry tangibility ratio. The results from Models 4 to 6 show that industry technological changes still have significant effects on the length of the incubation period after controlling for additional industry characteristics, so the technological change effect does not appear to be driven by other industry factors.

Finally, according to Table I, the length of the incubation period varies across industries, perhaps due to the difference in the time to market and the nature of the products. Therefore, in Models 9 to 12 of Table IV, I include industry dummy variables as defined according to the Venture Expert database for biotechnology, computer-related, communications, medical/health care, and non–high-tech industries. The results persist in suggesting a significant technological change effect on the length of the incubation period.

On the other hand, the length of the incubation period decreases with increases in *investor sentiment*, *industry M/B ratio*, and *industry ROA*; that is, more firms go public when the stock markets are overvalued (Lerner (1994)) and when industry valuations are higher (Pagano, Panetta and Zingales (1998)). Consistent with Chemmanur and Fulghieri's (1999) prediction, the length of the incubation period decreases with increases in the industry tangibility ratio, which is a proxy for capital requirements. Finally, greater industry competition (a lower Herfindahl index) results in a shorter incubation period, consistent with Chemmanur, Nandy, and He (2008) and in support of Maksimovic and Pichler (2001), namely, that concerns about revealing key information to potential rival firms delays firms' decision to go public.

C. VC Incubation Period and Post-IPO Patented Innovations

C1. Post-IPO Innovation Using OLS and Instrumental Variable Regressions

To examine the effect of the incubation period on post-IPO firm performance, I report, in Panel A of Table V, the effect of the incubation period on post-IPO patenting. In Model 1, the dependent variable is the natural logarithm of (1 + number of patents three years after IPO). The log transformation addresses the skewness in patent distributions. I also include firm age and two measures of firm innovativeness (has patents and the number of granted patents) at the initial VC investment, because the incubation period effect on post-IPO patenting could be confounded by the innovativeness of the firm before the VC's involvement. After controlling for these firm characteristics, I find that the length of the incubation period has a positive and statistically significant impact on post-IPO patenting (Model 1, Panel A), consistent with the univariate results (Table III), which strengthens the claim that VC involvement spurs greater innovations (Kortum and Lerner (2000)).

One of the main empirical concerns in Model 1 relates to potentially biased estimates due to endogenous explanatory variables. In particular, the length of the VC incubation period is endogenously determined, so the length of the incubation period correlates with the residuals. In turn, the ordinary least squares (OLS) result in Model 1 (Panel A, Table V) could render unreliable estimates. I use the instrumental variable approach and identify a set of instrumental variables that correlate with *VC Incubation Period* but not with the residuals for post-IPO patenting. To select these instrumental variables, I turn to the results from the previous section showing that both industry technological changes and investor sentiment influence the length of the incubation period. I therefore use the annual change in industry patenting (in hundreds) and the investor sentiment index one year before VC participation in the firm as instruments. Lagged variables offer appropriate instruments for ensuring the validity of instruments (MacKay and Phillips (2005), Murray (2006)). I also perform several tests to ensure the quality of instruments.

In Model 2 of Panel A of Table V, I provide estimates derived from the generalized method of moment (GMM) estimation. Compared with the standard instrumental variable approach, GMM improves the efficiency of estimates and provides more consistent estimates for a system of simultaneous equations (MacKay and Phillips (2005)). Controlling for potential endogeneity does not affect the sign or statistical significance of the coefficient of *VC Incubation Period*, and controlling for incubation period endogeneity increases its economic significance.

The bottom of Panel A features the under-identification test (Lagrange multiplier) for the relevance of the instrumental variables (correlated with the length of the incubation period), the weak identification test, and the Hansen J statistics for the validity of the instrumental variable (uncorrelated with the residuals). The 42.969 chi-square test statistic is significant at the 1% level, suggesting that the instruments are relevant, and the 38.093 Wald F statistics reject the null

hypothesis of the weak instruments, according to Hausman, Stock, and Yogo's (2005) test. Hansen's J statistics are not significant, in support of the instruments' validity. In summary, the positive and significant effect of the length of the incubation period on post-IPO patenting is robust, even when I control for the endogeneity of the incubation period.

C2. Post-IPO Innovation using Poisson and IV Poisson Regressions

Patent data typically exhibit a large proportion of zeros, with positive integers as the remaining values (Rossi (2006)). As Table II reveals, only 34.3% of the sample firms earn patents after their IPOs. To deal with these features and test the robustness of the OLS regression results, I employ Poisson regression models to estimate the effect of the VC incubation period on post-IPO patenting. Poisson regressions frequently appear in research dealing with patent data (Atanassov, Nanda, and Seru (2007), Griliches, Hall, and Hausman (1984), Wooldridge (2002)).

In Model 3 of Table V, I again find the same basic patterns: The positive and statistically significant coefficients for *VC Incubation Period* suggest that firms with longer VC incubation periods earn more patents after they go public. However, an incubation period endogeneity issue may also arise for the Poisson regression. Mullahy (1997) reveals how to estimate exponential models such as Poisson regressions with endogenous explanatory variables; his instrumental variable framework uses GMM but does not impose restrictions on the linearity of the outcome equation (see also Wooldridge (2002)).

In Table V, Model 4 of Panel A reflects the IV-Poisson regression based on Mullahy's (1997) approach. This regression uses the same instrumental variables: annual change in industry patenting and investor sentiment index one year before the VC's participation in the firm. The IV-Poisson regression not only confirms the statistical significance of *VC Incubation Period* but

also enhances its economic significance. Overall, the length of the incubation period and its effect on post-IPO patenting is robust under the Poisson regression framework.

C3. VC Experience, VC Incubation Period, and Post-IPO Innovation

Firms with a longer incubation period appear more innovative after their IPO. But is the effect of the VC incubation period identical across all VC-backed firms? In other words, if everything else is equal, do two firms with the same incubation period have the same level of post-IPO patenting? If not, what factors cause any differences in the incubation period effect?

One factor may be VC experience. More experienced VCs offer several advantages to their portfolio firms, including stronger networks within the industry and greater business expertise (Hsu (2004)). Therefore, VC experience could influence the effect of the VC incubation period on innovation. I measure VC experience as the age of the lead VC when it first invests in the firm, in line with previous literature (Gompers (1996), Lee and Wahal (2004)).

In Panel B of Table V, I report the results for both the OLS (Models 1 and 2) and the Poisson regression (Models 3 and 4). In both frameworks, *VC Experience* has positive and statistically significant effects on post-IPO patenting (Models 1 and 3). The effect of *VC Incubation* on post-IPO patenting remains significant even when *VC Experience* appears in the regression (Models 1 and 3), which suggests the incubation period effect on post-IPO patenting may not be driven by VC experience.

