The Life Cycle of Corporate Venture Capital

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Abstract

This paper establishes the life-cycle dynamics of Corporate Venture Capital (CVC) to explore the information-acquisition role of CVC investment in the process of corporate innovation. I exploit an identification strategy that allows me to isolate exogenous shocks to a firm's ability to innovate. Based on this strategy, I first find that the CVC life cycle typically begins following a period during which corporate innovation has deteriorated and external information is valuable, lending support to the hypothesis that firms conduct CVC investment to acquire information and innovation knowledge from startups. Building on this analysis, I show that CVCs acquire information by investing in companies that are technologically proximate but have a different knowledge base. Following CVC investment, parent firms internalize the acquired knowledge into internal R&D and external acquisition decisions. Human capital renewal, such as hiring additional inventors who are capable of integrating new innovation knowledge, is integral in this step. The CVC life cycle lasts about four years, terminating as innovation in the parent firms rebounds. These findings shed new light on discussions about firm boundaries, managing innovation, and corporate information choices.

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One important theme in economics is to understand how to make investment, organizational, and financial decisions to achieve innovation and long-term growth.[1] Under this theme, financial economists devoted tremendous efforts to understanding the economics of financing innovation by examining such activities as internal research and development, mergers and acquisitions, strategic alliances.[2] However, the map to innovation and long-term growth is far from complete (Lerner, 2012).

This paper attempts to contribute to this broad agenda by studying financing innovation through the lens of Corporate Venture Capital (CVC), an emerging yet understudied piece in the innovation puzzle. Unlike producing innovation internally (e.g., R&D) or purchasing external innovation (e.g., M&A), Corporate Venture Capital (CVC) divisions are created by established corporations to make systematic minority equity investments in early-stage entrepreneurial ventures. As an illustration, consider GM Ventures, the CVC unit of General Motors that was initiated in 2010. On behalf of GM, GM Ventures invested in dozens of auto-related technological startups through minority equity stakes, covering automotive cleantech, advance materials, among other fields. The case of GM Ventures is hardly an isolated occurrence. According to National Venture Capital Association (NVCA), CVC investments account for about 20% of VC investment in 2015,[3] and are undertaken not only by technology firms in the media spotlight (such as Google Venture and Intel Capital), but also are commonly used by moderate-size firms in a variety of industries.

Firms argue that they conduct CVC investment to acquire information—that is, to get exposures to new technologies and markets, which in turn will benefit the incumbent firms' innovation and broader corporate decisions (Siegel et al., 1988; Macmillan et al., 2008).[4] As remarked by GM Ventures, their mission as a CVC is to "invest in growth-stage

[1]See, e.g., Schumpeter (1942), Arrow (1962), Aghion and Tirole (1994), and Klette and Kortum (2002). This topic is crucial to understanding broad economic questions, including economic growth and productivity (Bloom, Schankerman, and Van Reenen, 2013; Aghion, Akcigit, and Howitt, 2013; Acemoglu, Akcigit, Bloom, and Kerr, 2013), finance (Brown, Fazzari, and Petersen, 2009; Hall and Lerner, 2010), entrepreneurship (Acemoglu and Cao, 2015; Chemmanur, Loutskina, and Tian, 2013), and organizational economics (Fulghieri and Sevilir, 2009; Hackbarth et al., 2012).

[2]See, e.g., Brown et al. (2009), Manso (2011), Seru (2014), Bena and Li (2014), Robinson (2008), among others.

[3]In 1999 and 2000, CVC investment peaked at almost $20 billion a year. Although the numbers throughout the VC industry fell in the 2000s, CVC growth has rebounded in recent years (37% increase in 2015, 69% increase in 2014, according to NVCA).

[4]Startups are an important source of technological and market knowledge, as well as innovative ideas

companies to enhance GM's ability to innovate." Theoretically, this "information acquisition" rationale echoes the long-lasting framework in the economics of managing and organizing innovation, dating back at least to Nelson (1982).[5] The innovation process is typically framed as a two-stage sequential process, in which firms "acquire information and generate ideas" (first stage) before they "invest in and produce those ideas" (second stage). Including this information-acquisition stage in studying innovation can reconcile many important patterns in economic growth and innovation dynamics (Jovanovic and Rob, 1989; Kortum, 1997).[6] Despite the importance of acquiring information, very little empirical work has studied how firms organize their investment to achieve this goal. Focusing on CVC, therefore, provides a unique empirical setting to understand how firms search and generate new ideas in the broad innovation process.

Motivated by CVCs' empirical significance and value for understanding the process of innovation, the main part of this paper develops empirical tests to assess CVC's role of acquiring information. Those tests examine each stage of a CVC, from why it is initiated, to how it is operated, to when it is terminated. The results help to establish an investment pattern of how CVC fits into the process of corporate innovation—labeled as the *CVC life cycle*—deteriorating incumbents in need of information launch CVC; they actively invest in and utilize valuable information and knowledge; and CVCs are terminated after firms regain innovation therefore informational benefit shrinks—lending support to the information-acquisition rationale. Built on this finding, this paper further explores alternative forces that could determine CVC investment and the management of innovation in general, and the implication of CVC on corporate innovation at both firm- and industry- levels. Figure 1 summarizes the CVC life cycle.

(Scherer, 1965; Acs and Audretsch, 1988; Kortum and Lerner, 2000; Zingales, 2000).

[5]See also Nelson and Winter (1982); Dosi (1988); Fleming and Sorenson (2004); Frydman and Papanikolaou (2015), among others.

[6]Existing studies have overwhelmingly focused on the second stage of the innovation process—investing and organizing innovation with an exogenous idea and pre-determined informational structure. Aghion and Tirole (1994) model several cases in which, taking the research idea and informational environment as given, equity investment is optimal to provide incentive for R&D projects; Mathews (2006) and Fulghieri and Sevilir (2009) study the problem of strategic equity investment from the industrial organization perspective, and theorize the benefits of coordinating market entry and obtaining competitive advantages; Hellmann (2002) emphasizes that asset complementarity and product market synergies lead firms to invest in synergistic entrepreneurial ventures, particularly when external financing is costly (Allen and Phillips, 2000).

[FIGURE 1 AROUND HERE]

The CVC life cycle begins with the *initiation* stage in which a firm launches CVC investment, typically following a deterioration in internal innovation. That is, when firms have lower productivity in generating ideas and producing innovation internally, therefore could benefit more from potential informational gains from connecting to highly innovative entrepreneurs, they are more likely to initiate CVC investment. Quantitatively, a two-standard-deviation decline in innovation quantity (quality) increases the probability that a firm will initiate CVC by about 52% (67%). Firms in the same industry cluster in their CVC activities when their industry experiences technological shocks, forming "industry CVC waves."

To mitigate the concern that innovation capability is endogenously determined, I identify plausibly exogenous shocks to firms' ability to generate ideas and produce innovation. The instrumental variable, *Knowledge Obsolescence*, captures the evolution of usefulness of a firm's knowledge base accumulated in the past, which results from exogenous technological evolution, but is independent to such endogenous factors as corporate governance, and product market status. Additionally, several potential alternative interpretations of the result, such as the effects of financial constraints and excess cash, do not explain this finding.

How do CVCs select and utilize information and innovative knowledge? At the *operation* stage of the CVC life cycle, I first examine how CVCs strategically choose portfolio companies to acquire information from. I find that CVCs primarily invest in startups that are innovating in technological areas that are close to the CVC parent, suggesting that CVCs prefer to invest in companies whose technologies can be adapted to the parent firms' innovation. Moreover, the portfolio companies appear to possess incremental knowledge, measured using less overlaps of innovation profiles and patent citations, which suggests that CVC parents aim to acquire updated knowledge with higher informational gain.[7] This means, for example, an automobile CVC parent firm is likely to invest in an engine startup, particularly when this startup specializes in cutting-edge clean-tech that the outdated parent firm does not possess.

[7]Interestingly, CVC investment appears to have a "reverse home bias"—even though CVCs are less likely to invest in geographically distant companies, they are also less likely to invest in companies in their own geographic regions, from which they may acquire information through local innovation spillover (Peri, 2005; Matray, 2014).

I perform two analyses to isolate how CVC-acquired information is incorporated into parent firms. First, CVC parent firms appear to internalize acquired knowledge by conducting research involving more intense usage of the new information acquired from their portfolio companies. Second, the informational benefit is also capitalized through increased efficiency when making information-sensitive decisions, such as external acquisitions of companies and innovations. Moreover, human capital renewal, such as hiring additional inventors who are capable of using the newly acquired knowledge, is integral to this information acquisition and integration.

The CVC life cycle ends with the *termination* stage as CVC parents stop making incremental investment in startups, typically when internal innovation begins to recover. The median duration of the life cycle is about four years. When CVC divisions last more than four years, firms typically hibernate CVC activities during years when internal innovation remains productive. This evidence is consistent with the information-acquisition rationale, which predicts decreased CVC activity when the marginal benefit shrinks after information is assimilated into parent firms. Interestingly, if innovation again deteriorates at the parent firm, the CVC life cycle begins anew.

All told, this paper presents the CVC life cycle in the course of examining CVC's role of acquiring information in the process of innovation. Essentially, CVC serves as a transitory information-acquiring step in regaining an upward innovation trajectory, typically after a firm experiences a deterioration in internal innovation. Centered around this overview, Section I discusses how to understand the information-acquisition rationale of CVC from various aspects, and its implications on corporate finance and entrepreneurial finance. We will then move on to data construction (Section II) and each stage of the CVC life cycle (Section III to V). Section VI concludes.

I. Discussion and Literature

The life-cycle pattern lends support to the "information acquisition" view of Corporate Venture Capital. How does this rationale help understand existing evidence on CVC activities; what trade offs do entrepreneurs face when accepting CVC investment and sharing their knowledge; how do CVC and its role of acquiring information fit into the innovation process; and what are some other forces that could shape CVC behaviors? This section discusses the implications of CVC and its information-acquisition rationale on corporate finance and entrepreneurial finance, in light of those specific questions.

A. Reconciling Existing CVC Evidence

An emerging literature, at the intersection of economics, finance, and strategy, attempts to understand the function and influence of CVC (Dushnitsky, 2006; Maula, 2007; Lerner, 2012; Chemmanur and Fulghieri, 2014). This paper adds to this literature in three ways. First, this paper asks an under-explored question on CVC and financing innovation. It deviates from the existing framework that takes CVC as given,[8] by asking for the economic rationale behind CVC investment and it role in the innovation process. The empirical analysis in this paper complements earlier work that surveyed corporate venture capitalist regarding their motivation.

Second, in the course of answering the question, this paper attempts to make two empirical contributions. I characterize the full CVC life-cycle dynamics from initiation to operation to termination, differing from existing approaches which typically focus on a single phase in CVC activities. Additionally, by collecting a large and longer sample of CVCs accompanied by detailed innovation, investment, and entrepreneurship records, this paper could better control for influences of superstar CVC cases (such as Google Venture and Intel Capital), specific industries, or specific time periods, therefore offer many findings that could be masked otherwise.

Third, conceptually, this paper studies the information-acquisition step of corporate innovation through the lens of CVC. This rationale, formally explored in this paper,[9] helps to explain CVCs' active participation in the due diligence of the startups (Henderson and Leleux, 2002), obtaining (sometimes non-voting) board seats (Maula et al., 2001; Bottazzi,

[8]See, e.g., Siegel, Siegel, and MacMillan (1988); Gompers and Lerner (2000); Bottazzi, Da Rin, and Hellmann (2004); Dushnitsky and Lenox (2006); Benson and Ziedonis (2010); Chemmanur, Loutskina, and Tian (2013); Dimitrova (2013); Ceccagnoli, Higgins, and Kang (2015); Wadhwa, Phelps, and Kotha (2015).

[9]Closer to this paper, Dushnitsky and Lenox (2005a) and Basu et al. (2011) indirectly support the information acquisition rationale of CVC by studying environmental variables affecting the efficiency of information acquisition with analyses tilted toward industry-level factors.

Da Rin, and Hellmann, 2004), and creating communication platforms for inventors in both the parent firm and entrepreneurial ventures (Dushnitsky and Lenox, 2005b). This information acquisition rationale is also consistent with the flexibility and lower adjustment cost (Lerner, 2012) of CVC, which enables firms to respond quickly, to change course easily (abandon a project with less sunk costs), and to leverage outside funding sources.[10]

B. *Entrepreneurs' Cost and Benefit*

The life-cycle CVC investment pattern and the information acquisition rationale lean heavily on the fact that entrepreneurs are willing to channel their knowledge to CVC investors. But what are the benefits for entrepreneurs from the relationship with CVC, which supports their willingness to share information? First of all, early research finds that CVC investors can better nurture innovative entrepreneurs by providing technical support and tolerating riskier projects. Consistent with this argument, Gompers and Lerner (2000) and Chemmanur, Loutskina, and Tian (2013) show that entrepreneurial companies backed up by CVCs have higher possibility of successful exit and become more innovative after the investment. Secondly, building relations with established corporations through CVC investment increases the potential for future business. Ceccagnoli et al. (2015) show that an ex ante CVC relation increases the possibility of ex post technology licensing. Last but not least, accepting CVC's equity investment actually aligns the interests of the startup and the CVC investor, working as an insurance against competitive behaviors from the incumbents (Mathews, 2006).

Admittedly, the efficiency of information acquisition factors in how entrepreneurs trade off the cost and benefit of receiving CVC investment. Hellmann (2002) and Hellmann (1998) discuss this problem and analyze reasons that entrepreneurs might prefer CVC over alternative entrepreneurial investment—a more formal test of the model will rely on detailed startup financing data which is beyond the scope of this paper.

[10] Indeed, this learning process often does not involve later asset consolidation (Dimitrova, 2013).

C. CVC and the Innovation Process

This paper highlights the information-acquisition step in the innovation process (Nelson, 1982), complementing existing studies that typically assume that the information structure is predetermined (Aghion and Tirole, 1994; Robinson, 2008; Bena and Li, 2014; Seru, 2014). This is in the same spirit as the recent endeavor of incorporating information acquisition in financial economics, which studies how economic agents search, process, and use information to guide their information-sensitive decisions.[11]

Second, the framework gives us the opportunity to not only study CVC alone, but also explicitly identify the process of integrating CVC-acquired knowledge into R&D and acquisition decisions. Ideally, these analyses can be viewed as stepping stones toward understanding the whole system of financing and organizing innovation, in which different organizational structures interact with each other in the dynamic innovation process.

