

When do Firms Undertake R&D by Investing in New Ventures?

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Abstract

We explore the conditions under which firms are likely to pursue equity investment in new ventures as a way to source innovative ideas. We find that firms invest more in new ventures – commonly referred to as “corporate venture capital” – in industries with high technological ferment, weak intellectual property protection, and where complementary distribution capability is important. Furthermore, we find that the greater a firm’s cash flow and history of innovation, the more likely it is to invest. Our results suggest that in Schumpeterian environments, incumbents may supplement their innovative efforts by tapping into the knowledge generated by new ventures.

Keywords: innovation, external R&D, corporate venture capital

Short Title: Corporate Ventures & Research

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Scholars have long been interested in the components and form of the “knowledge production function” – the process by which innovative inputs are transformed into innovative outputs. Historically, the innovation literature has focused on the role of internal research and development on firm innovation (e.g., Griliches, 1979). However, internal R&D expenditures play only a partial role in firm innovation rates. Increasingly, scholars recognize that the ability to exploit *external* knowledge is critical to firm innovation (Cohen and Levinthal, 1990; Henderson and Cockburn, 1994; Teece, Pisano, and Shuen, 1997). Indeed, in the past decade attention has shifted to the role of innovative inputs that reside outside the firm’s boundaries. Among others, researchers have looked at how firms access knowledge in academic and government labs through professional networks (Cohen, Nelson and Walsh, 2002), in established competitors through alliances (Hagedoorn and Schakenraad, 1994; Gulati, 1995; Powell, Koput and Smith-Doerr, 1996), and in new ventures through equity investment (Dushnitsky and Lenox, 2002).

For the most part, researchers have studied the potential for various external sources to provide innovative knowledge. The alliance literature has found that innovative alliance partners may provide important learning benefits to firms (Hagedoorn and Schakenraad, 1994; Dussauge, Garrette, and Mitchell, 2000; Stuart, 2000; Rothaermal, 2001). Others have found that maintaining links with universities and professional networks are important for innovating. However, the results of these studies are conditional on the firms successfully establishing linkages. Less studied are the factors affecting the initial selection of these external sources especially with respect to alternative investments such as internal research and development.

A handful of scholars have begun to address this issue in the alliance literature by examining the decision to form an R&D alliance (Gulati, 1995; Stuart, 1998; Ahuja, 2000). However, these studies are limited because they do not observe the cost to the firm of participating. As a result, they are unable to discern the elasticity of external investment with respect to various industry and firm factors including investment in internal R&D. While the decision to commit resources towards *internal* innovative inputs (i.e., R&D expenditures) has received much scrutiny (Hall, 1992; Himmelberg and Petersen, 1994), there remains a need to study firms' decisions to commit resources towards *external* innovative inputs.

In this paper, we focus on one strategy available for firms to source external knowledge. We explore the conditions under which established firms source innovative ideas through investment in external entrepreneurial ventures (Roberts and Berry, 1985). Commonly referred to as “corporate venture capital” (CVC), these investments consist of minority equity stakes in relatively new, not-publicly-traded companies that are seeking capital to continue operation. High-tech companies (e.g. Intel, Sony, and Motorola), pharmaceutical giants (e.g. J&J), and media moguls (e.g. News Corp.) have invested millions in start-ups. In the year 2000 alone, nearly \$16 billion was invested by over 300 corporations – representing 15% of the entire venture capital market. Despite the economic downturn and subsequent reduction in CVC investment, numerous companies have maintained a strident commitment to their venturing programs (Chesbrough, 2002).

Corporate venture capital investment is an appealing setting for the study of firms' decisions to pursue external innovative inputs. Previous work has found that CVC investment may be an effective way for firms to increase their innovative output (Dushnitsky and Lenox, 2002). Unlike other inter-organizational arrangements, CVC investment is a capital expenditure

that is easily observed and measured. The deployment of other external innovative inputs is often difficult to observe and even more difficult to determine their cost. For example, what price does one place on maintaining personal ties with star scientists (Cohen, Nelson and Walsh, 2002)? Data on the cost of maintaining R&D alliances is typically not available to researchers and may not even be calculated by alliance members. The ability to measure the dollar amount of corporate venture capital investments enables us to better capture its elasticity with respect to various industry and firm factors. More importantly, these investments are observed irrespective of their success or contribution to firm innovation rates.