A more interesting result emerges from Models 2 and 4 (Panel B, Table V), which feature the interaction of *VC Experience* and *VC Incubation Period.* The coefficients for both variables and their interaction term remain positive and significant; therefore, for firms with more

experienced VC, the incubation period effect on post-IPO innovation (as measured by patenting) is stronger.

The finding of a stronger incubation period effect for firms with more experienced VCs suggests two potential interpretations. First, they may indicate that more experienced VCs are better incubators of innovations, because these VCs may possess more "know-how" with regard to promoting innovations. Second, as Sorensen (2007) and Hsu (2004) note, experienced VCs are more likely to attract or select better investments. Thus, the findings may reflect a hierarchical sorting effect, such that better firms get matched with better VCs (Sorensen (2007)). Disentangling the value-creating effect from the hierarchical sorting effect of VC experience is important but beyond the scope of this paper. However, by introducing VC experience into the regression analysis, I confirm the robustness of the incubation period effect on post-IPO patenting: Firms with a longer incubation period earn more patents after their IPO, after controlling for VC investor heterogeneity.

D. VC Incubation Period and Post-IPO Performance and Survival

The incubation period also may affect the performance and survival of firms after their IPO. In Table VI, I report the regression results from both the OLS and the instrumental variable (GMM) approaches, using the same instrumental variables as in Panel A of Table V: annual change in industry patenting (in hundreds) and investor sentiment index. The dependent variables in Models 1 and 2 are industry-adjusted ROAs (ROA of the firm minus median ROA in the 3-digit SIC industry), averaged over the first three years after the IPO. Using industry-adjusted measures helps reveal the relative performance of the sample firms. The results indicate that *VC Incubation Period* has a positive and significant effect on industry-adjusted ROA. In

particular, in Model 2, after I control for potential incubation period endogeneity using the instrumental variable (GMM) approach, a one-year increase in the incubation period creates a 3.9% increase in the three-year average industry-adjusted ROA post-IPO.

A potential concern regarding the ROA measure is that it might not provide the best measure for sample firms characterized by high growth. To address this concern, I also investigate the effect of the incubation period on firms' industry-adjusted Tobin's Q after the IPO. Specifically, in Models 3 and 4 (Table VI), the dependent variable is the natural logarithm of (1 + industry-adjusted Tobin's Q), with the Tobin's Q averaged over the first three years after the IPOs. The results indicate the positive and significant effect of *VC Incubation Period* on firms' industry-adjusted Tobin's Q in both the OLS and the instrumental variable regressions. Therefore, firms with longer incubation periods not only achieve better operating performance but also enjoy higher growth potential and higher market value. This result also complements the finding that firms with a longer incubation period earn more patents after their IPO, because more innovative firms attain better market values (Hall, Tratjenberg, and Jaffe (2005), Rossi (2006)).

Finally, I investigate the effect of the incubation period on firms' survival probabilities after their IPO. In Models 5 and 6 (Table VI), I report the results of a Probit and instrumental variable Probit regression (or IV Probit), using the same instruments. In these regressions, the dependent variable is a post-IPO survival dummy equal to 1 if the firm is not delisted within five years after the IPO, for reasons other than mergers and acquisitions.[8] Consistent with the univariate results in Table III, firms with a longer incubation period are significantly more likely to survive, controlling for other pre-IPO firm characteristics.

[8] In an unreported analysis, I use an alternative survival dummy that equals 1 if firms are not delisted within three years of the IPO for reasons other than mergers and acquisitions. The results do not materially change.

To examine the quality of the instruments in the instrumental variable regressions, I report tests of the relevance, strength, and validity for Models 2 and 4 in Table VI. The 58.955 and 44.018 chi-square test statistics for Models 2 and 4, respectively, are significant at the 1% level; that is, the instruments are relevant. Furthermore, the 44.202 and 30.822 Wald F statistics reject the null hypothesis of weak instruments. Finally, Hansen's J statistics for Models 2 and 4 are 0.801 and 0.447, respectively, and are not statistically significant, in support of the validity of the instruments. These tests support the overall quality of the selected instruments. Finally, in Model 6 (Table VI), I perform the Wald test of endogeneity for the instrumental variable Probit regression; the insignificant 1.29 F-test statistics again suggest the validity of the instruments.

According to the results in Table VI, other pre-IPO firm characteristics affect post-IPO firm performance and survival as well. For example, larger firms (firms with higher *Log(Assets)*) achieve better post-IPO operating performance and survival probabilities, though lower Tobin's Q. Firms with a higher pre-IPO leverage ratio suffer worse industry-adjusted ROAs and are less likely to survive after their IPO.

IV. Robustness Checks

Further analyses regarding the incubation period effect on post-IPO performance examine the sensitivity of the preceding results to alternative model specifications. These analyses include regressions to control for survivorship bias and panel regressions.

A. VC Incubation Period Effect Controlling for Survivorship Bias of IPOs

In addition to incubation period endogeneity, the analyses of the incubation period effect on post-IPO firm innovation and performance are subject to some empirical concerns, including

a survivorship bias; we observe the incubation period effect only for firms that eventually go public. Because an IPO is considered the most successful exit type for VC investment, this survivorship bias may overexaggerate the incubation period effect. Cochrane (2005) finds that correcting the survivorship bias significantly reduces the returns of VC investments.

To correct the survivorship bias of IPOs, I employ standard Heckman two-step procedures (Heckman (1979). The equation estimated as a first step is a Probit model in which the dependent variable is a binary variable equal to 1 if the VC-backed firm goes public and 0 otherwise. In the second step, if the firm goes public, I regress post-IPO performance on *VC Incubation Period*, other control variables, and the inverse Mills ratio obtained in the first-step regression.

Table VII reports the estimation results from both the outcome regressions (incubation period effect on post-IPO performance) and the selection regressions (whether the VC-backed firm eventually goes public). In the outcome regressions, *VC Incubation Period* still has a positive and significant effect on post-PO patenting, performance, and survival. Furthermore, comparing the coefficients in Table VII with those reported in the OLS regression in Panel A of Table V and Table VI reveals that controlling for survivorship bias does not reduce the economic significance of the incubation period effect.

In the selection regression of Table VII, I include several explanatory variables to predict the probability of eventual IPOs. These variables include the experience of VCs, stock market conditions at the beginning of VC investment, an early stage dummy (1 if the firm is in its early stages at the initial VC investment), and a network dummy (1 if the VC-backed firm is located in California or Massachusetts). Following Hochberg, Ljungqvist and Lu (2008), I use the logarithm of the total firms invetsed by the VC as the VC experience measure. The results in

Table VII suggest that firms financed by more experience VCs are more likely to go public. Furthermore, consistent with Sorenson (2007), firms that are in their early stages when they first receive VC investments are less likely to go public. Positive and significant coefficients for *Network* suggest that firms located in California or Massachusetts enjoy the advantages of a better network and thus are more likely to go public, because most VCs are located in these two states. This result is consistent with the networking effect of VCs studied by Hochberg, Ljungqvist and Lu (2008). Finally, firms that receive investments during periods of stock market overvaluation are less likely to go public.