D. Alternative CVC Rationales

A nice feature of this life-cycle finding is that we can analyze several alternative CVC rationales through extending the framework. Early research on CVC and the general strategic investment proposed many economic forces that could shape CVC activities (Allen and Phillips, 2000; Hellmann, 2002; Mathews, 2006; Fee et al., 2006; Fulghieri and Sevilir, 2009). Results suggest that such factors as corporate governance, financial constraint, and purely outsourcing innovation seem to be secondary to the intention to acquire valuable technological knowledge from startups. Exhausting all potential economic forces that could affect CVC. which is definitely of interests, is beyond the scope of this paper. However, the extensions provided intend to provide a overview of those forces surrounding the central theme of information acquisition.

[11] See, for example, Dow and Gorton (1997); Chen, Goldstein, and Jiang (2007); Van Nieuwerburgh and Veldkamp (2010); Bond, Edmans, and Goldstein (2012); Yang (2013).

II. Sample and Data

I exploit a hand-collected sample of Corporate Venture Capital units affiliated with US-based public firms. I start with a list of CVCs identified by the VentureXpert Venture Capital Firms database (accessed through Thomson Reuters SDC Platinum), which is standard in VC studies (Chemmanur, Loutskina, and Tian, 2013). For each CVC on the list, it is manually matched to its unique corporate parent in Compustat by checking multiple sources (Factiva, Google, etc.). I remove VC divisions operated by financial firms, which are different from CVC arms of industrial firms (Hellmann, Lindsey, and Puri, 2008). From VentureXpert I obtain the investment history of each CVC, including basic information about the startup companies it invests in, and the timing and features of each CVC deal.

[TABLE I AROUND HERE]

The main sample consists of 381 CVC firms initiated between 1980 and 2006.[12] Table I summarizes this CVC sample by tabulating the time-series dynamic and the industry composition. Panel A presents the number of CVC division initiations and investment deals by year. CVC activities are heavily concentrated in the first half of the 1980s and the second half of the 1990s. This is consistent with existing studies on "CVC waves" (Gompers and Lerner, 2000; Dushnitsky, 2006) and will be revisited and refined in Section III.C. Panel B summarizes the industry distribution of CVC parent firms, where industries are defined by the Fama-French 48 Industry Classification. The Business Services industry (including IT) was the most active sector in CVC investment, with 90 firms investing in 821 venture companies. Electronic Equipment firms initiated 46 CVC divisions that invested in 921 companies. Pharmaceutical firms launched 28 CVCs and invested in 254 deals. Other active sectors include Computers and Communications.

The CVC sample is augmented with Compustat for financial statement data and with CRSP for stock market performance. Variable constructions are described in the Appendix. All data items are pre-winsorized at the 1% and 99% levels. SDC Platinum provides organizational information on mergers and acquisitions and strategic alliances. For corporate

[12] I focus on CVCs initiated no later than 2006 to allow for investment behaviors to realize (after 2006) and to ensure the quality of the innovation database, as will be described later.

governance data, I extract institutional shareholding information from the WRDS Thomson Reuters 13(f) data and obtain G-index data from Andrew Metrick's data library.[13]

Innovation is a crucial data component of this paper for three reasons. First, innovation knowledge generated in the entrepreneurial sector could create great value for CVC parent firms (Scherer, 1965; Acs and Audretsch, 1988; Kortum and Lerner, 2000; Macmillan et al., 2008), therefore it is an important part of the information set that CVCs intend to acquire. Second, the comprehensive innovation data creates a valuable setting to measure informational relationship (Bena and Li, 2014) and knowledge flows (Gomes-Casseres et al., 2006; Gonzalez-Uribe, 2013). Third, the quality of detailed innovation data maintained and updated by the United States Patent and Trademark Office (USPTO) is superior to most alternative data sources on corporate activities.

I obtain the basic innovation data from the NBER Patent Data Project and from Bhaven Sampat's patent and citation data.[14] The combined database provides detailed patent-level records on more than 3 million patents granted by USPTO between 1976 and 2012. I link this database to Compustat using the bridge file provided by NBER. Beyond the standard database, I also introduce several data sets and cleaning procedures that are relatively new to the literature (detailed in related sections and the Appendix)—I link the USPTO database to entrepreneurial companies in VentureXpert using a fuzzy matching method based on company name, basic identity information, and innovation profiles, similar to Gonzalez-Uribe (2013) and Bernstein, Giroud, and Townsend (2014); I also introduce the Harvard Business School inventor-level database in order to examine how firms adjust their innovative human capital as a specific channel to facilitate information acquisition and integration; at last, I introduce the Google Patent Assignment and Reassignment database, which tracks all the transactions of each patents.

The combined innovation data provides three layers of innovation information that is helpful for the analysis. First, I employ two main variables to measure basic corporate innovation performance. I measure innovation *quantity* by calculating the number of patent

[13]Accessed using `http://faculty.som.yale.edu/andrewmetrick/data.html`.

[14]For more information on the NBER Patent Data Project, please refer to Hall, Jaffe, and Trajtenberg (2001). The data used in this paper were downloaded from `https://sites.google.com/site/patentdataproject/`. Sampat's data can be accessed using `http://thedata.harvard.edu/dvn/dv/boffindata`.

applications, which are eventually granted, filed by a firm in each year. I use the patent's year of application instead of the year it is granted because that better captures the actual timing of innovation. I use the logarithm of one plus this variable, that is, $\ln(1+NewPatent)$ (denoted as $\ln(NewPatent)$), to fix the skewness problem for better empirical properties. I measure the *quality* of innovation, based on the average lifetime citations of all new patents produced by a firm in each year. Similar to the logarithm transformation performed on *quantity*, I use $\ln(1 + Pat.Quality)$ (denoted as $\ln(Pat.Quality)$).

The second layer of innovation data is citations firms make in their own patents. By tracking those citations a firm makes, we can measure the technological areas the firm works at and the specific underlying technologies. Moreover, examining the citation network among firms (including both established firms and startups) allows to construct variables capturing the technological relation between CVCs and startups and to measure dynamic information flows between firm pairs.

The third layer of innovation data concerns the micro-level information beyond patents. the inventors (engineers, scientists, etc.) who contributed to a firm's patents and their mobility. As shown in Gonzalez-Uribe (2013), Bernstein, Giroud, and Townsend (2014), and Brav et al. (2015), inventor-level information can help us imply the motivation behind corporate activities from the perspective of labor adjustment. Secondly, I construct a full set of patent transactions from the Google Patent database, and this panel of patent life cycles allows me to examine how information acquisition improves the efficiency in the market for technologies.

III. CVC Initiations: The Effect of Innovation Deterioration

Why do firms initiate CVC programs? Under the information acquisition view of Corporate Venture Capital, capacity-constrained firms trade off between acquiring information for new ideas and producing existing ideas. The allocation of capacity to information acquisition is determined by the quantity and quality of existing ideas available to the firm—the fewer (lower) the quantity (quality) of existing innovation ideas become, the more likely the firm implement information-acquisition strategies, such as CVC, in search for better innovation paths.

Figure 2 visualizes CVC parent firms' innovation dynamics before initiating their CVC divisions. Innovation performance, measured by patenting quantity (Panel (a)) and quality (Panel (b)), is tracked for five years from $t-4$ to t (t is the year of CVC initiation). Firm-year measures are adjusted by the averages of all peer firms in the same 3-digit SIC industry in the same year to exclude the influence of industry-specific time trends.

[FIGURE 2 AROUND HERE]

Panel (a) tracks innovation quantity of CVC parent firms, measured by the logarithm of the number of new patent applications. Four years before initiating their CVC units, CVC parents were significantly more innovative than their peers and on average doubled their peers' patent production. This advantage shrinks continuously by about 25% until year t. In Panel (b), CVC parent firms' innovation enjoys 15% higher average citations compared to their industry peers in $t-4$, and this number decreases to well below 0 at the time of CVC initiation. In untabulated results, I find that the performance deterioration pattern is robust to measures of product market performance, that is, ROA and sales growth. Overall, Figure 2 presents a clear pattern at the start of the CVC life cycle—that is, CVC initiations typically follow deteriorations in parent firms' internal innovation, which is consistent with the information acquisition view of CVC.

Building on Figure 2, this section will proceed by first confirming the relation between innovation deterioration and CVC initiation using a simple empirical setting. Then, I will explore an identification strategy which will control several endogeneity concerns, and sharpen the role of information acquisition motive by analyzing several alternative explanations of the pattern. Firm-level CVC initiation decisions will be aggregated to an industry-level pattern, which presents how the information-acquisition function fits into the technological evolution in each industry.

A. Baseline Results

To statistically identify the effect of innovation performance on CVC initiations, I start by estimating the following specification using a panel data of firm-year observations:

$$I(CVC)_{i,t} = \alpha_{industry \times t} + \beta \times \Delta_{\tau} Innovation_{i,t-1} + \gamma \times X_{i,t-1} + \varepsilon_{i,t}, \quad (1)$$

where $I(CVC)_{i,t}$ is equal to one if firm i launches a CVC unit in year t, and zero otherwise.[15] $\Delta_{\tau} Innovation_{i,t-1}$ is the change of innovation over the past τ years ending in $t-1$. I use a three-year ($\tau = 3$) innovation shock throughout the main analysis and report robustness checks using other horizons in the Appendix. Firm-level controls $X_{i,t-1}$ include ROA, size (logarithm of total assets), leverage, and R&D ratio (R&D expenditures scaled by total assets). Industry-by-year fixed effects are included to absorb industry-specific time trends in CVC activities and innovation. A negative β indicates that the probability of starting a CVC increases with innovation deterioration.

A.1. Summary Statistics

Table II presents descriptive statistics based on whether a CVC division is initiated in the firm-year. Only observations with valid ROA, size, leverage, R&D ratio, and at least $10 million in book assets are kept in the sample. Only "innovative firms," defined as those that filed at least one patent application that was eventually granted by the USPTO, are included in the panel sample. Industries (3-digit SIC level) with no CVC activities during the sample period are removed.

Table II provides a benchmark to position CVC parent firms in the Compustat universe of publicly traded corporations. First, CVC parents are typically large firms. On average, a CVC parent has $10.1 billion in book assets in 2007 USD (median is $2.4 billion) just before launching its CVC unit, while non-CVC parent firms have less than $3 billion in book

[15]Dummy variable $I(CVC)_{i,t}$, instead of the size of CVC investment each year, is more appropriate to capture the corporate decision on CVC investment for two reasons: (1) the decision to start a CVC unit is at the executive level, whereas the size of investment in subsequent years is plausibly determined by the CVC team; and (2) the data of investment size in VentureXpert has potential sample selection issues such as CVCs strategically hiding good deals they invested in (to avoid competition from other CVCs). I report the analysis on annual CVC investment size as an important result in Section V.

assets (median is \$0.2 billion). Second, CVC parent firms are innovation intensive in terms of patenting quantity, echoing the size effect. Third, corporate governance variables are comparable between the two subsamples. Overall, the basic characteristics are consistent with existing stylized facts that CVC parent firms tend to be larger corporations with more business resources (Dushnitsky and Lenox, 2005a; Basu, Phelps, and Kotha, 2011).

[TABLE II AROUND HERE]

Consistent with Figure 2, CVC parent firms on average experience more negative innovation shocks before starting their CVC divisions. CVC parents on average experience a -7% (-10%) change in patenting quantity (quality) three years before launching their CVC units, compared to the control firms, which experience a 12% (8%) shock. Similar to the deterioration in innovation, CVC parents appear to underperform in terms of ROA and market-to-book ratio before CVC initiations.

A.2. Results

[TABLE III AROUND HERE]

Table III presents the estimation results of model (1). Columns (1) and (2) focus on the effect of changes in innovation quantity. In column (1), the model is estimated using Ordinary Least Squares (OLS). The coefficient of -0.007 is negative and significant, meaning that a more severe decline in innovation quantity in the past three years is associated with a higher probability of initiating CVC investment. This estimate translates a two-standard-deviation decrease (2σ-change) in $\Delta \ln(NewPatent)$ into a 51.54% increase from the unconditional probability of launching CVCs. Column (2) reports the model estimation from a Logit regression and I report the marginal effect evaluated at sample mean. Column (2) delivers an almost identical message as column (1).

Columns (3) and (4) study the effect of deterioration in innovation quality and use OLS and Logit, respectively. In column (3), the coefficient of -0.004 means that a two-standard-deviation decrease in $\Delta \ln(Pat.Quality)$ increases the probability of CVC initiation by 67.09%, and this is economically comparable to that in column (1). Column (4) delivers a consistent message.

It is worth stressing the importance of incorporating industry-by-year fixed effects in the estimation. Previous studies on technological evolution and restructuring waves highlight the possibility that certain industry-specific technology shocks could be driving innovation changes and organizational activities at the same time (Mitchell and Mulherin, 1996; Harford, 2005; Rhodes-Kropf, Robinson, and Viswanathan, 2005). However, after absorbing this variation using industry-by-year fixed effects, the results in Table III are identified using the cross-sectional variation within an industry-by-year cell. This issue will be revisited and studied in Section III.C.

Overall, Table III confirms the pattern in Figure 2 that CVC initiations typically follow innovation deterioration, lending support to the information-acquisition view of CVC. However, what if the results are due to some endogenous common factor that drives both innovation dynamic and CVC activities (for example, poor management)? Moreover, what are the alternative economic forces, other than informational motives, that could be driving deteriorating firms launch CVC? The analyses that follow will adapt the framework in Table III to discuss those issues.

B. Identification Strategy

Potential endogeneity problems arise from unobservables that are hard to control for in model (1). For instance, agency problems (such as empire-building managers) could hinder innovation and lead simultaneously to CVC as a pet project, biasing the estimation in favor of finding a negative relation between innovation and CVC investment. On the other direction, CEOs who are more risk-tolerant could improve corporate innovation (Sunder, Sunder, and Zhang, 2014) as well as encourage interactions with entrepreneurs using CVC, biasing the estimation against finding the result.

B.1. Instrumental Variable and Empirical Strategy

To address the endogeneity concern and rule out competing interpretations, I construct a new instrumental variable by exploiting the influence of exogenous technological evolution on firm-specific innovation. The idea that technological evolution affects firms' innovation is intuitive—a firm specializing in 14-inch hard disk drive (HHD) was less likely to produce valuable innovation when 8-inch HHD technology came, and this happened repeatedly along the development of HHDs (5.25-inch, 3.5-inch, 2.5-inch, Solid State Drives). Indeed, "new technologies come and go, taking generations of companies with them" (Igami, 2014).