We propose a number of hypotheses concerning the decision to invest corporate venture capital. The driving logic behind our hypotheses is that a profit-seeking firm chooses to invest corporate venture capital when CVC's marginal innovative output is expected to be higher than that of internal R&D. An empirical test of these hypotheses is presented based on a sample of over 700 U.S. public firms during the time period 1969-1999. Primary data was gathered from Venture Economic's VentureXpert database of the venture capital industry. These data were augmented with data from Standard & Poor's Compustat dataset, the NBER version of the U.S. Patent database (Hall, Jaffe and Trajtenberg, 2001), and the Carnegie Mellon Survey (CMS) of Research and Development (Cohen, Nelson, and Walsh, 2001). Fixed-effect and random-effect specifications are adopted.

We find that firms invest more in new ventures in industries with high technological ferment, weak intellectual property protection, and where complementary distribution capability is important. Furthermore, we find that the greater a firm's cash flow and history of innovation, the more likely it is to invest. Interestingly, we present evidence that internal R&D and CVC investment are perhaps complements rather than substitutes vying for research dollars. These

results have important implications for the organization of R&D in general and the use of CVC in particular. Our results suggest that in Schumpeterian environments characterized by high innovation rates, incumbent firms may choose to tap into the knowledge generated by new ventures as a way to increase their own innovation rates.

Theory and Hypotheses

At the margin, one would expect that increases in external CVC investment would come at the expense of internal R&D. A profit-maximizing firm will thus choose to pursue more external CVC when its marginal innovative output is expected to be higher than that of internal R&D. Under what conditions should we expect CVC investment to show higher marginal productivity? A number of scholars have advanced the idea that entrepreneurial ventures are more likely to be the source of highly valuable and innovative ideas (Tushman and Anderson, 1986; Kortum and Lerner, 2000; Shane, 2001a). Indeed, Kortum and Lerner (2000) observe that entrepreneurial, human-capital intensive ventures generate higher levels of patenting output than established firms. This work suggests that, absent agency considerations, we would expect incumbent firms to favor CVC investment over internal R&D.

At the heart of this argument is a consideration of the ability of firms to employ star scientists in internal labs. In the later half of the twentieth century, highly skilled human capital (labor) has become more important in generating innovation than physical capital (Zingales, 2000). In this new setting, skilled researchers will likely disassociate themselves from his or her corporate laboratory and form independent firms (Aghion and Tirole, 1994). Amit, Muller and Cockburn (1995) conclude that the decision to self-employ is undertaken when the value of self-employment is higher than the opportunity cost (i.e., lost salary from incumbent).

Following this line of reasoning, researchers will opt away from fixed salary (i.e., remaining a corporate employee) and towards profit sharing (i.e., founding their own new venture) only when they think the idea is highly lucrative (Dix and Gandelman, 2000). Thus, we expect to observe the formation of new ventures only when entrepreneurs have highly innovative ideas (Aghion and Tirole, 1994). Consistent with this prediction, Shane (2001a) provides empirical evidence that the decision to form a new venture is associated with underlying entrepreneurial inventions that have high economic value.

However, even if we accept that the marginal R&D productivity of new ventures is higher than established firms, we must recognize that there are potential costs to incumbents using CVC investment as a vehicle to tap those innovations. First, the presence of significant information asymmetries between new ventures and their corporate investors opens incumbent firms to potential adverse selection – a problem that is likely far less pronounced in internal laboratories. Second, the independent entrepreneur has greater leverage to hold-up the investing firm.

Thus, *ex ante* adverse selection and *ex post* hold-up may negate the learning benefits of investing in innovative new ventures. In considering CVC investment, a focal firm regards the marginal R&D productivity of new ventures *net* of potential losses due to the inherent adverse selection and hold-up problems. Consequently, we expect to observe CVC investment when CVC's *net* marginal innovative output is expected to be higher than that of internal R&D. In the sections that follow, we develop a set of hypotheses concerning the conditions under which this balance will favor CVC investment and firms will consequently seek knowledge through equity investment in new ventures.