In addition to the logarithm of total firms invested by VCs, I use alternative VC experience measures, such as the cumulative total amount invested by the VC and the age of VCs. The positive and significant incubation period effect on post-IPO performance is robust against different VC experience measures in the first step (selection) regression.

B. VC Incubation Period Effect Controlling for Selection Bias of Venture Financing.

The incubation period effect on post-IPO firm innovation and performance may be subject to sample selection problems, because VCs may endogenously select firms for investment in a nonrandom fashion based on their geographical location and/or industry. Therefore, I again employ the Heckman two-step procedure to address potential selection bias. The equation estimated in the first step is a Probit model in which the dependent variable is a binary variable equal to 1 if the firm receives VC backing and 0 otherwise. In the second step, if VC backing equals 1, I estimate the incubation period effect on post-IPO performance.

Following Baker and Gompers (2003) and Lee and Wahal (2004), I use firm industry, firm state, and whether the firm was founded after 1980 as explanatory variables in the first

stage. Firms in young and high-tech industries, such as biotechnology and computer-related industries, are more likely to receive VC financing. Also, firms located in California or Massachusetts are more likely to receive VC funding because VCs cluster in these states. Finally, firms founded after 1980 are more likely to receive VC funding because of the amendment of the "prudent man" rule in 1979, which allowed pension funds to invest in VCs and thus caused a structural change in the entire VC industry.

In Table VIII, I present the regression results of the effect of VC incubation period using the Heckman two-step procedures. The same patterns hold after I control for the potential selection bias of VC financing: *VC Incubation Period* has a positive and statistically significant impact on post-IPO patenting, industry-adjusted ROAs, Tobin's Q, and firm survival. The inverse Mills ratio is not significant in any of the models, suggesting that the selection of VC financing does not affect the regression of post-IPO performance on the *VC Incubation Period*.

C. VC Incubation Period Effect: Panel Regressions

The regression results I have reported thus far regarding the effect of the incubation period reside at the firm level and are cross-sectional. The reason for such cross-sectional regressions is straightforward: Each VC-backed firm is associated with a unique VC incubation period length, and I am interested in investigating whether the length of the incubation period explains any cross-sectional variations in firms' post-IPO innovation and performance. The model for the firm-level cross-sectional regression takes the following form:

$$Patent_i(ROA_i / Q_i) = a_0 + a_1 VCIP_i + a_2 Log(Assets)_i + a_3 Log(CAPEX)_i + ... + \varepsilon_i, \qquad (1)$$

where $Patent_i$ is the three-year cumulative number of post-IPO patents for firm *i*; ROA_i is the three-year average industry-adjusted ROA for firm *i*; Q_i is the Tobin's Q for firm *i* averaged over

three years; $VCIP_i$ is the VC incubation period for firm *i*; and *Log(Assets), Log(CAPEX),* and other firm characteristic variables indicate the three-year pre-IPO averages for firm *i*. To check the robustness of the effect of the VC incubation period on post-IPO firm performance, I estimate the regression with the following panel data model:

$$Patent_{i,t}(ROA_{i,t} / Q_{i,t}) = a_0 + a_1 VCIP_i + a_2 Log(Assets)_{i,t-1} + a_3 Log(CAPEX)_{i,t-1} + .. + \mu_i + \varepsilon_{i,t},$$

(2)

where $Patent_{i,t}(ROA_{i,t} / Q_{i,t})$ is the number of patents (ROA or Q) for firm *i* at year *t*; $Log(Assets)_{i,t-1}$ and $Log(CAPEX)_{i,t-1}$ are, respectively, the logs of firm assets and capital expenditures for firm *i* at year $t-1$, where *t* ranges from one to three years after the IPO; and the other firm characteristic variables take the same firm and time subscripts as $Log(Assets)_{i,t-1}$ and $Log(CAPEX)_{i,t-1}$. The analysis of the effect of VC incubation period with a panel regression framework alleviates potential concerns that the cross-sectional results reflect specific industries.

The panel regression results for post-IPO performance in Table IX include both the OLS and the instrumental variable frameworks. I also use lagged values of the annual changes in industry patenting and the investor sentiment index as instruments. After controlling for industry-fixed effects and other firm characteristics, I find that firms with a longer incubation period earn more patents and enjoy better three-year industry-adjusted ROAs and Tobin's Q after they go public. In the instrumental variable regressions (Models 2, 4, and 6 of Table IX), the quality of the instruments are robust to the tests of under-identification, weak instruments, and Hansen's J. Overall, the panel regression results further support the positive effect of the VC incubation period on the post-IPO performance of VC-backed firms.

D. Other Robustness Checks

The sample in this paper includes 1,755 VC-backed firms that went public between 1980 and 2004, so the sample period covers the Internet bubble (1999 and 2000). Literature documents several IPO anomalies during this period, including clusters of young and high-tech firms going public, extremely high underpricing, and poor post-IPO stock and operating performance after the IPOs. To ensure this unusual period does not drive the incubation-period effects on post-IPO performance, I exclude the sample of firms that went public during the bubble period. The results suggest that the incubation period effects do not materially change after excluding these IPOs; these results are available upon request.

Another empirical issue pertains to a potential confounding effect. For example, the incubation period effect on post-IPO performance might reflect total VC investments in the firm or the experience of VCs rather than the incubation period per se. To address these potential confounders, I include the log of the total VC investment in the firm, as well as different VC experience measures in the regressions of the incubation period effect. Including these variables does not affect the economic or statistical significance of the VC incubation on post-IPO patenting, performance, and survival.

V. Conclusions

In this paper, I study whether changes in industry fundamentals determine the length of the VC incubation period, and analyze the effect of the VC incubation period on post-IPO patenting, operating performance, and survival rates for the portfolio firms. The incubation period decreases with increasing industry technological changes, yet firms with longer incubation periods earn more patents and exhibit better performance and a greater chance of

post-IPO survival. These results are robust when I control for various potential empirical issues, including the endogenous VC incubation period and survivorship biases.

This paper also shows that firms financed by more experienced VCs earn more patents after their IPO. Moreover, the incubation period effect on post-IPO patenting is stronger for firms receiving financing from more experienced VCs, but the incubation period effect is still robust to controlling for the experience of VCs.

These findings have implications for the appropriate size and performance of private equity funds. If a longer incubation period creates more value, private equity funds may want to hold their investments longer. However, holding existing investments also may pose a restriction on the size and the growth of their portfolios, because private equities' human capital, in the form of their business expertise, monitoring, and mentoring, suffers capacity constraints (Michelacci and Suarez (2004)). Consistent with this conjecture, Fulghieri and Sevelir (2008) show that it is beneficial for VCs to maintain the size of their portfolio, and Kaplan and Schoar (2005) find persistent private equity fund performance and that better performing funds grow proportionally slower. The relationship among investment turnover rates, fund size, and the performance of private equity funds requires further research investigation.