Earlier studies formalize this intuition and identify several mechanisms that technological evolution affects firms' ability to innovate. A negative shock to the value of a firm's accumulated knowledge space implies a longer distance to the knowledge frontier and a higher knowledge burden to identify valuable ideas and produce radical innovation (Jones, 2009). Firms working in a fading area will benefit less from knowledge spillover (Bloom, Schankerman, and Van Reenen, 2013), which in turn dampens growth in innovation and productivity.[16]

To implement the idea and measure the influence of exogenous technological evolution on each firm's capability to innovate, I build on bibliometrics and scientometrics literature, which measure obsolescence and aging of a discipline/technology using the dynamics of citations referring to the discipline/technology. The instrument, termed as *Knowledge Obsolescence* (*Obsolescence* hereafter), attempts to capture the τ-year (between $t-\tau$ and t) rate of obsolescence of the knowledge possessed by a firm. For each firm i in year t, this instrument is constructed in three steps (formally defined in formula (2)). First, firm i's predetermined knowledge space in year $t-\tau$ is defined as all the patents cited by firm i (but not belonging to i) up to year $t-\tau$. I then calculate the number of citations received by this $KnowledgeSpace_{i,t-\tau}$ in $t-\tau$ and in t, respectively. Last, $Obsolescence^{\tau}_{i,t}$ is defined as the change between the two, and a larger *Obsolescence* means a larger decline of the value and usefulness of a firm's knowledge,

$$Obsolescence^{\tau}_{i,t} = -[\ln(Cit_t(KnowledgeSpace_{i,t-\tau})) - \ln(Cit_{t-\tau}(KnowledgeSpace_{i,t-\tau}))]. \tag{2}$$

The validity of the exclusion restriction rests on the assumption that, controlling for

[16] One concern is that when a firm's knowledge space becomes hotter, product market competition becomes more severe, which in turn could disincentivize innovation and imply that emerging knowledge value could lead to lower innovation performance. This concern, however, is shown to be secondary by Bloom, Schankerman, and Van Reenen (2013), and is further resolved by the first-stage regression in Table IV.

industry-specific technological trends and firm-specific characteristics, the technological evolution regarding a firm's knowledge space, which is predetermined and accumulated along its path, is orthogonal to its current decision on CVC other than through affecting innovation performance. One might worry that a firm's knowledge space could be affected by the type and capability of its managers, but this concern should be minimized by using a predetermined knowledge space formed along the corporate history rather than the concurrent one. One might also worry that the firm itself could be the main driver of the technological evolution. This concern is addressed first by excluding patents owned by the firm from its own knowledge space and by excluding all citations made by the firm itself in the variable construction. It is mitigated further by a robustness check on a subsample of medium and small firms, which are less likely to endogenize technological evolution.

In Table II, I report summary statistics for *Obsolescence*. The number of citations received by a firm's predetermined knowledge space decays by 8% in the control group, which can be interpreted as a very mild three-year natural decay of knowledge. The knowledge space on average decays by 29% in the three years before a parent firm initiates its CVC arm, which is a much more severe hit by the technological evolution.

I exploit the instrument in a standard 2SLS framework. In the first stage, I instrument the change in innovation with $Obsolescence^{\tau}_{i,t}$ using the following form:

$$\Delta_{\tau}\widehat{Innovation}_{i,t-1} = \pi'_{0,industry\times t} + \pi'_1 \times Obsolescence^{\tau}_{i,t-1} + \pi'_2 \times X_{i,t-1} + \eta_{i,t-1}. \quad (3)$$

The predicted change in innovation is then used in the second stage to deliver a consistent estimator, that is,

$$I(CVC)_{i,t} = \alpha_{industry\times t} + \beta \times \Delta_{\tau}\widehat{Innovation}_{i,t-1} + \gamma \times X_{i,t-1} + \varepsilon_{i,t}. \quad (4)$$

B.2. 2SLS Results

Table IV presents the estimation results of models (3) and (4). Column (1) reports a reduced-form regression in which *Obsolescence* is used to explain the decision to launch a CVC program. The positive coefficient 0.001 indicates that firms experiencing larger technological decays are more likely to initiate CVC activities.

Columns (2) and (4) report first-stage regressions where $\Delta Innovation$ (*Innovation* measured by the quantity and quality of new patents) is predicted using *Obsolescence* and a larger *Obsolescence* (faster rate of technological decaying) is associated with poorer innovation performance. The estimate of -0.114 in column (2) translates a 10% increase in the rate of obsolescence of a firm's knowledge space into a 1.14% decrease in its patent applications; this same change is associated with a 1.28% decrease in the quality of its patent quality as measured by lifetime citations. The F-statistics of these first-stage regressions are both well above the conventional threshold for weak instruments (Stock and Yogo, 2005).

[TABLE IV AROUND HERE]

Columns (3) and (5) show the second-stage estimation results. The key explanatory variables are now fitted innovation changes predicted from the first stage. The causal effect of innovation shocks on starting a CVC unit is both economically and statistically significant. The coefficient of -0.007 in column (2) translates a 2σ-change in $\Delta \ln(NewPatent)$ to a 52% change in the probability of launching CVC investment.

The gaps between the OLS estimates (in Table III) and the 2SLS estimates are very small. This comparison suggests that endogeneity issues are not biasing the OLS estimation in any clear direction on net. This does not mean, however, that there are no endogeneity issues involved—as discussed earlier, competing endogenous forces could drive the OLS bias in either direction and the net effect is therefore mitigated. The Appendix shows that the result is robust to several sampling criteria, such as excluding the IT and Pharmaceutical sectors, excluding California-based firms, and excluding very big or very small firms.

C. Industry CVC Waves

In previous analyses that focus on firm-level evidence, I control industry-by-year fixed effects to absorb potential confounding factors. In this section, I will look into this part of variation that was controlled for by fixed effects, to examine the industry-by-year pattern of CVC investment and how it speaks to the information-acquisition view of CVC.

Existing CVC research documents that CVC investment clusters as waves and shows strong cyclicality (Gompers, 2002; Lerner, 2012). Figure 3 plots the time series of the 381 CVCs studied in the sample. Both the number of launches of new CVC units and the number of deals invested are plotted. Similar to Gompers (2002) and Dushnitsky (2006), the graph highlights two waves—most of the CVC units were launched in either the early to mid-1980s or the later 1990s. More than 20 firms started their CVC investments each year from 1983 to 1986, and 71 firms started their CVC units in 1999. CVC deals experienced two similar waves: in the first wave from 1983 to 1986, CVCs invested in about 60 deals each year; and this number was not reached again until 10 years later, in 1996, at the beginning of the second CVC wave.

[FIGURE 3 AROUND HERE]

Existing explanations for these CVC waves emphasize macro-level factors (tax change, market condition, etc.) that do not directly speak to one important aspect that attracts less attention: CVC waves do not happen uniformly in each industry, that is, some industries waved in only one of the two waving periods, with little activity in the other waving period. In Figure 4, the sample is broken down by industry to produce a by-industry CVC investment graph. Four industries are presented—machinery, printing and publishing, business services (including IT), and pharmaceuticals. Two observations can be gleaned from these figures. First, CVC investments cluster not only at the aggregate level (as in Figure 3) but also at the industry level, and this industry-level clustering is what can be termed an "industry CVC wave." Second, and more importantly, different industries waved at different times. Specifically, most CVC investments in the machinery industry were made in the 1980s, but the industry was not heavily involved in the second aggregate CVC wave in the 1990s. In contrast, printing and publishing firms were relatively silent during the 1980s CVC wave but rode the second wave in the later 1990s. Even IT firms, the overall most active group in the CVC field, were relatively uninvolved in the first aggregate wave but invested aggressively in the second wave. The pharmaceutical industry, another highly active industry in CVC investments, was almost equally active during the two aggregate waves, and this industry continued investing even during the non-waving period (in contrast to most other industries).

[FIGURE 4 AROUND HERE]

[TABLE V AROUND HERE]

Figure 4 suggests that some industry-specific factor motivates firms in the industry to implement Corporate Venture Capital investment simultaneously. Table V Panel A compiles a list of industry CVC wave periods, jointly defined using the clustering of CVC initiations and investment. I limit each wave period to at most four years. In general, most industries experience at least one wave period and more than 50% of the CVC investments were made during that short window. For example, printing and publishing firms initiated six CVC units and invested in 71 deals between 1997 and 1999; the total deals made by this industry between 1980 and 2006, however, number just 88. IT firms made most of their CVC investments during the dot-com boom. Pharmaceutical firms have a less clear wave pattern but still had two time windows when they were more active than usual.

D. Additinoal Economic Forces and Robustness

Table IV controls the endogeneity problem when establishing the causality between innovation deterioration and the CVC initiation decision. This is consistent with the information-acquisition view, which predicts that firms in need of new knowledge are more active in reaching to the innovative entrepreneurial sector. Built on this framework, this section discusses several additional tests to serve two main purposes—to further explore the informational motivation, and to study additional economic forces that could affect firms' decision to take the CVC route.[17]

Technological Uncertainty. I first explore heterogeneous effects of innovation deteriorations on CVC initiations across uncertainty levels that firms face in their informational environment. The working hypothesis is that the impact of innovation deterioration should be stronger when the uncertainty level is higher, that is, when identifying valuable innovation opportunities becomes more difficult and information is therefore more valuable. I estimate an extended model based on the OLS model (1) and 2SLS models (3) and (4). The sample is categorized into two subgroups by the median of uncertainty levels of firms' informational

[17] More analysis can be found at the Online Appendix.

environment, indicated by $I_{uncertainty}$. The results are reported in Table A.I, which shows that the causal relation between deterioration in innovation and the decision to engage in CVC investment is stronger when there is higher demand to acquire information on new technologies and new markets, which favors the informational rationale behind CVC.

This result cannot be explained by the interpretation that firms make CVC investments before acquiring a new technology, as a way to wait for the uncertainty to resolve. Indeed, CVC investments seldom evolve to acquisition of the portfolio company. Recent studies examine acquisition cases when CVC investors acquire portfolio companies in which they invested (Benson and Ziedonis, 2010; Dimitrova, 2013). In general, acquiring portfolio companies is rare—fewer than one-fifth of CVC investors acquired their portfolio companies. CVCs that did conduct such acquisitions acquired fewer than 5% of their portfolio companies (that is, one out of 20 investments).

Managerial Desperation and Leapfrog Innovation. Early research shows that desperate managers, after experiencing a negative shock, might aggressively seek outside solutions to the deterioration, which typically lead to even worse outcomes (Higgins and Rodriguez, 2006). Therefore, one could reasonably worry that the result simply documents that desperate managers are more likely to conduct CVC investment for leapfrog innovations. I investigate this issue by studying the success rate of the portfolio companies invested by CVCs categorized by the severity of innovation declines at initiation. If the concern is indeed the case, we would expect CVC parents that experienced the largest hit before initiating to have lower performance as they mostly make the decision under desperation. In Table A.II, I find that those CVCs whose parents' performance decline the most actually score a similar, if not higher success rate compared to other CVCs.

Financial Returns. What is the role of financial condition in firms' decision to operate a CVC? On the one hand, anecdote cases (e.g., Google, Intel) leave us the impression that CVC is an investment channel for cash-rich firms to make equity investment in the startup market. On the other hand, the structure and features of CVC investment could lead us to hypothesize that CVC could be poor-man's innovation, that is, declining firms are more financially constrained and cannot conduct internal R&D or M&As, which are on average more costly than CVC. In Table A.III, I show that the main result is robust on the subsample of firms whose KZ-index is below industry median or cash flow ratio above industry median (less financially constrained).

More Robustness. In order to confirm the results are not driven by the sampling process or specifications, I conduct a vast of robustness checks. In the Appendix, I show that the result is not sensitive to the length used to capture innovation changes ($\tau = 3$ in the paper); the result is robust to removing firms that are large/small, that are from specific industries (such as IT or pharmaceuticals), or that are located in specific locations (in California). The result also holds for deteriorations of product market performance such as ROA and growth rate in sales.

IV. CVC Operations: Select, Acquire, and Integrate Information

Section III presents evidence consistent with the view that the information-acquisition motive drives the initiation of CVC life cycle. To further explore the information-acquisition view, this section moves to examine how CVCs select portfolio companies to acquire valuable information from, and to identify the information spillover from those startups to CVC parents. Empirically, I construct a comprehensive data set on innovation-related activities in both CVC parents and the entrepreneurial sector. Using this database, I can test the information-acquisition view through examining if CVCs target entrepreneurial companies that could potentially provide higher informational value to the parents, and through tracking the dynamic of incorporating new information into corporate activities within parents.

A. CVC Portfolio Formation

I start by examining how CVCs' selection of portfolio companies reflects the information-acquisition rationale. Selecting portfolio companies involves trading off multiple factors that determine the efficiency of information-acquisition. The first consideration is the technological proximity between the parent firm and a startup. The conceptual idea is that investing in technologically proximate companies facilitates the process of absorbing and integrating information therefore creating greater informational benefit (Cohen and Levinthal, 1990; Dushnitsky and Lenox, 2005b). The second factor is the incremental informational value through investment. Indeed, investing in companies with very similar knowledge sets contributes little marginal informational benefit, although it could be efficient for creating synergies (Bena and Li, 2014). The third determinant is the availability of alternative information-acquisition channels. The working hypothesis here is that CVC investors should pursue information that would be difficult to acquire without the CVC channel, that is, we should expect CVC investment to concentrate on companies with little informational communication otherwise.

To empirically analyze how CVC parent firms balance these economic forces in selecting portfolio companies, I construct a data set by pairing each CVC i with each entrepreneurial company j that was ever invested by a VC. I remove cases when the active investment years (between initiation and termination) of CVC firm i and active financing years of company j (between the first and the last round of VC financing) do not overlap. I estimate a probability model on this sample to predict the decision of CVC i investing in company j, that is,

$$\begin{aligned} I(CVC_i\text{-}Target_j) = \alpha + \beta_1 \times TechProximity_{ij} + \beta_2 \times Overlap_{ij} \\ + \beta_3 \times SameCZ_{ij} + \gamma \times X_{i,j} + \varepsilon_{ij}, \end{aligned} \tag{5}$$

where the dependent variable, $I(CVC_i\text{-}Target_j)$ indicates whether CVC i actually invests in company j.