While our hypotheses assume that firms invest in new ventures to acquire knowledge, we must recognize that a firm may pursue CVC investment simply to generate a high return on investment (Block and MacMillan, 1993; Chesbrough, 2002; Siegel, Siegel, and MacMillan, 1988). During the stock market bubble of the late 1990's, some firms viewed CVC investment as a way to capitalize on the inflated values of technology ventures. Firms gained a return on investment primarily by selling shares in a venture after an initial public offering (Gompers and Lerner, 2001). During the latter half of the nineties, the price of many ventures doubled on the first day of trading (Ritter, 2001). Such lucrative exits were highly dependent on market conditions and had a strong periodicity corresponding to the stock market.

While it is important to consider financial drivers of CVC investment, we propose that firms mainly pursue such investments for strategic reasons. Previous research suggests that most firms view CVC investment as a window on technology. The declared goal of Nokia Ventures, the CVC program of Nokia, is to “fuel future growth and to boost new product and long-term business development” (Business Wire, 1998). Surveys support this observation (Block and MacMillan, 1993; Chesbrough, 2002; Winter and Murfin, 1988). Yost and Devlin (1993) report that 93% of corporate venture capitalists in their sample, view strategic objectives as one of their main objectives. Siegel, Siegel, and MacMillan (1988) report that corporations rank “exposure to new technologies and markets” as the leading objective for engaging in corporate venture capital programs. Similar results are reported by Block and MacMillan (1993) and Winter and Murfin (1988). Further support is provided by recent empirical work examining the relationship between CVC investment and firm innovation (Dushnitsky and Lenox, 2002).

Industry Drivers

First we examine the degree to which general industry and technology characteristics may drive the decision to seek innovations through equity investment in new ventures. We propose that the marginal benefit of CVC will be greatest in industries with rich technological opportunities, weak intellectual property protection (in particular, patent protection), and where complementary capabilities (e.g. in manufacturing or distribution) are important to appropriate the returns to innovation. We will consider each in turn.

The marginal benefit of CVC should be greater in industries with more technological opportunity – i.e. when “technical advance, at prevailing input prices, is less costly (Cohen, 1995).” The level of technological opportunity is affected first and foremost by advancements in basic science and underlying technological fields (Klevorick, Levin, Nelson and Winter, 1995). Klevorick et al. (1995) find that industries differ significantly in their level of technological opportunity.

In industries with greater technological opportunities, entrepreneurs are more likely to identify valuable new innovations, and, in the presence of these lucrative opportunities, start new ventures (Shane, 2001a). In the presence of a large pool of highly innovative entrepreneurial ventures, the marginal benefit of CVC investment will rise relative to internal R&D. In essence, as the likelihood of new ideas increases (and thus the expected returns to research effort increase), researchers are more likely to leave and start their own ventures. Hence, the cost of securing quality researchers in internal labs increases. Meanwhile, the potential to learn from investing in new ventures is increasing on average.

Hypothesis 1: The greater technological opportunities, the greater a firm’s investment in new ventures.

The relative advantage of CVC investment to internal R&D expenditures will be more pronounced the weaker the intellectual property (IP) protection. We define a weak IP regime as one where ventures struggle to protect their innovations from imitation through legal mechanisms such as patents (Cohen, Nelson and Walsh, 2001). In such environments, CVC serves as an effective channel for learning from quality ventures (Dushnitsky and Lenox, 2002). Absent the legal protection of a patent, a new venture is likely to rely on secrecy to protect their intellectual property. CVC investment provides a way to pierce the veil of secrecy. Investing firms typically sit on the board of directors. In many cases, the investing firm will set up a liaison program with the venture to increase dialogue between its scientists and the venture's researchers.

When patent protection is weak, a venture may not have the means to prohibit investors from appropriating its core knowledge. Established firms are more likely to have the resources necessary to fight lawsuits and other challenges to their patents (Somaya, 2002). Furthermore, these firms are more likely to possess complementary capabilities in research, manufacturing, and distribution channels, which they can leverage to their advantage. Conversely, new ventures may find it too costly to receive patents for their technology and lack the deep pockets necessary to pursue effective legal protection. Hence, a venture may not be able to put a stop to knowledge leaked to investors when patent protection is weak thus increasing the incentives of incumbents to seek CVC investment over internal R&D.

Hypothesis 2: The weaker the IP regime, the greater a firm's investment in new ventures.