Appendix. Construction of Variables

Citation-Weighted Patent Measures

I use two citation-weighted patent measures, following Aghion et al. (2005) and Atanassov, Nanda, and Seru (2007): (1) the citation-weighted patent in which the weight is equal to the number of citations received by the patent, divided by the number of citations received by all

patents in a given year, and (2) the citation-weighted patent in which the weight is equal to the number of citations received by the patent, divided by the total number of citations received by all patent within a technology class in a given year, where the technology classes are defined by the U.S. Patent and Trademark Office. Using these two measures, I construct the measures of industry technological changes using the annual changes in the total citation-weighted patent counts in a three-digit-SIC industry.

Investment Sentiment Index

Baker and Wurgler (2006) find that greater beginning-period investor sentiment is associated with lower subsequent returns on small, young, and high-volatility stocks, suggesting that these categories of stocks are relatively overvalued in high-sentiment states. I use the following investment sentiment index, proposed by Baker and Wurgler (2006):

$$SENTIMENT_t = -0.241 CEFD_t + 0.242 TURN_{t-1} + 0.253 NIPO_t + 0.257 RIPO_{t-1} + 0.112 S_t - 0.283 P_{t-1}^{D-ND},$$

where *CEFD* is the closed-end fund discount; *TURN* is the natural log of the raw NYSE share turnover ratio, detrended by the five-year moving average; *NIPO* is the number of IPOs; *RIPO* is the lagged average first-day returns; and P^{D-ND} is the dividend premium, defined as the log difference of the average market-to-book ratios of payers and nonpayers. All variables are expressed on an annual basis.

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Table I
Distribution of VC Incubation Period

The distribution of VC incubation periods and firm ages at IPO by industry for the sample of 1,755 VC-backed firms that went public between 1980 and 2004. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the firm's IPO date. *Firm Age at IPO* is the period from the founding date of the firm to the firm's IPO date. Data for the founding date come from Jay Ritter. Data on the first investment date of VC-backed firms and their industries come from the Venture Xpert database.

		VC Incubation Period		*Firm Age at IPO*	
	N	**Mean (Years)**	**Median (Years)**	**Mean (Years)**	**Median (Years)**
Biotechnology	188	5.369	4.282	7.968	6.000
Communications and Media	221	4.516	3.504	7.149	6.000
Computer Hardware	141	4.527	3.745	7.787	6.000
Computer Related	1	6.597	6.597	7.000	7.000
Computer Software and Services	292	4.148	3.341	8.298	7.000
Consumer-Related	114	4.317	3.251	14.851	8.000
Industrial/Energy	74	4.391	3.625	10.986	7.000
Internet-Specific	207	2.860	2.682	5.618	4.000
Medical/Health	269	4.686	4.003	7.918	6.000
Other Products	95	4.527	3.364	14.116	9.000
Semiconductors	153	5.984	5.225	9.974	8.000
Total	1755	4.489	3.600	8.702	6.000

Table II
Summary Statistics

Characteristics of 1,755 VC-backed firms that went public from 1980 to 2004. *Number of Patents Granted* is the number of patents granted to firms within three years after IPO. *Percentage of Firms Granted Patents* is the percentage of firms that received at least one patent within three years after their IPO. *Industry-adjusted ROA(EBITDA/Assets)* is the average of firm ROA (ratio of operating income to book value of assets) minus the industry median ROA over the three years post-IPO. *Industry-adjusted Q Ratio* is the average of firm market-to-book ratio minus the industry median market-to-book ratio over the three years post-IPO. *Percentage of Delisting* is the percentage of sample firms that are delisted within five years after their IPO for reasons other than mergers and acquisitions. Averaged values for the following variables are calculated for the three years immediately prior to the firms' IPOs, including the IPO year, unless otherwise noted: *Assets before IPO* is the average book value of assets, measured in 2003 dollars. *Sales before IPO* is the average book value of sales, measured in 2003 dollars. *CAPEX before IPO* is the average capital expenditure, measured in 2003 dollars. *R&D Expenses before IPO* is the average R&D expenses, measured in 2003 dollars. *Leverage Ratio* is the ratio of market leverage to assets. *M/B (Q) Ratio before IPO* is the average ratio of market value of assets to book value of assets. *Total VC Investments* is the total investment made by VCs in the firm.

	N	Mean	*Median*	Standard Deviation
Post-IPO Performance Variables				
Number of Patents Granted	1666	3.140	0	10.400
Percentage of Firms Granted Patents	1666	0.343	0	0.475
Industry-adjusted ROA (EBITDA/Assets)	1604	-0.119	-0.027	0.328
Industry-adjusted Q Ratio	1598	0.865	0.215	2.554
Percentage of Delisting	1755	0.115	0	0.319
Pre-IPO Firm Characteristics				
Assets before IPO ($millions)	1745	127.090	53.961	345.847
Sales before IPO ($million)	1745	81.215	34.121	226.360
CAPEX before IPO ($millions)	1735	9.468	2.733	28.394
R&D expenses before IPO ($millions)	1449	9.794	6.204	25.107
Number of Patents Granted before VC Investment	1743	0.635	0	2.291
Have Patents before VC Investment	1743	0.175	0	0.380
Leverage Ratio before IPO	1719	0.060	0.015	0.108
M/B (Q) Ratio before IPO	1712	3.937	2.760	4.916
VC Investor Characteristics				
Total VC Investments ($millions)	1745	17.378	6.900	40.836
Age of the Lead VC investor (Years)	1417	15.116	12.890	14.046

Table III
Univariate Analysis

Univariate analysis of the relationship of post-IPO firm performance to VC incubation period and VC experience. Panel A reports the difference of five post-IPO performance measures for firms with long and short VC incubation periods. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the firm's IPO date. Long (short) values of VC incubation period are those above (below) the median of the whole sample. *Industry-adjusted ROA* is the average of firm ROA minus the industry median ROA over the three years post-IPO. *Industry-adjusted Q Ratio* is the average of firm market-to-book ratio minus the industry median market-to-book ratio over the three years post-IPO. *Percentage of Delisting* is the percentage of firms that are delisted within five years after IPO for reasons other than mergers and acquisitions. In Panel B, *VC Experience* is the age of the lead VC investors at the date of the initial VC investment. High (low) values of VC experience are those above (below) the median of the whole sample. ***, **, and * indicate significance of the Wilcoxon two-sample test at the 1%, 5%, and 10% levels, respectively.