A.1. Measurements

The key variables of interest in model (5) are *TechProximity*, *Overlap*, and *SameCZ*, which capture the informational relation between a CVC parent firm i and an entrepreneurial company j, echoing the three potential portfolio determinants outlined above.[18]

The first measure, *Technological Proximity* (*TechProximity*), is calculated as the *Cosine*-similarity between the CVC's and startup's vectors of patent weights across different technology classes (Jaffe, 1986; Bena and Li, 2014). A higher *Technologial Proximity* indicates that the pair of firms work in closer areas in the technological space.

The second measure, *Knowledge Overlap* (*Overlap*), is calculated as the ratio of—(1)

[18]The Appendix describes the methodology identifying innovation activities of entrepreneurs through merging patent data sets with VentureXpert and defines those variables more formally.

numerator: the cardinality of the set of patents that receive at least one citation from CVC firm i *and* one citation from entrepreneurial company j; (2) denominator: the cardinality of the set of patents that receive at least one citation from either CVC i *or* company j (or both). A higher *Knowledge Overlap* means that the pair of firms share broader common knowledge in their innovation.

In order to provide a clean interpretation of the estimation, both *Technological Proximity* and *Knowledge Overlap* are measured as of the last year before CVC i and company j both enter the VC-startup community. For example, if firm i initiates the CVC in 1995 while company obtained its first round of financing in 1998, the measure is constructed using the patent profiles in 1997. The rationale for this criterion is to mitigate the potential interactions between CVCs and startups before investment.

To construct a proxy for the availability of alternative information-acquisition channels, I rely on recent studies showing that geographic proximity influences the intensity of knowledge spillover between firms (Jaffe et al., 1993; Peri, 2005). The main variable is a dummy indicating whether CVC firm i and company j are located in the same Commuting Zone (CZ). I use CZ as the geographic delineation because it has been shown that CZ is more relevant for geographic economic activities (Autor, Dorn, and Hanson, 2013; Adelino, Ma, and Robinson, 2014) and innovation spillover (Matray, 2014). Projecting the information-acquisition hypothesis on this context, we should expect that CVCs invest less in companies that are in the same geographic location, from which they could learn through the more inexpensive mechanism of local knowledge spillover.

A.2. Results

Table VI presents coefficients estimated from model (5). In column (1), a positive and significant coefficient means that the *Technological Proximity* between a CVC and an entrepreneurial company increases the likelihood of a CVC deal formation. This result is consistent with the interpretation that CVCs select companies from which they are more capable of absorbing knowledge for their core business.

[TABLE VI AROUND HERE]

Column (2) examines the effect of *Knowledge Overlap*. The negative coefficient means that after conditioning on the technological proximity, CVC parent firms prefer to invest in companies with different knowledge bases. In other words, CVCs select portfolio companies through which they are exposed to more new innovation knowledge. Importantly, this result could potentially distinguish the information-acquisition rationale for CVC with the alternative rationale that CVC is conducted for product market synergies and asset complementarity. Under non-informational strategic concerns, firms favor targets with both close technological proximity and high knowledge overlap in order to achieve economic synergies (Bena and Li, 2014).

In column (3), I study the effect of alternative information-acquisition channels, knowledge spillover specifically, on CVC's portfolio selection. The literature on VCs, and on investment more broadly, has documented a "home (local) bias" phenomenon—when investing in companies that are geographically closer, investors can better resolve the information asymmetry problem and conduct more efficient monitoring (Da Rin, Hellmann, and Puri, 2011). In column (3), however, I find that CVCs do not really invest in their "home" companies. The dummy variable indicating that the CVC and the startup are located in the same Commuting Zone negatively affects the probability of investment, which is consistent with the explanation that CVC parent firms can acquire information from startups in the same CZ through local innovation spillover (Matray, 2014), which decreases the marginal benefit of making a CVC investment in them.

Overall, Table VI shows that CVCs strategically select information sources and invest in companies from which they could acquire beneficial information. They invest in companies that work in similar technological areas and possess knowledge new to the parent firm. They are less likely to invest in companies located in the same geographic areas from which they could gain information through inexpensive local knowledge spillover.

B. Internalizing Acquired Information

The rationale of information-acquisition for CVC investment is convincing only if CVC parents can use newly gathered information to improve their operations. Several economic frictions could hinder CVCs from gathering and integrating information from startups, challenging the information-acquisition rationale. Hellmann (2002) theoretically shows that entrepreneurs could intentionally avoid CVC investment to protect their own innovation. Dushnitsky and Lenox (2005b) and Kim, Gopal, and Hoberg (2013) argue that the absorptive ability (Cohen and Levinthal, 1990) of CVC parent firms imposes a limit on the knowledge transferred through the relationship. Gompers and Lerner (2000) suggest that the efficiency of CVC is constrained by the incentive problem embedded in its organizational and compensation structure. Additionally, high adjustment costs of R&D investment (Hall, Griliches, and Hausman, 1986; Lach and Schankerman, 1989) can decrease the speed and intensity of the integration of new knowledge acquired through CVC.

Showing how information is incorporate into corporate decisions can be challenging due to the invisible nature of information. In this subsection, I undertake two empirical settings to study how information acquired through CVC influences the parent firm—first, following the literature that uses patent citations as a measure of knowledge spillover (Gomes-Casseres et al., 2006), I study how CVC parent firms internalize acquired information into organic R&D by tracking patent citations made to their portfolio companies; I then switch to another setting where I look at the efficiency of corporate decisions where the acquired information could be crucial.

B.1. Internal Research and Development

I start by identifying the specific information flow from portfolio companies that is further incorporated into parents' internal innovative activities. Empirically, I follow the economic literature on knowledge spillover (Jaffe and Trajtenberg, 2002),[19] , and estimates whether CVC parent firm i makes new citations to startup company j's patents or knowledge after the CVC invests in the startup, using the following model:

$$\begin{aligned} Cite_{ijt} = \alpha + \beta \cdot I(CVCParent) \times I(Post) \times I(Portfolio) \\ + \Phi[I(CVCParent), I(Post), I(Portfolio)] + \varepsilon_{ijt}. \end{aligned} \tag{6}$$

To control for observed characteristics of CVC parents that could influence their behaviors

[19] Gomes-Casseres et al. (2006) and Alcacer and Gittelman (2006), among others, discuss the advantages and potential pitfalls in using this approach.

in citing entrepreneurial companies, we need to construct a proper control group for those firms. I use a propensity score matching method and match each CVC parent firm i that launches its CVC unit with two non-CVC firms from its CVC launch year and 2-digit SIC industry that have the closest propensity score estimated using firm size (the logarithm of total assets), market-to-book ratio, $\Delta Innovation$, and patent stock,[20] similar to the sample construction strategy in Bena and Li (2014). The CVC launching year for a CVC parent firm is also the "pseudo-CVC" year for its matched firms.

Observations are at the i-j-t level. The full set of i-j pairs then denotes the potential information flow that could happen between a CVC parent firm (or a matched firm) and a startup, captured by patent citations. $I(CVCParent)$ is a dummy variable indicating whether firm i is a CVC parent or a matched control firm. $I(Portfolio)$ indicates whether company j is in the CVC portfolio of firm i. For each i-j pair, two observations are constructed, one for the five-year window before firm i invests in company j, and one for the five-year window after the investment.[21] $I(Post)$ indicates whether the observation is within the five-year post-investment window. The dependent variable, $Cite_{ijt}$, indicates whether firm i makes new citations to company j's innovation knowledge during the corresponding time period.

[TABLE VII AROUND HERE]

The key variable of interest, $I(CVCParent) \times I(Post) \times I(Portfolio)$, captures the incremental intensity of integrating a portfolio company's innovation knowledge into organic innovation after a CVC invests in the company. Table VII column (1) shows the regression results. The coefficient of 0.159, means that the citing probability increases by 15.9% after establishing the link through CVC investment.

I further explore the depth of information-acquisition from portfolio companies. Specifically, column (3), I perform an analysis similar to that in column (1) except that I look at the probability that a CVC parent firm cites not only patents owned by the startup but also patents previously cited by the startup. In other words, the potential citation now covers a broader technological area that the startup works in. Column (3) extends the message

[20]Patent stock is constructed as the total number of patents applied for by the firm up to year $t-1$.

[21]A matched control firm is assumed to have the same investment history as the CVC parent firm to which it is matched to.

conveyed in column (1)—CVC parent firms not only cite the portfolio company's own patents, but also benefit from the knowledge indirectly carried by portfolio companies, reaching to the broader knowledge behind.

Does information-acquisition concentrate only on successful investment? I explore this question by modifying model (6) and separately estimate the intensity of citing knowledge possessed by companies that either exit successfully (acquired or publicly listed) or fail at last. The result is reported in columns (2) and (4), and it appears that CVC parents acquire knowledge from both successful and failed ventures.

B.2. Using Information through External Acquisitions

After presenting how firms integrate acquired innovation knowledge into internal R&D, in this section, I explore an alternative channel through which firms could benefit from CVC-acquired information—acquiring external innovation. Acquiring innovation has become an important component of corporate innovation (Bena and Li, 2014; Seru, 2014), and identifying promising acquisition targets (companies or innovation) requires a valuable information set, such as great understandings on markets and technological trends. Under the information-acquisition hypothesis, CVC-acquired information allows parent firms to form more precise expectations on acquisition deals, thereby improving efficiencies when making acquisition decisions.[22]

I first study how efficiently CVC parent firms conduct acquisitions of companies. Following the literature, acquisition efficiency is measured using three-day, five-day, and seven-day cumulative abnormal returns (CAR) of an acquisition deal centered on the acquisition announcement day. The analysis is performed on a cross section of mergers and acquisitions deals conducted by CVCs and their matched control firms between five years before and five years after (pseudo-) CVC initiations, and the unit of observation is an acquisition deal. The key variable of interest is the difference-in-differences variable $I(CVCParent)_i \times I(Post)_{i,t}$ indicating whether the acquirer i is within five years after launching its CVC division. If firms could conduct more efficient external acquisitions based on the information gathered

[22]Those acquisitions are not necessarily limited to their CVC portfolio companies, and can reach to a broader domain using the general innovation and industry knowledge they learn from CVC experience.

from CVC investment, one would expect the abnormal announcement returns to be higher for these deals.

[TABLE VIII AROUND HERE]

Table VIII Panel A presents the result. Columns (1) to (3) examine three-day, five-day and seven-day CAR (in *basis points, bps*), respectively. The positive and significant coefficients across all three columns confirm that firms conduct more successful external acquisitions as they internalize the information acquired through their CVC investment. Quantitatively, compared to their industry peers, acquisitions made by CVC parent firms experience a 65 bps improvement in the three-day abnormal return from one-day before the announcement to one-day after the announcement, and a greater than 130 bps increase in abnormal return during the $[-3, 3]$ window.

To study how CVC-acquired information is capitalized through acquisitions of innovation, I compile a detailed data set on firms' acquisition of patents (either "company and patents" or "patents only"). The database on patent transactions is based on USPTO patent assignment files, hosted by Google Patents. This database provides useful information for identifying patent transactions: the assignment date; the participating parties, including the assignee—the "buyer" in a transaction—and the assignor—the "seller" in a transaction; and comments on the reason for the assignment. To gather additional information on the original assignee and patent technology classes, I merge the raw assignment data with the USPTO patent databases, and with the HBS inventor database. I then follow a procedure, based on Serrano (2010) and Akcigit, Celik, and Greenwood (2013), in which I separate patent transactions from all patent reassignment records, that is, I remove reassignments associated with cases such as a patent transfer from the employee inventor to the employer firm, or a patent transfer between different subsidiaries of a firm. A more detailed description of the data and methodology is provided in the Appendix.

I perform the analysis on the sample of patent purchases conducted by CVC parent firms and their control firms, and the unit of observation is a patent transaction.[23] The dependent variable is calculated as the citation growth from the n-year ($n = 1, 2, 3$) period before the

[23]To be clear, some patents are transacted under one "deal," and I necessarily treat each of them as one individual observation.

patent transaction to the same length after the transaction.[24] This variable intends to capture whether the purchased patents better fit the buyer than the seller, thereby signaling a more efficient transaction. As in Panel A, the key variable of interest is the difference-in-differences term $I(CVCParent)_i \times I(Post)_{i,t}$, indicating whether the patent buyer i is within five years after launching its CVC division. If firms could capitalize the information learned from CVC by conducting more efficient patent purchases, one would expect a positive coefficient to be associated with the difference-in-differences term.

In Panel B of Table VIII, I report the citation growth around patent transactions. The positive coefficient in column (1), 0.200, means that after benchmarked by patent transactions conducted by their matched control firms and pre-CVC transactions, patents purchased by CVC parent firms receive on average 0.2 more citations during the first year under the new owner than the last year under the old owner. Column (2) uses a two-year horizon to calculate citation increases, and the economic magnitude increases to 0.607. Column (3) shows an amplified result due to a three-year horizon.

It is worth discussing the economic interpretation behind this spike in citations after CVC firms' patent transactions. In principle, a spike in citations indicates that the underlying patent becomes increasingly visible and popular, plausibly because it better fits the overall innovation profile of the new owner or is commercialized more successfully after the transaction. Specifically in our context, this particularly strong increase in citations is consistent with the interpretation that CVC parent firms acquire innovation that is in turn better commercialized and made visible to the industry.

C. Human Capital Renewal and Information Acquisition

Evidence thus far suggests that CVC parent firms devote effort to integrating and utilizing information acquired from the entrepreneurial sector. Identifying, processing, and integrating new information is difficult, how do CVC parents accomplish this task? I identify one important channel that CVC parents actively manage: human capital renewal. Indeed,

[24] For example, when $n = 3$, $\Delta Citation[-3, +3]$ is calculated as total citations received by the transacted patent from one year to three years after the transaction *minus* total citations received from 3 years to one year before the transaction.

inventors, usually highly educated scientists and engineers, are key in absorbing, processing, and using information to produce new innovation. Recent studies also find that firms actively reallocate innovative human resources to spur innovation and adjust the scope of innovation (Lacetera, Cockburn, and Henderson, 2004; Bernstein, 2015; Brav, Jiang, Ma, and Tian, 2015). In this section, I explore the role of inventors in facilitating knowledge gathering and use.

I rely on Harvard Business School patenting database for inventor-level information.[25] This database includes unique inventor identifiers that are constructed based on a refined disambiguation algorithm employing multiple characteristics (Lai, D'Amour, and Fleming, 2009). After matching inventors to employer firms, I track the employment history and annual patenting activities of each inventor.[26] Using a similar criterion as in Bernstein (2015) and Brav et al. (2015), I identify the number of inventors who leaves the company and the number of inventors who are newly hired in each year.