The discussion above raises an interesting conflict. While the contribution of CVC to firm innovative output is directly related to the quality of the ventures invested, high quality ventures may shun corporate investors in order to prevent leakage of their valuable knowledge

(especially in weak IP regimes). Gans and Stern (2000) argue that the benefits to the venture from allying with an established firm may under some circumstances offset the costs of expropriation due to the disclosure of the innovation. These benefits include complementary capabilities in manufacturing and distribution that new ventures are often lacking. Based on a survey of more than 100 entrepreneurial ventures, Gans, Hsu and Stern (2001) verify that cooperation with incumbent firms (either through licensing, strategic alliances or outright acquisition) is the preferred course of action when incumbents' tightly-held complementary assets are crucial to the commercialization of the invention.

Entrepreneurial ventures stand to benefit from CVC-backing not only due to the availability of funding and the enhancement of their own reputation, but also through an actual improvement of its R&D, manufacturing, marketing and distribution operations. First, a corporate venture capital investor can provide value-added services similar to those provided by quality VC funds (Block and MacMillan, 1993; Hsu, 2002). Second, it can extend unique services, which capitalize on corporate resources. For example, investing firms may provide the right to use the firm's complementary assets such as laboratories, access to the firm's network of customers and suppliers, a readily available beta site, and access to domestic and foreign distribution channels (Acs, Morck, Shaver and Yeung, 1997; Maula and Murray, 2002; Pisano, 1991; Teece, 1986). Finally, the fact that a focal venture is chosen by an industry incumbent acts as an endorsement effect towards third parties and/or the capital markets (Stuart, Hoang and Hybels, 1999). These arguments are consistent with the findings of Maula and Murray (2001), who report that ventures co-financed by CVC programs receive higher valuations than comparable ventures funded solely by VCs.

It is difficult to gauge the actual level of contribution made by an established firm to its portfolio ventures, especially ex-ante. Nevertheless, we know that in some industries access to complementary assets is more crucial than others (Cohen, Nelson and Walsh, 2001). For example, complementary assets are more tightly-held by incumbents in the chemicals and pharmaceuticals sectors where large scale manufacturing and distribution are important. We can therefore expect that in those industries where established firms control crucial complementary assets, entrepreneurs are inclined to affiliate with corporate investors. As a result, firms who pursue CVC in those industries are able to – on average – tap higher quality ventures, and realize a higher marginal contribution to their innovative output.

Hypothesis 3: The greater the importance of complementary assets, the greater a firm's investment in new ventures.

Firm Drivers

Now we turn our attention to firm level drivers of CVC activity. The most thoroughly examined firm characteristic in the context of internal R&D has been cash flow (Cohen, 1995). Cash flow is a measure of the availability of funds. Initially, scholars predicted that internal R&D expenditures would be highly sensitive to cash flow, much in the way that a firm's capital investments in general are sensitive to the availability of internal funds (Fazzari and Athey, 1987; Fazzari, Hubbard and Petersen, 1988). This conjecture builds on Myers and Majluf (1984) who stipulate that moral hazard problems hinder external financing of risky business activities. That is, since insiders have superior knowledge of investment opportunities and outsiders recognize this information asymmetry, the cost of financing investment via external funds is higher than the cost of internal funding. Consequently, investment is likely sensitive to availability of internal funds (firm cash flow).

Interestingly, contrary to prediction, scholars report low sensitivity of R&D to cash flow (Hall, 1992; Himmelberg and Petersen, 1994). This finding has been attributed to adjustments costs (Griliches and Hausman, 1986; Himmelberg and Petersen, 1994). Since R&D personnel are difficult to come-by, and their departure might have an adverse effect, firms set R&D levels in accordance with the “permanent” level of internal funds. That is, if a firm believes that a change in cash flow is transitory, it will not change its R&D levels.

CVC investing is a considerable capital expenditure much like internal R&D. However, unlike R&D, we expect corporate venture capital to exhibit high sensitivity to firm’s cash flow. On the one hand, outsiders are likely to recognize the superior knowledge of insiders, thus leading to higher cost of financing investment via external funds. On the other hand, corporate venturing activity does not face the problems of retaining highly skilled R&D personnel. The *raison d’être* of corporate venture capital as an innovative mechanism is to access the pool of scientists and entrepreneurs who would be difficult to employ in the organization. Therefore, we expect that contrary to internal innovative inputs (i.e. R&D expenditure); corporate venture capital will be affected by the availability of cash.