Panel A. VC Incubation Period

Performance Measure	Long	Short	Wilcoxon Test
Number of Patents 3 Years Post IPO (Mean)	4.016	2.321	3.34***
Has Patents 3 Years Post IPO	0.385	0.267	5.28***
Industry-adjusted ROA (Median)	-0.019	-0.039	2.80***
Industry-adjusted Q (Median)	0.227	0.205	0.95
Percentage of Delisting	0.074	0.158	-5.34***
Has Patents before VC Investment	0.158	0.191	-1.81*

Panel B. VC Experience

Performance Measure	High	Low	Wilcoxon Test
Number of Patents 3 Years Post IPO (Mean)	3.857	2.540	2.23***
Has Patents 3 Years Post IPO	0.331	0.320	0.42
Industry-adjusted ROA (Median)	-0.032	-0.023	-0.16
Industry-adjusted Q (Median)	0.194	0.235	-0.93
Percentage of Delisting	0.100	0.118	-1.10
Has Patents before VC Investment	0.182	0.161	1.07

Table IV
Technological Changes and the Length of the VC Incubation Period

Survival analysis of the determinants of the length of the VC incubation period. I provide estimates from a Cox proportional-hazard regression of the *VC Incubation Period* on variables that proxy for industry technological changes and other explanatory variables. The dependent variable is the length of *VC Incubation Period*, measured in years. Δ *Industry Patents* is the annual change in patent counts (in hundreds) between the observation year and the previous year in the three-digit SIC industry. Δ *Industry Citation Weighted Patent by Year* is the annual change in citation-weighted patents in the three-digit SIC industry, and the weight is the number of citations received by a patent divided by the total number of citations received by all patents in a given year. Δ *Industry Citation Weighted Patent by Tech. Category* is the annual change in citation-weighted patents in the three-digit SIC industry, and the weight is the number of citations received by a patent divided by the total number of citations received by all patent within a technology class in a given year. *Sentiment index* is the investor sentiment index proposed by Baker and Wurgler (2006). *Early Stage Dummy* is a dummy variable equal to 1 if the firm was in an early investment stage at the initial VC investment date. *Hightech Dummy* is a dummy variable equal to 1 if the firm is in a high-tech industry. *Invested between 1995 and 2000* is a dummy variable equal to 1 if the firms receive investments from VCs between 1995 and 2000. *Log(Total Firm Investment)* is the natural logarithm of the total amount of investment made by VCs in the firm. *Industry M/B ratio* is the median market-to-book ratio of firms' three-digit SIC industry. *Herfindahl Index* is the concentration ratio of firms' three-digit SIC industry. *Industry Tangibility Ratio* is the median ratio of fixed assets to total assets in the three-digit SIC industry. *Industry ROA* is the median return on assets in the three-digit SIC industry. Industry dummy is the dummy variables of six industries defined in the Venture Xpert Database. Chi-square statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent Variable:	*VC Incubation Period* (in years)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Δ*Industry Patents*	0.015**			0.015**			0.012*		
	(6.09)			(5.61)			(3.34)		
Δ*Industry Citation Weighted Patent by Year*		30.597***			26.133***			23.843***	
		(21.38)			(14.29)			(11.23)	
Δ*Industry Citation Weighted Patent by Tech.Catgory*			7.296***			5.846***			5.482***
			(18.80)			(11.45)			(9.79)
Sentiment Index	0.106***	0.117***	0.117***	0.102***	0.108***	0.111***	0.106***	0.111***	0.113***
	(8.00)	(9.80)	(9.80)	(6.92)	(7.75)	(8.20)	(7.27)	(7.94)	(8.17)
Early Stage Dummy	-0.306***	-0.298***	-0.301***	-0.300***	-0.296***	-0.296***	-0.292***	-0.287***	-0.285***
	(30.56)	(29.03)	(29.48)	(28.83)	(28.14)	(28.04)	(26.73)	(25.91)	(25.54)
Hightech Dummy	-0.161***	-0.191***	-0.161***	-0.140**	-0.153***	-0.137**	-0.221***	-0.234***	-0.225***
	(9.32)	(12.97)	(9.63)	(6.20)	(7.36)	(6.01)	(13.32)	(14.71)	(13.68)
Invested between 1995 and 2000	1.013***	1.054***	1.039***	1.097***	1.118***	1.111***	0.108***	1.102***	1.094***
	(254.72)	(268.58)	(265.83)	(268.93)	(276.98)	(275.07)	(240.97)	(248.60)	(246.82)
Log(Total Firm Investment)	-0.106***	-0.102***	-0.101***	-0.102***	-0.101***	-0.099***	-0.101***	-0.100***	-0.098***
	(43.45)	(40.08)	(39.94)	(38.91)	(37.98)	(36.63)	(37.78)	(37.42)	(36.04)
Industry M/B Ratio				0.213***	0.200***	0.198***	0.187***	0.177***	0.173***
				(35.34)	(30.13)	(29.65)	(26.74)	(23.33)	(22.55)
Herfindhal Index				0.712***	0.670**	0.612**	0.487*	0.479*	0.407
				(7.28)	(6.53)	(5.42)	(2.97)	(2.97)	(2.15)
Industry Tangibility Ratio				0.662***	0.692***	0.641***	0.920***	0.944***	0.904***
				(7.48)	(8.20)	(7.10)	(13.58)	(14.29)	(13.20)
Industry ROA				0.643**	0.442	0.613**	0.809**	0.602*	0.743**
				(4.30)	(1.94)	(3.92)	(5.62)	(3.01)	(4.73)
Industry Dummy	No	No	No	No	No	No	Yes	Yes	Yes
N	1585	1585	1585	1583	1583	1583	1583	1583	1583

Table V
Effect of VC Incubation Period on Post-IPO Patenting

Estimates from the ordinary least squares (OLS), Poisson regression, and instrumental variable regressions of post-IPO patenting on *VC Incubation Period* and other control variables. In Models 1 and 2 of Panel A, the dependent variable is the log of (1 + number of patents firms received within the three years post-IPO). In Models 3 and 4 of Panel A, the dependent variable is the total number of patents granted to the firm within the three years post-IPO. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the firm's IPO date. *Firm Age at Initial VC Investment* is the period from the founding date of the firm to the date of the initial VC investment. Averaged values for the following variables are calculated for the three years immediately prior to the firms' IPOs, including the IPO year, unless otherwise noted. *Log(Assets)* is the log of the average of firm assets. *Log(CAPEX)* is the log of the average of capital expenditures. *Number of Patents before IPO* is the total number of patents before VC investment in the firm. *Has Patents before VC Investment* is a dummy variable equal to 1 if the firm has at least one patent before VC investment in the firm. *Tangibility Ratio* is the average ratio of fixed assets to total assets. *Log(Q)* is the log of the average of firm market-to-book ratio. *Leverage Ratio* is the average ratio of book leverage to assets. Industry dummy is the dummy variables of six industries defined in the Venture Xpert Database. *T*-statistics are reported in parentheses in model (1). *Z*-statistics are reported in parentheses from model (2) to (4). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A. VC Incubation Period and Post-IPO Patenting