[TABLE IX AROUND HERE]

I start by examining the intensity of human resource adjustment around the years of initiating CVC investment. The analysis is performed on the same firm-year panel of CVC firms and their propensity score-matched controls. In Table IX Panel A, I study the number of inventors leaving the firm (columns (1) and (2)) and the number of inventors newly hired by the firm (columns (3) and (4)). The coefficient, 0.119 in column (1), can be interpreted as showing that CVC parent firms have 11.9% more inventors leaving the firm (leavers) than the period before CVC investment. The vacancies created by leavers are filled by inventors newly hired by the firm; the 0.110 estimated in column (3) means that CVC parents hire about 11% more new inventors compared to the years before CVC investment, benchmarked by their industry peers.

In columns (5) and (6), I examine the proportion of patents mainly contributed by inventors new to the firm. A patent is considered as "mainly contributed by new inventors"

[25] Available at: `http://dvn.iq.harvard.edu/dvn/dv/patent`.

[26] One limitation of this analysis is that we detect inventor mobility conditional on new patent filings; the observed mobility is thus associated with inventors who patent more frequently. But at any rate, these people should be those who are economically more important to the firm. See Bernstein (2015) for a detailed discussion of the limitations associated with this database.

if at least half of the patent's inventor team have three or fewer years of patenting experience in the firm as of the patent application year. The positive coefficient of 17.1% in column (5) means that CVC parent firms rely more heavily on new inventors when operating a CVC, consistent with the proposition that firms hire new inventors to process new information and produce innovation.

Table IX Panel B presents new inventors' intensity of incorporating new knowledge. The patent-level sample consists of all the patents produced by CVC parent firms and their matched control firms from five years before the event to five years after it. Beyond the standard terms $I(CVCParents)_i$ and $I(Post)_{i,t}$, I introduce an indicator variable $I_{\text{New Inventor's Pat}}$ that equals one if new inventors contribute at least half of the patent and zero otherwise. The unconditional effect of $I_{\text{New Inventor's Pat}}$ is positive, meaning that patents produced by firms' new inventors typically incorporate more knowledge new to the firm. Meanwhile, the interaction term $I(CVCParents) \times I(Post)$ is associated with higher *New Cite Ratio* and *Explorativeness*, consistent with Table A.VII. A key result in this table is the positive coefficient in front of the triple difference $I_{\text{New Inventors' Pat}} \times I(CVCParent) \times I(Post)$, which implies that new inventors in CVC parent firms concentrate more heavily on processing and integrating new information and innovation knowledge. In column (3), I focus on the sample of all patents produced by CVC parent firms during the five-year window after CVC initiation (that is, $I(CVCParents) = I(Post) = 1$), and find that new inventors are more likely to use knowledge acquired from CVC portfolio companies in their new innovation.

V. CVC Terminations: Staying Power and Investment Dynamics

In a frictionless world, CVC parents would want to keep investing in CVC to acquire information from entrepreneurs. However, with frictions, CVC could become less appealing as the companies' internal innovation recovers. For example, a capacity-constrained firm will allocate less resources to information acquisition yet more to innovation production once the internal innovation becomes more premising (Nelson, 1982; Jovanovic and Rob, 1989). Additionally, the cannibalization concern (Arrow, 1962) will disincentivize innovative incumbents to search for newer ideas which will replace the existing ones, and this effect could be particularly large with high adjustment cost and organizational complexity. Overall, as firms assimilate information into their innovation decisions and begin to have an upward innovation trajectory, the benefit of keeping a standalone CVC unit shrinks. In this scenario, CVC investment may fade out as internal innovation recovers and firms devote more resources to this regained innovation path. This section examines this implication of the information-acquisition hypothesis by focusing on the termination stage of the CVC life cycle.

The analysis provides further opportunities to distinguish the important strategic motivation behind CVC investment. Under alternative CVC rationales, CVC remains advantageous in organizing innovation due to its superior ability to obtain asset complementarity (Hellmann, 2002), motivate entrepreneurs (Aghion and Tirole, 1994; Chemmanur, Loutskina, and Tian, 2013), and obtain competitive advantages (Mathews, 2006; Fulghieri and Sevilir, 2009). Even though these studies focuses primarily on static trade-offs and does not concern intertemporal dynamics, it implicitly implies that firms might invest persistently in CVCs long periods of time.

A. *The Staying Power of Corporate Venture Capital*

I start by examining the staying power of Corporate Venture Capital. To do so, it is necessary to define the date of terminating each CVC unit, which is not widely disclosed. When this termination date is not available, I define it as the date of the CVC's last investment in a portfolio company. As a result, the staying power analysis could underestimate the duration of CVCs, particularly toward the end of the sample. To mitigate bias, I categorize a CVC as "active" if its last investment happened after 2012 (as of March 2015) and VentureXpert codes its investment status as "Actively seeking new investments," and I exclude those active CVCs from the analysis. The duration of a CVC is calculated as the period between the initiation and termination of the division.

[TABLE X AROUND HERE]

Table X tabulates the duration of CVC divisions. The median duration of a CVC is four years, and a significant portion (46%) of CVCs actively invest for three years or less,[27] lending

[27] They certainly could interact with their portfolio companies for longer periods of time after terminating

support to the argument that the benefit from CVC investment shrinks as information is assimilated. However, a large number of firms (27%) operate CVCs for a long period (more than 10 years). To understand why this is so, I report the median number of total and longest consecutive years that a CVC is put into hibernation, defined as a year when no incremental investment was made. When the CVC duration is short, the years between initiation and termination are mostly active. As their duration increases, an increasing proportion of years are under hibernation. When I examine these hibernation periods, I find a pattern of consecutive hibernating years—for example, CVCs with eight-year durations have a median of four years of consecutive hibernation. In other words, these CVCs typically have a length pause in their CVC experience, bridging two shorter active periods of investment.

One might conclude that the short average CVC life cycle indicates that some CVC parent firms are incompetent in the VC business and thus terminate their CVC divisions quickly. To rule out this concern, in the last column of Table X, I calculate the success rate of deals invested by CVCs categorized by CVC durations. An investment deal is defined as a "success" if the entrepreneurial company was acquired or went public (I exclude cases when the company is still alive without a successful exit). Success rates of investments do not correlate with CVC duration, inconsistent with the idea of CVC incompetence.

B. Innovation Improvements and CVC Termination

What determines the termination and hibernation of CVCs? To echo Table III, which shows that innovation deterioration motivates CVC initiations, I conclude my analysis of the CVC life cycle by examining corporate innovation at termination. Table XI Panel A performs simple statistical tests that compare innovation levels at the initiation and termination of the CVC life cycle. The analysis is performed on all CVCs that can be assigned a termination date (upper panel) and on the subgroup that stayed in business for at least five years. When examining the industry-year adjusted innovation measures, we observe statistically significant improvements at the CVC termination point compared to the initiation stage.

[TABLE XI AROUND HERE]

incremental investment.

I exploit a hazard model to statistically relate innovation improvements and the decision to terminate a CVC. A CVC parent firm enters the sample in the year of CVC initiation. The key variable of interest is $\Delta Innovation$, which measures the difference between innovation level in year t and that of the initiation year. The result is shown in columns (1) and (2) of Table XI Panel B. The positive and significant coefficients mean that larger improvements of innovation from the initiation year motivate parent firms to terminate CVC investment.

To capture how innovation improvements affect the decision to put CVC into hibernation, I investigate the intensive margin of CVC investment—the number of portfolio companies a CVC invests in each year and the key variables of interests, $\Delta Innovation$, are defined as above. Columns (3) and (4) present the results, and the findings are consistent with columns (1) and (2)—innovation improvements are associated with a lower level of CVC activities.

Overall, Table XI matches the finding at the initiation stage, and is consistent with the information-acquisition hypothesis, which predicts that when firms regain their upward trajectory in corporate innovation, the marginal informational benefit of CVC shrinks, which in turn leads to the termination or hibernation of CVC.

VI. Conclusion and Literature Revisited

How do corporations finance and manage their innovation process in the pursuit of long-term growth? This paper shed new light on this fundamental question by studying an emerging economic phenomenon, Corporate Venture Capital (CVC). Armed with an identification strategy that allows me to isolate firm-specific innovation shocks, I find that firms launch CVC programs following innovation deterioration, and the main motivation is to acquire information and innovation knowledge from the entrepreneurial sector. This information-acquisition rationale leads me to further characterize the life-cycle dynamics of CVC—evolving through *initiation*, *operation*, and *termination* stage—in which CVC parent firms strategically select information sources (portfolio companies), actively integrate newly acquired information into corporate decisions, and terminate CVCs when informational benefit shrinks.

Beyond establishing the CVC life cycle and the information-acquisition rationale behind these activities, I view this paper as a stepping stone toward understanding several broad economic questions.

Organizing Innovation. This paper joins the endeavor to understand the architecture of innovation and contributes to this literature by suggesting three areas for future work. First, more work should be done to achieve a better understanding of details in CVC operations. Second, this paper highlights the information-acquisition motive behind organizing innovation, which has been largely overlooked in the literature (Tirole, 2010) but is worth future exploration. Third, this paper explicitly considers the interaction between CVC investment and alternative organizational forms, calling for future studies that could consider the system of organizing innovation as a whole, by seriously incorporating the interactions among different organizational structures and a dynamic intertemporal scope.

Information Economics. Information is important in all areas of finance, yet information choices have been hard to study both in asset pricing and in corporate finance, either theoretically or empirically (Van Nieuwerburgh and Veldkamp, 2010). Empirical work on corporate decisions regarding information management is particularly limited by the unobservability of related behaviors. By examining the CVC life cycle, we obtain several results regarding information acquisition and utilization that would be hard to show under alternative settings. Future work could explore the CVC setting to answer more questions at the intersection of information economics and corporate finance.

Creative Destruction. In broader terms, this paper provides new evidence concerning the co-movement of entrepreneurship, creative destruction, and economic growth. Entrepreneurial companies and incumbent firms differ in their ability to develop radical and disruptive innovation and to capture new investment opportunities (Hall, 1993; Henderson, 1993; Jensen, 1993; Adelino, Ma, and Robinson, 2014; Acemoglu and Cao, 2015), and this difference generates the creative destruction momentum. By highlighting CVC as an effective incumbent-entrepreneur bridge, this paper essentially suggests that the two seemingly disentangled sectors could be closely intertwined, which in turn affects both micro-level corporate behaviors and the aggregate process of creative destruction.

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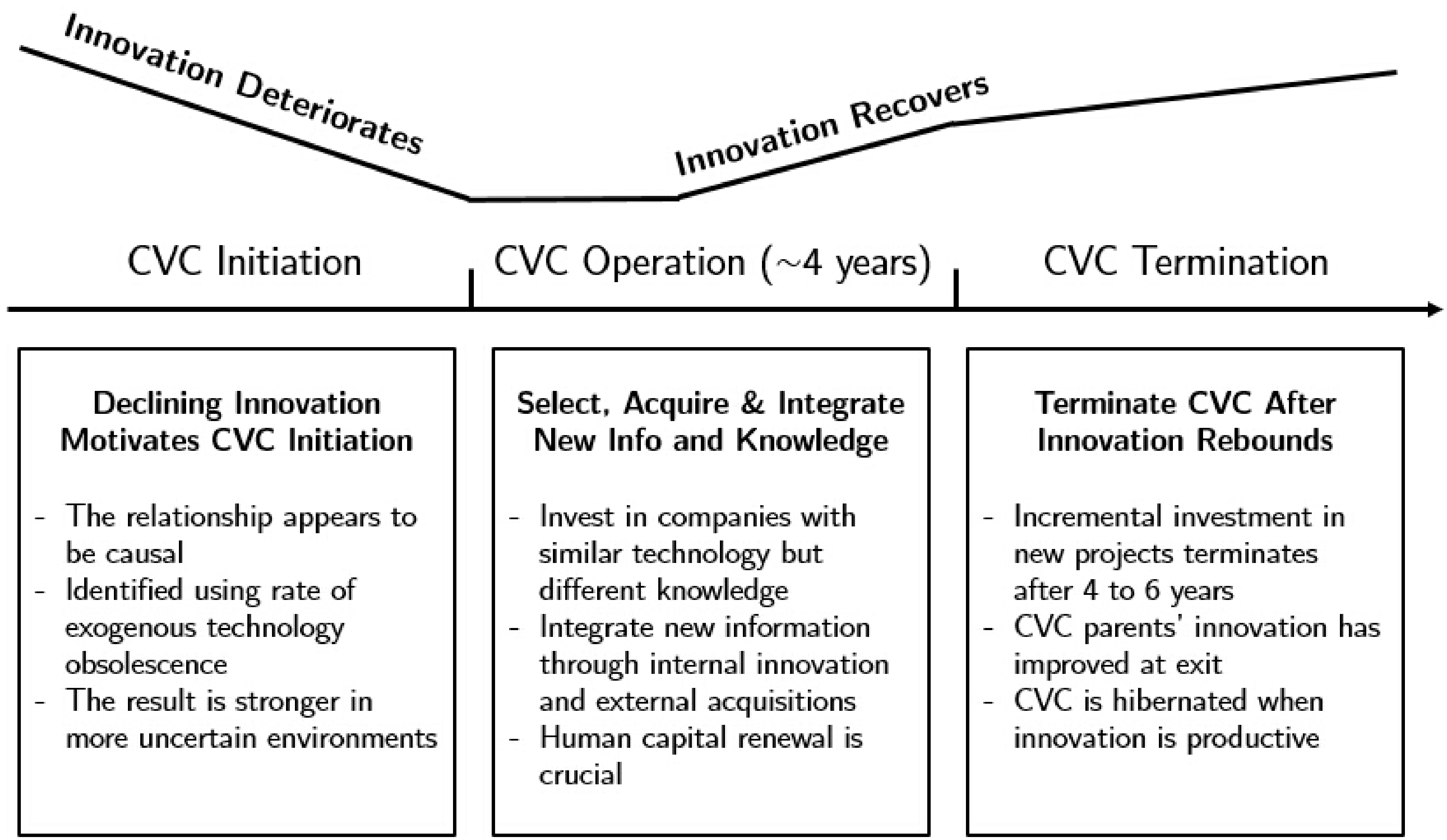
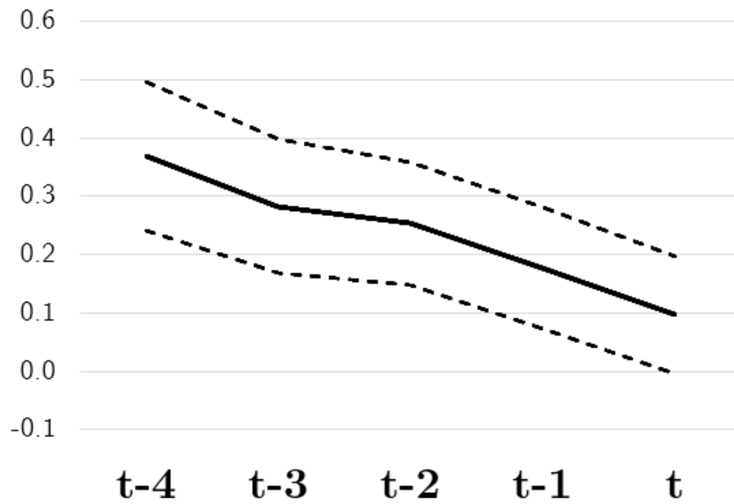
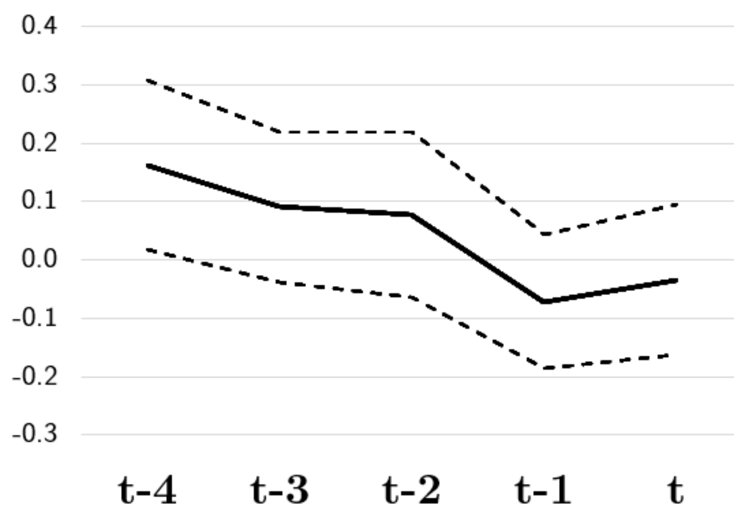