Dependent Variable	OLS Log(1+Post-IPO Patents)		Poisson Post-IPO Patents	
	(1)	(2)	(3)	(4)
	OLS	IV (GMM)	Poisson	IV Poisson
VC Incubation Period	0.039***	0.096***	0.028***	0.781***
	(5.17)	(2.78)	(7.89)	(2.79)
Firm Age at Initial VC Investment	-0.005*	-0.006**	-0.008***	0.014
	(-1.67)	(-2.07)	(-3.87)	(0.60)
Log(Assets)	0.030	0.042	0.161***	-0.404
	(0.62)	(0.80)	(5.99)	(-1.55)
Log(CAPEX)	0.086**	0.105**	0.235***	0.755***
	(2.18)	(2.40)	(10.20)	(3.42)
Number of Patents before VC investments	0.039***	0.037**	0.002	0.132**
	(2.62)	(2.36)	(0.39)	(2.17)
Has Patents before VC investments	0.696***	0.702***	0.841***	1.839***
	(8.36)	(7.27)	(23.34)	(4.75)
Tangibility Ratio	-0.612***	-0.678***	-1.402***	-1.593**
	(-2.82)	(-2.93)	(-9.66)	(-1.97)
Log(Q)	0.083**	0.090*	0.187***	0.618***
	(1.98)	(1.91)	(7.36)	(2.68)
Leverage Ratio	-0.850***	-0.540	-2.093***	-4.044**
	(-2.71)	(-1.62)	(-8.41)	(-2.31)
Industry Dummy	Yes	Yes	Yes	Yes
Intercept	0.119	-0.145	-0.412***	-2.139**
	(0.65)	(-0.58)	(-3.71)	(-2.41)
Under-identification Test	-	42.969***	-	-
Weak Identification Test	-	38.093***	-	-
Hansen's J Statistics	-	1.360	-	-
N	1327	1327	1327	1327

Table V (Continued)
Effect of VC Incubation Period on Post-IPO Patenting

Panel B contains estimates from the ordinary least squares (OLS), Poisson regression, and instrumental variable regressions of post-IPO patenting on *VC Experience*, *VC Incubation Period*, the interaction term of *VC Experience* and *VC Incubation Period*, and other control variables. *VC Experience* is the age of the lead VC at the initial VC investment date. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the firm's IPO date. *VC Experience*VC Incubation Period* is the multiple of *VC Experience* and *VC Incubation Period*. *Firm Age at Initial VC Investment* is the period from the founding date of the firm to the date of the initial VC investment. Averaged values for the following variables are calculated for the three years immediately prior to the firms' IPOs, including the IPO year, unless otherwise noted. *Log(Assets)* is the log of the average of firm assets. *Log(CAPEX)* is the log of the average of capital expenditures. *Number of Patents before IPO* is total number of patents before VC investment in the firm. *Has Patents before VC Investment* is a dummy variable equal to 1 if the firm has at least one patent before VC investment in the firm. *Tangibility Ratio* is the average ratio of fixed assets to total assets. *Log(Q)* is the log of the average of firm market-to-book ratio. *Leverage Ratio* is the average ratio of book leverage to assets. Industry dummy is the dummy variables of six industries defined in the Venture Xpert Database. *T*-statistics are reported in parentheses in model (1) and (2). *Z*-statistics are reported in parentheses in model (3) and (4). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel B. Effect of VC Experience and VC Incubation Period on Post-IPO Patenting

Dependent Variable:	**OLS** **Log(1+Post-IPO Patents)**		**Poisson** **Post-IPO Patents**	
	(1)	**(2)**	**(3)**	**(4)**
VC Experience	0.004*	0.005**	0.011***	0.009***
	(1.95)	(2.25)	(12.90)	(9.76)
VC Incubation Period	0.044***	0.051***	0.073***	0.072***
	(4.61)	(5.19)	(15.60)	(15.05)
VC Experience VC Incubation Period*		0.002***		0.002***
		(2.96)		(7.87)
Firm Age at Initial VC Investment	-0.004	-0.004	-0.003	-0.001
	(-1.35)	(-1.14)	(-1.17)	(-0.27)
Log(Assets)	0.036	0.043	0.244***	0.261***
	(0.64)	(0.78)	(7.96)	(8.47)
Log(CAPEX)	0.089*	0.085*	0.226***	0.219***
	(1.94)	(1.87)	(8.96)	(8.67)
Number of Patents before VC Investment	0.020	0.027	-0.024***	-0.019***
	(1.15)	(1.57)	(-3.49)	(-2.72)
Has Patents before VC investment	0.683***	0.674***	0.917***	0.926***
	(7.17)	(7.10)	(22.73)	(22.90)
Tangibility Ratio	-0.736***	-0.736***	-1.425***	-1.419***
	(-2.83)	(-2.84)	(-8.39)	(-8.36)
Log(Q)	0.048	0.044	0.106***	0.094***
	(1.01)	(0.93)	(3.81)	(3.41)
Leverage Ratio	-0.775**	-0.808**	-1.917***	-1.863***
	(-2.11)	(-2.20)	(-6.88)	(-6.71)
Industry Dummy	Yes	Yes	Yes	Yes
Intercept	0.055	-0.001	-1.215***	-1.236***
	(0.25)	(-0.00)	(-8.56)	(-8.72)
N	1049	1049	1049	1049
R^2	0.2796	0.2850	0.2774	0.2813