Figure 1: The Life Cycle of Corporate Venture Capital



(a) ln($NewPatents$)



(b) ln($Pat.Quality$)

Figure 2: Corporate Innovation before CVC Initiations

This figure tracks corporate innovation performance of CVC parents before the initiation of their CVC units. ln($NewPatent$) is the logarithm of the number of new patents applied by a firm in each year. ln($Pat.Quality$) is the logarithm of average citations of new patents. Each measure is adjusted by the mean of firms in the same year and industry (3-digit SIC level). The graph starts from four years before a firm launches its CVC unit ($t-4$) and ends in the year of launching (t). 95% confidence intervals are plotted in dotted lines.

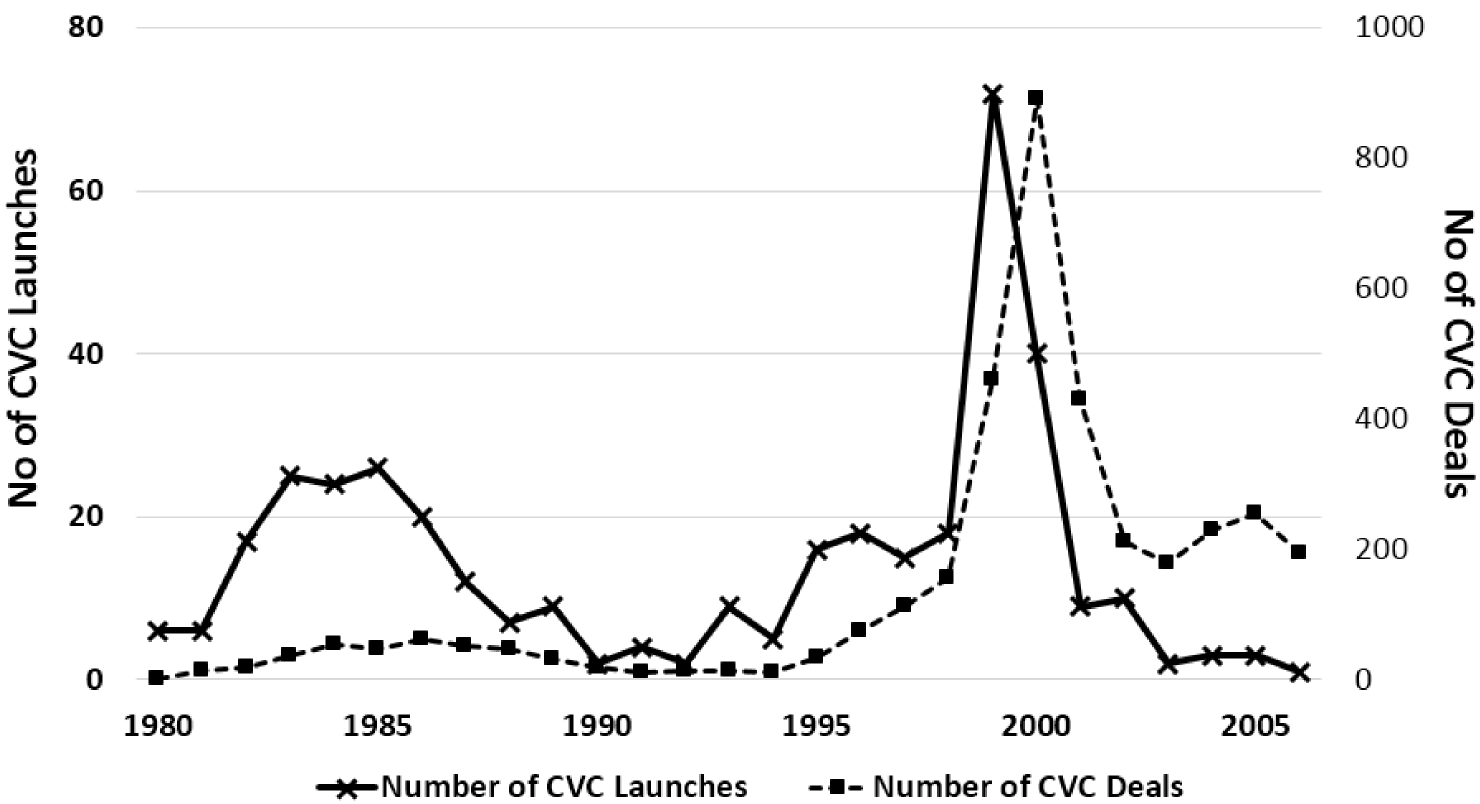
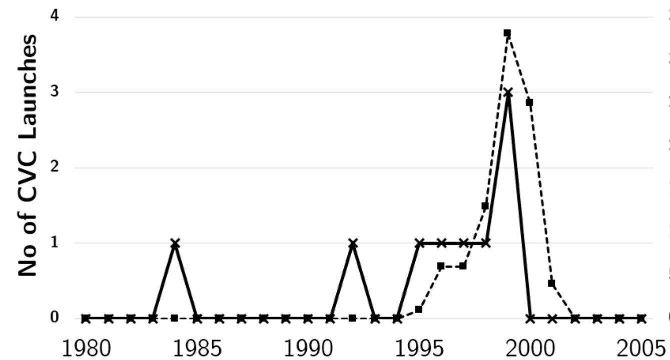


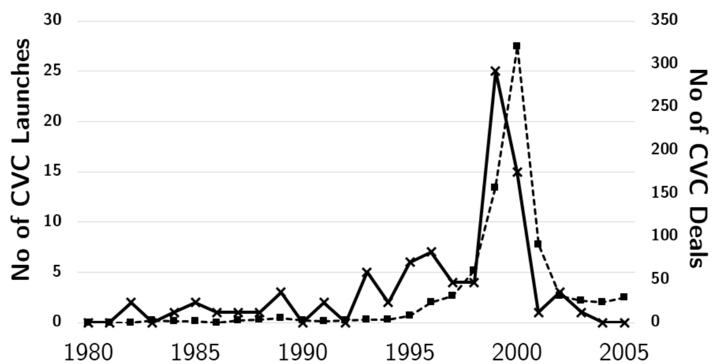
Figure 3: Time Series of CVC Investment

This figure plots the time series (1980 to 2006) of CVC investments covered in the sample. These are CVCs affiliated to US public non-financial firms that were started between 1980 and 2006. The CVC data are from the VentureXpert Venture Capital Firm Database, accessed through Thomson Reuters SDC Platinum. CVC investment is measured as the launch of new CVC units (left axis) and the number of deals invested in (right axis). CVC deals include only the first investment that a CVC invest in a portfolio company.

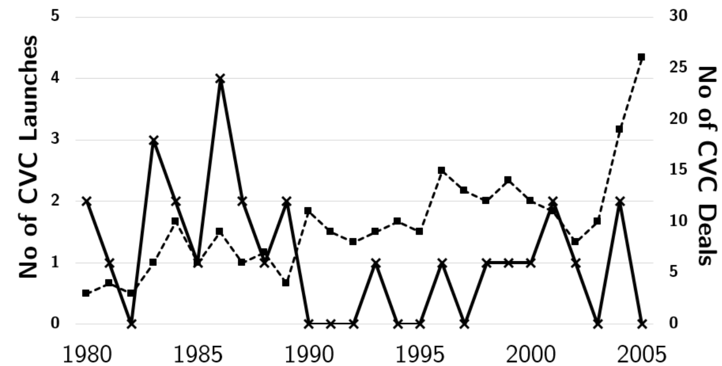
(a) Machinery Industry



(b) Printing and Publishing Industry



(c) IT Industry



(d) Pharmaceutical Industry

Number of CVC Launches   Number of CVC Deals

Figure 4: Time Series of CVC Investment—By Industry

This figure plots the by-industry time series (1980 to 2006) of CVC investments covered in the sample. These are CVCs affiliated to US public non-financial firms that were started between 1980 and 2006. The CVC data are from the VentureXpert Venture Capital Firm Database, accessed through Thomson Reuters SDC Platinum. CVC investment is measured as the launch of new CVC units (left axis) and the number of deals invested in (right axis). CVC deals include only the first investment that a CVC invested in a portfolio company. Industries are classified by the Fama-French 48 Industry Classfications, based on the main SIC code of a firm reported in Compustat.

Table I: Summary Statistics of the CVC Sample

This table provides descriptive statistics on Corporate Venture Capital activities by year (Panel A) and by industry (Panel B). CVCs are identified from the VentureXpert Venture Capital Firm Database, accessed through Thomson Reuters SDC Platinum, and are hand-matched to their unique corporate parent firms. CVC parent firms in the sample are US-based public non-financial firms. Panel A reports the annual number of CVC initiations and investment (deals) between 1980 and 2006. Panel B reports the industry distribution of CVC activities, where the industries are defined by the Fama-French 48 Industry Classification.

Panel A: CVC Activities by Year

Year	No. of Launches	No. of Deals	Year	No. of Launches	No. of Deals	Year	No. of Launches	No. of Deals
1980	6	2	1989	9	32	1998	18	155
1981	6	14	1990	2	18	1999	72	460
1982	17	18	1991	4	11	2000	40	891
1983	25	37	1992	2	14	2001	9	430
1984	24	54	1993	9	14	2002	10	211
1985	26	46	1994	5	11	2003	2	179
1986	20	63	1995	16	33	2004	3	229
1987	12	51	1996	18	74	2005	3	255
1988	7	46	1997	15	112	2006	1	194

Panel B: CVC Activities by Industry (Fama-French 48 Industry Classification)

Industry	**No. of CVCs**	**No. of Deals**	**Industry**	**No. of CVCs**	**No. of Deals**
Agriculture	2	21	Shipbuilding, Railroad Equipment	1	5
Food Products	2	4	Defense	1	11
Tobacco Products	1	6	Non-Metallic and Industrial Metal Minin	1	6
Entertainment	2	114	Coal	1	4
Printing and Publishing	9	88	Petroleum and Natural Gas	8	10
Consumer Goods	4	48	Utilities	9	48
Healthcare	4	28	Communication	40	120
Medical Equipment	7	109	Business Services	90	821
Pharmaceutical Products	28	254	Computers	44	617
Chemicals	11	48	Electronic Equipment	46	921
Rubber and Plastic Products	2	7	Measuring and Control Equipment	4	32
Textiles	1	2	Business Supplies	2	10
Construction Materials	4	7	Shipping Containers	1	2
Steel Works Etc.	3	15	Transportation	3	9
Machinery	5	15	Wholesale	10	87
Electrical Equipment	9	44	Retail	14	79
Automobiles and Trucks	6	42	Restaurants, Hotels, Motels	4	13
Aircraft	2	7			

Table II: Summary Statistics of the Regression Sample

This table summarizes firm characteristics at the firm-year level from 1980 to 2006. CVC observations ($I(CVC)_{i,t} = 1$) are those when firm i launched a CVC division in year t (and those firms are categorized as non-CVC observations in other years). The CVC sample is defined in Table I. Observations are required to have valid ROA, size (logarithm of total assets), leverage, R&D ratio (R&D expenditures scaled by total assets), and with at least $10 million in book assets, and variables are winsorized at the 1% and 99% levels to remove influential outliers. A firm is included in the panel sample only after it filed a patent application that was eventually granted by the USPTO. Industries (3-digit SIC) that did not involve any CVC activities during the sample period are removed. For each variable, mean, median, and standard deviation are reported. Variable definitions are provided in the Appendix.