Table VI
Effect of VC Incubation Period on Post-IPO Performance and Survival

Estimates from the ordinary least squares (OLS) and the instrumental variable regressions of post-IPO firm performance and survival probabilities on *VC Incubation Period* and other control variables. The dependent variable in Models 1 and 2 is the three-year average of firm ROA minus the industry median ROA post-IPO. The dependent variable in Models 3 and 4 is the log of (1 + industry-adjusted Q), where the industry-adjusted Q is the three-year average of the firm Tobin's Q ratio minus the industry median Q ratio post-IPO. The dependent variable in Models 5 and 6 is a dummy variable equal to 1 if the firm is delisted within five years after the IPO for reasons other than mergers and acquisitions. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the firm's IPO date. *Firm Age at Initial VC Investment* is the period from the founding date of the firm to the date of the initial VC investment. Averaged values for the following variables are calculated for the three years immediately prior to the firms' IPOs, including the IPO year, unless otherwise noted. *Log(Assets)* is the log of the average of firm assets. *Log(CAPEX)* is the log of the average of capital expenditures. *Number of Patents before IPO* is total number of patents before VC investment in the firm. *Has Patents before VC Investment* is a dummy variable equal to 1 if the firm has at least one patent before VC investment in the firm. *Tangibility Ratio* is the average ratio of fixed assets to total assets. *Log(Q)* is the log of the average of firm market-to-book ratio. *Leverage Ratio* is the average ratio of book leverage to assets. Industry dummy is the dummy variables of six industries defined in the Venture Xpert Database. *T*-statistics are reported in parentheses for Models (1) and (3). *Z*-statistics are reported in parentheses for Models (2), (4) to (6). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent Variable	Industry-adjusted ROA		Industry-adjusted Q		Post-IPO Survival	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV (GMM)	OLS	IV (GMM)	Probit	IV Probit
VC Incubation Period	0.010***	0.039***	0.013**	0.152***	0.061***	0.126**
	(5.37)	(2.94)	(2.15)	(2.84)	(2.93)	(2.20)
Firm Age at Initial VC Investment	0.003***	0.005***	-0.004	-0.000	0.005	0.010
	(3.78)	(3.83)	(0.206)	(-0.04)	(0.75)	(1.38)
Log(Assets)	0.077***	0.061***	-0.107***	-0.228***	0.341***	0.224**
	(4.97)	(3.05)	(-2.87)	(-3.90)	(3.88)	(2.27)
Log(CAPEX)	0.030**	0.044***	0.034	0.095**	-0.105	-0.039
	(2.33)	(2.82)	(1.08)	(2.15)	(-1.40)	(-0.49)
Number of Patents before VC investments	-0.005	-0.003	0.015	0.028*	-0.042*	-0.035
	(-1.43)	(-0.84)	(1.35)	(1.83)	(-1.72)	(-1.41)
Has Patents before VC investments	0.011	0.030	-0.028	0.025	0.330*	0.345**
	(0.44)	(1.03)	(-0.33)	(0.25)	(1.91)	(1.99)
Tangibility Ratio	-0.048	-0.109	0.129	-0.064	0.501	-0.046
	(-0.71)	(-1.37)	(0.75)	(-0.26)	(1.28)	(-0.11)
Log(Q)	-0.002	0.011	0.784***	0.863***	0.225***	0.242***
	(-0.18)	(0.74)	(14.59)	(13.84)	(2.94)	(3.20)
Leverage Ratio	-0.344***	-0.356***	0.260	0.901**	-3.300***	-3.036***
	(-4.33)	(-3.08)	(1.09)	(2.23)	(-6.58)	(-4.82)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	-0.447***	-0.553***	-0.076	-0.430	-0.334	-2.540
	(-7.61)	(-6.76)	(-0.48)	(-1.55)	(-1.00)	(-0.62)
Under-Identification Test	-	58.955***	-	44.018***	-	-
Weak Identification Test	-	44.202***	-	30.822***	-	-
Hansen's J Statistics	-	0.801	-	0.447	-	-
Wald Test of Exgogeneity	-	-	-	-	-	1.29
N	1576	1430	1478	1334	1692	1537
R^2	0.1757	0.1059	0.2344	0.0522	0.1516	-

Table VII
Effect of VC Incubation Period Controlling for Survivorship Bias of IPO

Estimates from the Heckman's two-step procedure of the incubation period, correcting for the survivorship bias of IPO. The dependent variable in Model 1 is the log of (1 + number of patents firms received within the three years post-IPO) The dependent variable in Model 2 is the three-year average of firm ROA minus the industry median ROA post-IPO. The dependent variable in Model 3 is the log of (1 + industry-adjusted Q), where the industry-adjusted Q is the three-year average of firm Tobin's Q ratio minus the industry median Q ratio post-IPO. The dependent variable in Model 4 is a dummy variable equal to 1 if the firm is delisted within five years after its IPO for reasons other than mergers and acquisitions. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the date of the firm's IPO. *Firm Age at Initial VC Investment* is the period from the founding of the firm to the date of the firm's initial VC investment. Averaged values for the following variables are calculated for the three years immediately prior to the firms' IPOs, including the IPO year, unless otherwise noted. *Log(Assets)* is the log of the average of firm assets. *Log(CAPEX)* is the log of the average of capital expenditures. *Number of Patents before IPO* is total number of patents before VC investment in the firm. *Has Patents before VC Investment* is a dummy variable equal to 1 if the firm has at least one patent before VC investment in the firm. *Tangibility Ratio* is the average ratio of fixed assets to total assets. *Log(Q)* is the log of the average of firm market-to-book ratio. *Leverage Ratio* is the average ratio of book leverage to assets. Industry dummy is the dummy variables of six industries defined in the Venture Xpert Database. *Z*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependenant Variable	**Patent**	**Industry-adjusted ROA**	**Industry-adjusted Q**	**Post-IPO Survival**
	(1)	**(2)**	**(3)**	**(4)**
VC Incubation Period	0.041***	0.010***	0.013*	0.060***
	(5.36)	(4.47)	(1.81)	(3.82)
Firm Age at Initial VC	-0.005*	0.003***	-0.004	0.004
Investment	(-1.76)	(3.55)	(-1.64)	(0.95)
Log(Assets)	0.020	0.078***	-0.105**	0.330***
	(0.42)	(5.89)	(-2.46)	(4.18)
Log(CAPEX)	0.091**	0.030***	0.033	-0.101
	(2.32)	(2.73)	(0.90)	(-1.57)
Number of Patents before VC	0.039***	-0.005	0.015	-0.041*
investments	(2.62)	(-1.34)	(1.17)	(-1.86)
Has Patents before VC	0.688***	0.012	-0.025	0.317**
investments	(8.30)	(0.48)	(-0.33)	(1.96)
Tangibility Ratio	-0.621***	-0.048	0.131	0.494
	(-2.89)	(-0.75)	(0.64)	(1.37)
Log(Q)	0.082**	-0.002	0.786***	0.218***
	(1.97)	(-0.18)	(19.18)	(3.00)
Leverage Ratio	-0.783**	-0.347***	0.237	-3.210***
	(-2.50)	(-3.80)	(0.79)	(-6.58)
Industry Dummy	Yes	Yes	Yes	Yes
Intercept	0.671*	-0.474***	-0.324	0.110
	(1.95)	(-4.56)	(-0.95)	(0.17)
Selection Model				
Log(Number of VC	0.046***	0.053***	0.054***	0.052***
Investments)	(7.43)	(9.03)	(9.06)	(9.17)
Earlystage	-0.107***	-0.083***	-0.089***	-0.082***
	(-3.54)	(-2.90)	(-3.06)	(-2.91)
Nerwork	0.098***	0.104***	0.114***	0.102***
	(3.30)	(3.73)	(4.02)	(3.72)
Beginning Sentiment	-0.274***	-0.231***	-0.221***	-0.232***
	(-12.99)	(-11.60)	(-10.92)	(-11.87)
Industry Dummy	Yes	Yes	Yes	Yes
N	20776	21025	20927	21141

Table VIII
Effect of VC Incubation Period Controlling for Selection Bias of VC Financing