	$I(CVC)_{i,t} = 0$			$I(CVC)_{i,t} = 1$		
	Mean	Median	S.D.	Mean	Median	S.D.
$\Delta \ln(NewPatent)$	0.12	0.07	0.52	-0.07	-0.05	0.61
$\Delta \ln(Pat.Quality)$	0.08	0.13	1.25	-0.10	-0.11	1.14
$Obsolescence$	0.08	0.00	0.41	0.29	0.21	0.54
New Patents	20.15	1.00	70.58	50.35	1.00	128.27
Patent Citations	21.03	7.26	29.80	15.46	2.64	32.81
Scaled Citations of New Patents	1.31	1.03	1.25	1.16	1.01	1.11
Firm R&D	0.09	0.05	0.11	0.07	0.06	0.07
Firm ROA	0.06	0.10	0.24	0.03	0.08	0.21
Total Assets (Million)	2884.93	195.27	9325.25	10177.02	2430.89	17049.50
M/B	2.87	1.94	2.33	2.68	1.83	2.58
Leverage	0.19	0.15	0.18	0.20	0.17	0.19
Cash Flow	0.11	0.09	0.10	0.12	0.11	0.15
KZ Index	0.39	0.52	1.93	0.72	0.72	1.99
G-Index	9.09	9.00	2.74	9.13	9.00	2.39
Inst. Shareholding	0.24	0.23	0.16	0.26	0.25	0.13
Innovation Uncertainty	0.62	0.16	1.50	0.73	0.25	1.57

Table III: Innovation Deterioration and CVC Initiation

This table documents the relation between innovation deterioration and the initiation of Corporate Venture Capital. The analysis is performed using the following specification:

$$I(CVC)_{i,t} = \alpha_{industry \times t} + \beta \times \Delta Innovation_{i,t-1} + \gamma \times X_{i,t-1} + \varepsilon_{i,t},$$

The panel sample is described in Table II. $I(CVC)_{i,t}$ is equal to one if firm i launches a Corporate Venture Capital unit in year t, and zero otherwise. $\Delta Innovation_{i,t-1}$ is the innovation change over the past three years (i.e., the innovation change from $t-4$ to $t-1$). Innovation is measured using innovation quantity (the natural logarithm of the number of new patents in each firm-year plus one), shown in columns (1) and (2) and innovation quality (the natural logarithm of average citations per new patent in each firm-year plus one), shown in columns (3) and (4). Firm-level controls $X_{i,t-1}$ include ROA, size (logarithm of total assets), leverage, and R&D ratio (R&D expenditures scaled by total assets). The model is estimated using Ordinary Least Squares (OLS) and Logit, respectively. Industry-by-year dummies are included in the model to absorb industry-specific time trends in CVC activities and innovation. T-statistics are shown in parentheses and standard errors are clustered by firm. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Economic significance is calculated by changing two standard deviations of the $\Delta Innovation$ and is reported below the estimation results.

	(1) OLS	(2) Logit	(3) OLS	(4) Logit
$\Delta \ln(NewPatent)$	-0.007***	-0.004***		
	(-6.227)	(-3.057)		
$\Delta \ln(Pat.Quality)$			-0.004***	-0.003**
			(-4.459)	(-2.263)
Firm ROA	-0.003	0.000	-0.003	0.000
	(-1.275)	(0.703)	(-1.567)	(0.935)
Size (Log of Assets)	0.003***	0.001***	0.003***	0.001***
	(11.090)	(10.584)	(11.034)	(8.832)
Leverage	-0.005**	-0.003***	-0.004**	-0.003***
	(-2.371)	(-3.006)	(-2.051)	(-2.908)
Firm R&D	0.015***	0.005	0.011***	0.004
	(3.439)	(1.637)	(3.093)	(1.356)
Observations	25,976	25,976	25,976	25,976
Pseudo R-squared	0.126	0.261	0.125	0.268
Industry × Year FE	Yes	Yes	Yes	Yes
	Economic Significance—2σ-change			
$\Delta \ln(NewPatent)$	51.54%	29.45%		
$\Delta \ln(Pat.Quality)$			67.09%	50.32%

Table IV: Innovation Deterioration and CVC Initiation—Causality

This table documents the causal relationship between innovation deterioration and the initiation of Corporate Venture Capital. The analysis is performed using the following Two-Stage Least Squares (2SLS) specification:

$$\Delta \widehat{Innovation}_{i,t-1} = \pi'_{0,industry \times t} + \pi'_1 \times Obsolescence_{i,t-1} + \pi'_2 \times X_{i,t-1} + \eta_{i,t-1},$$
$$I(CVC)_{i,t} = \alpha_{industry \times t} + \beta \times \Delta \widehat{Innovation}_{i,t-1} + \gamma \times X_{i,t-1} + \varepsilon_{i,t}.$$

The panel sample is described in Table II. Column (1) reports the reduced-form regression, which predicts the decision to initiate CVC using *Obsolescence* as defined in (2) in the paper. Columns (2) and (4) report the first-stage regression, which regress the three-year change in innovation quantity (the natural logarithm of the number of new patents in each firm-year plus one) and innovation quality (the natural logarithm of average citations per new patent in each firm-year plus one) on the three-year *Obsolescence*. Columns (3) and (5) report the second-stage regression, where $I(CVC)_{i,t}$ is equal to one if firm i launches a Corporate Venture Capital unit in year t, and zero otherwise. $\Delta \widehat{Innovation}_{i,t-1}$ is the fitted innovation change over the past three years (i.e., the innovation change from $t-4$ to $t-1$). In the 2SLS framework, firm-level controls $X_{i,t-1}$ include the ROA, size (logarithm of total assets), leverage, and R&D ratio (R&D expenditures scaled by total assets). Industry-by-year dummies are included in the model to absorb industry-specific time trends in CVC activities and innovation. T-statistics are shown in parentheses and standard errors are clustered by firm. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1) Reduced Form	(2) First Stage	(3) 2SLS	(4) First Stage	(5) 2SLS
Obsolescence	0.001**	-0.114***		-0.128***	
	(2.171)	(-12.165)		(-17.064)	
$\Delta \ln(NewPatent)$			-0.007***		
			(-3.597)		
$\Delta \ln(Pat.Quality)$					-0.004***
					(-2.577)
Firm ROA	-0.000	0.090***	-0.003	0.070***	-0.003
	(-0.071)	(4.711)	(-1.289)	(4.170)	(-1.600)
Size (Log of Assets)	0.003***	0.028***	0.003***	0.031***	0.003***
	(6.353)	(12.664)	(11.401)	(16.106)	(11.238)
Leverage	0.002	-0.103***	-0.005**	-0.091***	-0.004**
	(0.921)	(-5.155)	(-2.484)	(-5.179)	(-2.095)
Firm R&D	0.006*	0.489***	0.015***	0.420***	0.011***
	(1.794)	(11.931)	(3.476)	(11.423)	(3.157)
F-Statistic		147.99		291.18	
Observations	25,976	25,976	25,976	25,976	25,976
R-squared	0.315	0.398	0.122	0.370	0.117
Industry × Year FE	Yes	Yes	Yes	Yes	Yes

Table V: Industry CVC waves

This table studies the industry clustering in CVC investment on the sample of Corporate Venture Capital (CVC) which are affiliated to US public non-financial firms between 1980 and 2006. The CVC data are from VentureXpert Venture Capital Firm Database, accessed through Thomson Reuters SDC Platinum. Panel A compiles all of the industry CVC wave periods, jointly defined using the clustering of launches of CVC units and investment deals made by CVCs. Each wave period is limited to at most four years. Industry is defined using the Fama-French 48 Industry Classification. Panel B lists potential economic and technological changes affecting CVC investment for the important industry CVC wave periods, as discovered in Panel A. The explaining events column is partially motivated by Table 2 in Harford (2005).

Panel A: Clustering of CVC Investment and Industry CVC Waves (1980 to 2006)

Industry	Cluster Years (CYs)	Total CVC Launches	CVC Launches in CYs	Total CVC Deals	Deals in CYs
Bus Svc (incl/ IT)	1998 to 2000	90	43	821	536
Electronic Equipment	1984 to 1986, 1998 to 2000	46	25	921	389
Computers	1984 to 1986, 1998 to 2001	44	22	617	428
Communications	1998 to 2000	40	19	120	66
Pharmaceutical	1984 to 1987, 1999 to 2001	28	10	254	65
Chemicals	1983 to 1985	11	8	48	22
Printing and Publishing	1997 to 1999	9	6	88	71
Electrical Equipment	1982 to 1983, 1996 to 1998	9	7	44	22
Utility	1997 to 2000	9	5	48	37
Petroleum	1980 to 1982	8	4	10	7
Automobile	1984 to 1985, 2000	6	3	42	29
Machinery	1983 to 1985	5	4	15	3
Healthcare	1983 to 1985	4	3	28	11
Measuring and Control Equipment	1998 to 2000	4	3	32	15

Panel B: Economic Events around Industry CVC Wave

Industry	Cluster Years (CYs)	Explaining Events
Bus Svc (incl/ IT)	1998 to 2000	IT became more important and new technology/services were developing rapidly
Electronic Equipment	1984 to 1986, 1998 to 2000	Electronic equipment manufacturers attempted to shift from small regional players to larger global players capable of infrastructure, IT, etc.
Computers	1984 to 1986, 1998 to 2001	Expansion of the personal computer market and booming innovation; the Internet
Communications	1998 to 2000	Deregulation in 1996; technological changes
Pharmaceutical	1984 to 1987, 1999 to 2001	Development of new technologies, large profit margins; threats from growing buyer strength (HMOs, governments); technology revolution through the introduction of life sciences
Chemicals	1983 to 1985	Increased environmental concerns and demand for specialty products
Printing and Publishing	1997 to 1999	Development of new publishing media (CD-ROM, Internet, etc.) and new marketing websites
Electrical Equipment	1982 to 1983, 1996 to 1998	Foreign competition, technological change (e.g., microcomputers)
Utility	1997 to 2000	Deregulation in some markets, creating opportunities for business expansion
Petroleum	1980 to 1982	Deregulation and high oil prices; US gas firms transition to secondary or tertiary fields
Automobile	1984 to 1985, 2000	Technological innovation (FWD, brake system, etc.) and sharp decline of oil prices
Machinery	1983 to 1985	Demand for microcomputers for numerical controls
Healthcare	1983 to 1985	Industry consolidation and development of new drugs
Measuring and Control Equipment	1998 to 2000	Strong structural changes in the semiconductor industry

Table VI: The Selection of CVC Portfolio Companies

This table studies how CVCs strategically select portfolio companies. I construct a cross-sectional data set by pairing each CVC i with each entrepreneurial company j that was ever invested by a Venture Capital investor. I remove cases when the active investment years of CVC firm i (between initiation and termination) and active financing years of company j (between the first and the last round of VC financing) do not overlap. The analysis is performed using the following specification:

$$I(CVC_i\text{-}Target_j) = \alpha + \beta_1 \cdot TechProximity_{ij} + \beta_2 \cdot Overlap_{ij} + \beta_3 \cdot SameCZ_{ij} + \gamma \times X + \varepsilon_{ij},$$

where the dependent variable, $I(CVC_i\text{-}Target_j)$, is equal to one if CVC i actually invests in company j, and zero otherwise. *Technological Proximity* is calculated as the *Cosine*-similarity between the CVC's and startup's vectors of patent weighting across different technological classes (Jaffe, 1986; Bena and Li, 2014). *Knowledge Overlap* is calculated as the ratio of the cardinality of the set of patents that receive at least one citation from CVC firm i and one citation from the entrepreneurial company j, and the cardinality of the set of patents that receive at least one citation from either CVC i or company j (or both). Geographical distance is measured using a dummy variable if the CVC firm i and company j are located in the same Commuting Zone (CZ), $I(SameCZ)$. The Appendix defines those variables more formally. In order to provide a clean interpretation of the estimation, both *Technological Similarity* and *Knowledge Overlap* are measured as of the last year before CVC i and company j both enter the VC-startup community, and the goal is to mitigate the potential interaction between them in the VC-startup community. Fixed effects at CVC firm and entrepreneurial company level are included. T-statistics are shown in parentheses and standard errors are clustered by CVC firm. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)
	$I(CVC_i\text{-}Target_j)$		
Technological Closeness			
Technological Proximity	0.029**	0.039**	0.035**
	(2.020)	(1.969)	(2.358)
Knowledge Overlap		-0.018*	-0.014**
		(-1.756)	(-2.169)
Geographical Closeness			
$I(SameCZ)$			-0.008***
			(-2.818)
Observations	868,323	868,323	847,102
R-squared	0.129	0.129	0.130
CVC FE	Yes	Yes	Yes
Portfolio Company FE	Yes	Yes	Yes

Table VII: Direct Information Acquisition from Portfolio Companies

This table studies the direct information acquisition of CVC parent firms from their portfolio companies by investigating how investing in an entrepreneurial company affects the CVC parent firm's possibility of innovating based on the entrepreneurial company's innovation. I first identify all the patents applied by a CVC parent firm (or a matched control firm) i, and all the patents cited by those patents. I then identify all the patents applied by an entrepreneurial company j. These data further allow me to determine whether firm i makes a new citation, which it never cited before, to a patent that is possessed by company j. The analysis is performed based on the following framework:

$$\begin{aligned} Cite_{ijt} = \alpha + \beta \cdot I(CVCParent) \times I(Post) \times I(Portfolio) \\ + \Phi[I(CVCParent), I(Post), I(Portfolio)] + \varepsilon_{ijt}. \end{aligned}$$

The sample is at the i-j-t level. The full set of i-j pairs then denotes the potential information flow that could happen between a CVC parent firm (or a matched firm) and a startup, captured by patent citations. $I(CVCParent)$ is a dummy variable indicating whether firm i is a CVC parent or a matched control firm. $I(Portfolio)$ indicates whether company j is in the CVC portfolio of firm i. For each i-j pair, two observations are constructed, one for the five-year window before firm i invests in company j, and one for the five-year window after the investment. $I(Post)$ indicates whether the observation is within the five-year post-investment window. The dependent variable, $Cite_{ijt}$, indicates whether firm i makes new citations to company j's innovation knowledge during the corresponding time period. The key variable of interest, $I(CVCParent) \times I(Post) \times I(Portfolio)$, captures the incremental intensity of integrating a portfolio company's innovation knowledge into organic innovation after a CVC invests in the company. Column (1) reports the result. Column (3) performs an analysis similar to that in column (1) except that it estimates the probability that a CVC parent firm cites not only patents owned by the startup but also patents previously cited by the startup. In other words, the potential citation now covers a broader technological area that the startup works in. Columns (2) and (4) separately estimate the intensity of citing knowledge possessed by companies that either exit successfully (acquired or publicly listed) or fail at last. All specifications include fixed effects imposing analysis across firms in the same industry and same year of (pseudo-) launching their CVC programs to absorb time-variant industrial technological trends. T-statistics are shown in parentheses and standard errors are clustered by firm. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
	Citing a Company's Patents		Citing a Company's Knowledge	
$I(CVCParent) \times I(Post) \times I(Portfolio)$	0.159***		0.297***	
	(74.13)		(86.54)	
$\times Successful$		0.184***		0.354***
		(63.90)		(73.94)
$\times Failed$		0.128***		0.239***
		(39.83)		(48.70)
$I(CVCParent) \times I(Post)$	0.018***		0.049***	
	(205.12)		(382.49)	
$I(CVCParent) \times I(Portfolio)$	0.003		0.057*	
	(1.60)		(1.75)	
$I(CVCParent)$	0.003***		0.019***	
	(38.95)		(146.12)	
$I(Post)$	0.002***		0.002***	
	(38.04)		(26.08)	
Observations	1,406,734		1,406,734	
R-squared	0.01		0.02	
Industry × CVC Year FE	Yes		Yes	