Estimates from Heckman's two-step procedure of the incubation period, correcting for the survivorship bias of VC financing. The dependent variable in Model 1 is the log of (1 + number of patents firms received within the three years post-IPO). The dependent variable in Model 2 is the three-year average of firm ROA minus the industry median ROA post-IPO. The dependent variable in Model 3 is the log of (1 + industry-adjusted Q), where the industry-adjusted Q is the three-year average of firm Tobin's Q ratio minus the industry median Q ratio post-IPO. The dependent variable in Model 4 is a dummy variable equal to 1 if the firm is delisted within five years after its IPO for reasons other than mergers and acquisitions. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the date of the firm's IPO. *Firm Age at Initial VC Investment* is the period from the founding of the firm to the date of the firm's initial VC investment. Averaged values for the following variables are calculated for the three years immediately prior to the firms' IPOs, including the IPO year, unless otherwise noted. *Log(Assets)* is the log of the average of firm assets. *Log(CAPEX)* is the log of the average of capital expenditures. *Number of Patents before IPO* is total number of patents before VC investment in the firm. *Has Patents before VC Investment* is a dummy variable equal to 1 if the firm has at least one patent before VC investment in the firm. *Tangibility Ratio* is the average ratio of fixed assets to total assets. *Log(Q)* is the log of the average of firm market-to-book ratio. *Leverage Ratio* is the average ratio of book leverage to assets. Industry dummy is the dummy variables of six industries defined in the Venture Xpert Database. *Z*-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependenant Variable	**Patent**	**Industry-adjusted ROA**	**Industry-adjusted Q**	**Post-IPO Survival**
VC Incubation Period	0.040***	0.010***	0.012*	0.061***
	(5.27)	(4.45)	(1.77)	(3.87)
Firm Age at Initial VC Investment	-0.003	0.003***	-0.005**	0.005
	(-1.03)	(3.40)	(-2.02)	(0.97)
Log(Assets)	0.026	0.078***	-0.105**	0.341***
	(0.55)	(5.90)	(-2.47)	(4.40)
Log(CAPEX)	0.087**	0.030***	0.033	-0.105
	(2.21)	(2.73)	(0.92)	(-1.62)
Number of Patents before VC investments	0.041***	-0.005	0.015	-0.042*
	(2.74)	(-1.35)	(1.15)	(-1.86)
Has Patents before VC investments	0.691***	0.011	-0.029	0.331**
	(8.38)	(0.47)	(-0.38)	(2.02)
Tangibility Ratio	-0.544**	-0.050	0.102	0.506
	(-2.53)	(-0.79)	(0.50)	(1.39)
Log(Q)	0.065	-0.002	0.793***	0.223***
	(1.55)	(-0.14)	(19.32)	(3.07)
Leverage Ratio	-0.735**	-0.350***	0.186	-3.286***
	(-2.36)	(-3.84)	(0.62)	(-7.12)
Industry Dummy	Yes	Yes	Yes	Yes
Intercept	0.424**	-0.462***	-0.266	-0.303
	(2.12)	(-7.92)	(-1.40)	(-0.89)
Selection Model				
Firm Industry and State Dummy	Yes	Yes	Yes	Yes
Firm Founded before 1980	Yes	Yes	Yes	Yes
N	4742	5215	5117	5331

Table IX
Effect of VC Incubation Period: Panel Regressions

Estimates from panel regressions of post-IPO patent counts and three measures of returns on assets for VC incubation period and control variables. In Models 1 and 2, the dependent variable is the log of (1 + the number of patents granted to the firm in the observation year). In Models 3 and 4, the dependent variable is the industry-adjusted ROA in the observation year. In Models 5 and 6, the dependent variable is the log of (1 + industry-adjusted Q) in the observation year. The observation year is from one to three years after the IPO. *VC Incubation Period* is the period from the date of the initial VC investment in the firm to the date of the firm's IPO. *Firm Age at Initial VC Investment* is the period from the founding of the firm to the date of the firm's initial VC investment. Averaged values for the following variables are calculated for the three years immediately prior to the firms' IPOs, including the IPO year, unless otherwise noted. *Log(Assets)* is the log of the average of firm assets. *Log(CAPEX)* is the log of the average of capital expenditures. *Number of Patents before IPO* is the total number of patents before VC investment in the firm. *Has Patents before VC Investment* is a dummy variable equal to 1 if the firm has at least one patent before VC investment in the firm. *Tangibility Ratio* is the average ratio of fixed assets to total assets. *Log(Q)* is the log of the average of firm market-to-book ratio. *Leverage Ratio* is the average ratio of book leverage to assets. Industry dummy is the dummy variables of six industries defined in the Venture Xpert Database. *T*-statistics are reported in parentheses in model (1), (3), and (5). *Z*-statistics are reported in parentheses in model (2), (4), and (6). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent Variable	Patent		Industry-adjusted ROA		Industry-adjusted Q	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV (GMM)	OLS	IV (GMM)	OLS	IV (GMM)
VC Incubation Period	0.018***	0.061***	0.011***	0.050***	0.001	0.083**
	(5.24)	(5.55)	(8.04)	(5.40)	(0.26)	(2.36)
Firm Age at Initial VC Investment	-0.003***	-0.003**	0.004***	0.006***	-0.005**	-0.003
	(-2.81)	(-2.44)	(5.69)	(5.86)	(-2.07)	(-1.02)
Log(Assets)	-0.019	-0.020	0.084***	0.078***	-0.077***	-0.117***
	(-1.30)	(-1.18)	(8.00)	(6.19)	(-2.82)	(-3.64)
Log(CAPEX)	0.054***	0.065***	-0.005	0.002	-0.023	-0.013
	(4.11)	(4.37)	(-0.64)	(0.87)	(-1.01)	(-0.47)
Number of Patents before VC investments	0.013*	0.014*	-0.011***	-0.007*	0.006	0.016
	(1.65)	(1.75)	(-3.00)	(-1.91)	(0.67)	(1.56)
Has Patents before VC investments	0.357***	0.362***	0.028	0.059**	0.056	0.094
	(8.11)	(8.04)	(1.36)	(2.53)	(0.99)	(1.50)
Tangibility Ratio	-0.390***	-0.406***	0.184***	0.141**	0.413***	0.413***
	(-5.10)	(-4.31)	(3.90)	(2.35)	(3.18)	(2.60)
Log(Q)	0.096***	0.097***	0.058***	0.068***	0.657***	0.684***
	(7.58)	(7.28)	(6.23)	(6.78)	(19.69)	(19.37)
Leverage Ratio	-0.102	0.044	-0.108***	-0.100	0.243	0.489**
	(-1.36)	(0.49)	(-2.13)	(-1.47)	(1.56)	(2.32)
Industry Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Intercept	0.177***	-0.008	-0.550***	-0.766***	-0.065	-0.412*
	(2.75)	(-0.09)	(-12.22)	(-11.22)	(-0.57)	(-1.95)
Under-Identification Test	-	173.896***	-	144.315***	-	113.653***
Weak Identification Test	-	174.165***	-	136.603***	-	103.339***
Hansen's J Statistics	-	2.698	-	0.072	-	0.316
N	3899	3531	3515	3185	3184	2862