Table VIII: Integration of CVC-Acquired Information through External Acquisitions

This table studies the efficiency of acquiring companies or innovation around the start of CVC investment. The analysis is based on the following standard difference-in-differences (DiD) framework:

$$y_{i,t} = \alpha_{FE} + \beta \cdot I(CVCParent)_i \times I(Post)_{i,t} + \beta' \cdot I(CVCParent)_i + \beta'' \cdot I(Post)_{i,t} + \gamma \times X_{i,t} + \varepsilon_{i,t}.$$

The sample consists of acquisition deals (Panel A) and patent purchases (Panel B) conducted by CVCs and their matched control firms during five years before CVC initiations and five years after CVC initiations, and the unit of observation is an acquisition deal (Panel A) and a patent purchase (Panel B). The sample consists of CVCs and their propensity score-matched firms. The dependent variables $y_{i,t}$ are cumulative abnormal returns (CARs) for acquisition of companies (Panel A) and annual citation growth for purchases of patents (Panel B). $I(CVCParent)_i$ is a dummy variable indicating whether firm i is a CVC parent or a matched control firm. $I(Post)_{i,t}$ indicates whether the firm-year observation is within the $[t+1, t+5]$ window after (pseudo-) CVC initiations. The model includes industry-by-year fixed effects $\alpha_{industry \times t}$. Firm-level control variables include ROA, size (logarithm of total assets), leverage, and R&D ratio (R&D expenditures scaled by total assets). T-statistics are shown in parentheses and standard errors are clustered by firm. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Abnormal Returns when Acquiring Companies (in *basis points*)			
	(1)	(2)	(3)
	$CAR[-1,+1]$	$CAR[-2,+2]$	$CAR[-3,+3]$
$I(CVCParent) \times I(Post)$	65.811*	131.378**	135.693*
	(1.697)	(2.164)	(1.765)
$I(CVCParent)$	-55.009	-46.766	-185.444
	(-0.575)	(-0.385)	(-1.510)
$I(Post)$	11.615	23.546	16.984
	(0.120)	(0.208)	(0.134)
Observations	1,502	1,502	1,502
R-squared	0.272	0.275	0.281
Controls	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes

Panel B: Citation Growth after Purchasing Patents			
	(1)	(2)	(3)
	$\Delta Citation[-1,+1]$	$\Delta Citation[-2,+2]$	$\Delta Citation[-3,+3]$
$I(CVCParent) \times I(Post)$	0.200***	0.607***	1.358***
	(3.112)	(3.805)	(6.121)
$I(CVCParent)$	-0.023	-0.097	-0.095
	(-0.177)	(-1.081)	(-1.007)
$I(Post)$	0.015	0.040	0.108
	(0.375)	(0.395)	(0.764)
Observations	43,874	39,167	32,254
R-squared	0.045	0.093	0.082
Controls	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes

Table IX: Inventor Adjustment and Information Acquisition

This table studies the role of inventor adjustment in information acquisition for CVC parent firms. The Harvard Business School Patent Database provides inventor-level information, which allows me to identify inventor mobility and characteristics of the inventor team for each patent. In Panel A, the analysis is based on the following standard difference-in-differences (DiD) framework:

$$y_{i,t} = \alpha_{FE} + \beta \cdot I(CVCParent)_i \times I(Post)_{i,t} + \beta' \cdot I(CVCParent)_i + \beta'' \cdot I(Post)_{i,t} + \gamma \times X_{i,t} + \varepsilon_{i,t}.$$

The sample consists of CVCs and their propensity score-matched firms. The dependent variables $y_{i,t}$ are the logarithm of inventor leavers (columns (1) and (2)), the logarithm of newly hired inventors (columns (3) and (4)), and the proportion of patents mainly contributed by new inventors (columns (5) and (6)). A patent is considered as mainly contributed by new inventors if as least half of the inventor team are have three or fewer years' experience in the firm in the patenting year. $I(CVCParent)_i$ is a dummy variable indicating whether firm i is a CVC parent firm or a matched control firm. $I(Post)_{i,t}$ indicates whether the firm-year observation is within the $[t+1, t+5]$ window after (pseudo-) CVC initiations. Panel B studies the characteristics of patents produced by new inventors. The sample consists all the innovation produced by CVC parents and matched control firms from five years before the event to five years after the event. $I_{\text{New Inventor's Pat}}$ equals one if new inventors contribute at least half of the patent. *New Cite Ratio* and *Explorativeness* are defined in the Appendix. All specifications include industry-by-year fixed effects $\alpha_{industry \times t}$ to absorb time-variant industrial technological trends. Firm-level control variables include ROA, size (logarithm of total assets), leverage, and R&D ratio (R&D expenditures scaled by total assets). T-statistics are shown in parentheses and standard errors are clustered by firm. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Inventor Mobility during CVC Operation

	(1)	(2)	(3)	(4)	(5)	(6)
	$\ln(1 + Leavers)$		$\ln(1 + NewHires)$		New Inventors' Pat (%)	
$I(CVCParent) \times I(Post)$	0.119***	0.078*	0.110***	0.086**	0.171**	0.154*
	(3.478)	(1.896)	(2.791)	(2.142)	(2.402)	(1.948)
$I(CVCParent)$	0.015		0.019		-0.073	
	(1.217)		(1.380)		(-0.240)	
$I(Post)$	0.023	0.052*	0.003	0.037**	0.069	-0.024
	(1.297)	(1.921)	(0.149)	(2.360)	(0.774)	(-0.385)
Observations	10,289	10,289	10,289	10,289	4,834	4,834
R-squared	0.220	0.633	0.235	0.659	0.275	0.440
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year FE	Yes	No	Yes	No	Yes	No
Year FE	No	Yes	No	Yes	No	Yes
Firm FE	No	Yes	No	Yes	No	Yes

Panel B: New Inventors and New Information

	(1) *New Cite Ratio*	(2) *Explorativeness*	(3) *Citing Portfolio*
$I_{\text{New Inventors' Pat}} \times I(CVCParent) \times I(Post)$	0.031**	0.038**	
	(2.364)	(2.218)	
$I_{\text{New Inventors' Pat}} \times I(CVCParent)$	0.007	0.005	
	(0.368)	(0.215)	
$I_{\text{New Inventors' Pat}} \times I(Post)$	-0.009	-0.013	
	(-0.753)	(-0.762)	
$I_{\text{New Inventors' Pat}}$	0.050***	0.068***	0.005***
	(4.621)	(5.080)	(2.671)
$I(CVCParent) \times I(Post)$	0.069***	0.044***	
	(2.656)	(2.854)	
$I(CVCParent)$	-0.041	-0.060	
	(-1.570)	(-0.703)	
$I(Post)$	-0.015	-0.022	
	(-0.888)	(-0.911)	
Observations	132,407	132,407	43,236
R-squared	0.151	0.124	0.010
Controls	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	–

Table X: The Staying Power of Corporate Venture Capital

This table documents the staying power of Corporate Venture Capital by summarizing the durations of CVCs and investment characteristics sorted by duration. When the date of CVC termination is not available, I define it as the date of last CVC investment on portfolio companies. I categorize a CVC as "active" if its last investment happened after 2012 (as of March 2015) and VentureXpert categorizes the CVC's investment status as "Actively seeking new investments." *Duration* is calculated as the period between the initiation and termination of CVC investment. *Hibernation* (*Hiber*) is calculated as the number of years that are between CVC initiation and termination yet without any investment in entrepreneurial companies. Consecutive hibernation years are calculated as years of the CVC's longest consecutive hibernation. An investment deal is defined as a "success" if the entrepreneurial company was acquired or went public (I exclude cases when the company has neither gone public or been acquired but is still alive).

Duration	Number	%	Cum. Prob.	Years in Hiber (Median)	Consecutive Hiber (Median)	Success Rate
≤3	151	45.90%	45.90%	1	0	57%
4	21	6.38%	52.28%	1	1	54%
5	21	6.38%	58.66%	2	1	69%
6	10	3.04%	61.70%	2	1	59%
7	13	3.95%	65.65%	4	2	47%
8	13	3.95%	69.60%	4	4	56%
9	12	3.65%	73.25%	5	3	57%
≥10	88	26.75%	100.00%	6	5	57%
Total	329					
Still Active	52					

Table XI: Innovation Improvement and the Termination of CVC Life Cycle

This table studies the decision to terminate Corporate Venture Capital. Panel A examines average innovation improvement through the CVC life cycle by comparing innovation performance at CVC initiation and CVC termination (definition as in Table X). Innovation performance is measured using innovation quantity and quality, and both are adjusted using the industry (3-digit SIC level) peers in the same year. I also report the t-statistics for the differences in means between the two time points. *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. The analysis is performed on all CVCs with a disclosed or defined termination date and the subgroup that lasts for at least five years.

Panel B studies the effect of innovation improvement on CVC termination and investment decisions. The regressions are performed on the panel of CVC sample in their active years. The key variable $\Delta Innovation_{i,t}$ is defined as the difference of innovation between year t and the year of initiation. In columns (1) and (2), the dependent variable is a CVC termination dummy, and the specification is estimated using a Hazard model. In columns (3) and (4), the dependent variable is the annual number of investments in portfolio companies, and the model is estimated using Ordinary Least Squares (OLS). Firm-level control variables include ROA, size (logarithm of total assets), leverage, and R&D ratio (R&D expenditures scaled by total assets). *, **, *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Innovation at CVC Initiation and Termination

All	Initiation-Mean	Exit-Mean	Difference	T-Stat
Adjusted $\ln(NewPatent)$	0.75	0.91	0.16	2.18**
Adjusted $\ln(Pat.Quality)$	-0.03	0.23	0.26	1.90*

Duration $\geq$ 5	Initiation-Mean	Exit-Mean	Difference	T-Stat
Adjusted $\ln(NewPatent)$	0.79	1.03	0.24	2.43**
Adjusted $\ln(Pat.Quality)$	-0.05	0.43	0.48	2.57**

Panel B: Innovation CVC Exit and Investment

	(1)	(2)	(3)	(4)
	Hazard of Termination		Number of New CVC Deals	
$\Delta\ln(NewPatent)$	0.355***		-2.291***	
	(5.585)		(-2.647)	
$\Delta\ln(Pat.Quality)$		0.276***		-0.591*
		(6.277)		(-1.776)
Controls	Yes	Yes	Yes	Yes
Observations	2,489	2,489	2,489	2,489
Log-likelihood	-697.86	-363.88		
R-squared			0.127	0.128

Appendix

Appendix A. Key Variable Definitions

Variable	Definition and Construction
	a. Instrumental Variables
Obsolescence	The variable is constructed as the changes in the number of citations received by a firm's predetermined knowledge space. Formally defined by formula (2) in the paper.
	b. Innovation Variables
New Patents	Number of patent applications filed by a firm in a given year. The natural logarithm of this variable plus one is used in the paper, i.e., $\ln(NewPatent) = \ln(New\ Patent + 1)$.
Patent Quality	Average citations received by the patents applied by a firms in a given year. The natural logarithm of this variable plus one is used in the paper, i.e., $\ln(Pat.Quality) = \ln(Patent\ Quality + 1)$.
New Cite Ratio	The ratio of citations made to patents not belonging to a firm's existing knowledge, divided by the number of total citations made by the patent. Transformed to firm-year level by averaging across all patents produced in the firm in each year.
Explorative	Percentage of explorative patents filed in a given year by the firm; a patent is classified as explorative if at least 80% of its citations are not based on existing knowledge.
Inventor Leavers	An inventor is defined as a leaver of firm i in year t, if he or she generates at least one patent in firm i between $[t-3, t-1]$ and generates at least one patent in a different firm between $[t+1, t+3]$. Identified from the Harvard Business School patenting database.
Inventor New Hires	An inventor is defined as a new hire of firm i in year t, if he or she generates at least one patent in another firm between $[t-3, t-1]$ and generates at least one patent in firm i between $[t+1, t+3]$. Identified from the Harvard Business School patenting database.
New Inventors' Pat	Proportion of patents to which new inventors of a firm contribute at least 50%.
	c. CVC-Startup Relationship
SameCZ	Dummy indicating whether CVC firm i and entrepreneurial company j are located in the same Commuting Zone (CZ). In cases when the CVC and the firm headquarter are located in different areas, I use whichever is closer to the startup.
$\ln(Distance)$	Natural logarithm of the mile distance between firm i and entrepreneurial company j (accurate at Zipcode-level). In cases when the CVC and the firm headquarter are located in different areas, I use whichever is closer to the startup.

Technological Proximity	Degree of similarity between the distribution of two firms' (i and j) patent portfolios across two-digit technological classes using the same technique as in Jaffe (1986) and Bena and Li (2014). Formally, $$TechnologicalProximity = \frac{S_i S_j'}{\sqrt{S_i S_i'}\sqrt{S_j S_j'}},$$ where the vector $S = (S_1, S_2, \cdots, S_K)$ captures the distribution of the innovative activities, and each component S_k is the percentage of patents in technological class k in the patent portfolio.
Knowledge Overlap	Firm i's knowledge in year t, $K_{i,t}$ is constructed as the patents that received at least one citation from firm i up to year t, and similar for firm j's knowledge $K_{j,t}$. *Knowledge Overlap* is calculated as the ratio of—(1) numerator: the cardinality of the set of patents that receive at least one citation from CVC firm i and one citation from entrepreneurial company j; (2) denominator: the cardinality of the set of patents that receive at least one citation from either CVC i or company j (or both). That is, $$KnowledgeOverlap_{ij,t} = \frac{Card(K_{i,t} \cap K_{j,t})}{Card(K_{i,t} \cup K_{j,t})}$$
d. Firm Characteristics	
Size (Log of Assets)	The natural logarithm of total assets in millions, adjusted to 2007 US dollars.
Firm ROA	Earnings before interest, taxes, depreciation, and amortization scaled by total assets.
M/B	The market value of common equity scaled by the book value of the common equity.
Leverage	Book debt value scaled by total assets.
Cash Flow	(Income before extraordinary items + depreciation and amortization) scaled by total assets.
Firm R&D	Research and development expenses scaled by total assets.
Institutional Shareholding	Total shares (in %) held by the top five institutional shareholders in the firm.