Hypothesis 4: The greater the firm’s cash flow, the greater a firm’s investment in new ventures.

The degree to which a firm may learn from its CVC investments will depend in part on the absorptive capacity of the firm. Cohen and Levinthal (1990) advance the view that internal and external sources of innovations are interdependent. In line with their absorptive capacity argument, Kleinknecht and van Reijnen (1992) report that having an internal R&D department increases the likelihood of co-operative R&D with other firms. Pisano (1991) reports that firms with an expertise in a given research domain exhibit higher levels of knowledge absorption from external sources. The causality runs the other way as well. Colombo and Gerrone (1996) find

that firms with internal R&D tend to pursue more co-operative R&D, while co-operation may also stimulate in-house R&D. Thus the authors conclude that internal R&D and external R&D (i.e., co-operative R&D) are complements. Gambardella (1992) and Veugelers (1997) also report that external sourcing of R&D is more effective when done in the presence of own R&D.

We propose that the impact of investment in entrepreneurial ventures on firm innovation rates will be greater for those firms who have a strong base in innovation. Thus, the ability of an investing firm to transfer or create knowledge through its interaction with a venture likely requires a firm to have sufficient technical understanding to both grasp and capitalize on that knowledge. Internal research and development provides the foundation upon which firms may learn from the ventures they invest. For example, a number of corporate venture capital programs use personnel from their R&D unit to run their CVC initiatives. Henderson and Leleux (2002) conduct a case study of six European corporate venture capitalists and find that “a person or team from the business unit was involved in the due-diligence process”. This practice is common in other CVC programs, including Dell, Nortel Networks and SmithKline Beecham PLC (Corporate Strategy Board, May 2000). Firm liaisons with new ventures often reside in and are supported by the R&D unit.

Hypothesis 5: The greater a firm’s absorptive capacity, the greater a firm’s investment in new ventures.

Data and Method

In our analysis, we explore firm’s inclination to pursue external innovative inputs. Specifically, we explore the varying levels of firm CVC investment as a function of firm level and industry level drivers. To that end, we constructed a database of U.S. public firms that invested corporate venture capital or operated in the similar industry during the period 1969-

1999. To the best of our knowledge, our database is unique in that it provides detailed information of firm financial, corporate venturing and patenting activities.

Sample

We constructed a large, unbalanced panel of U.S. public firms during the period 1969-1999. The panel includes public firms that invested corporate venture capital or patented during this period. The resulting dataset includes 749 firms and 14,972 firm-year observations. The database contains information on firms' venturing activity collected from Venture Economic's VentureXpert database, patenting activity from the Hall, Jaffe, and Tratjenberg (2001) dataset derived from the U.S. Patent Office, financial data from Standard & Poor's Compustat database, and appropriability data from the Carnegie Mellon Survey of Research & Development.

To construct our database, we first identified the population of firms engaging in corporate venturing activity through the VentureXpert database.¹ The database contains a comprehensive coverage of investment, exit, and performance activity in the private equity industry from 1969 to 1999. We searched the population of all private equity investments for any investments by firms or their funds.² For these firms, we collected data on the annual amount of venturing investments (disbursements). We augmented our CVC data with patenting data constructed by Hall, Jaffe, and Tratjenberg (2001) (hereafter HJT) that are based on the U.S. Patent Office database. We added to our sample all U.S. firms within the same industries (based

¹ The database is offered by Venture Economics, a division of Thomson Financial. The data are collected through industry associations (European Venture Capital Association, the National Venture Capital Association, and other key associations in Asia and Australia) and the investment banking community. These data have been used in several academic studies on the venture capital industry (Bygrave 1989; Gompers 1995).

² We included the following VentureXpert categories: Non-Financial Corp Affiliate or Subsidiary Partnership, Venture/PE Subsidiary of Non-Financial Corp., Venture/PE Subsidiary of Other Companies NEC, Venture/PE Subsidiary of Service Providers, Direct Investor/Non-Financial Corp, Direct Investor/Service Provider, SBIC Affiliate with non-financial Corp. and Non-Financial Corp. Affiliate or Subsidiary. We excluded investments by corporate pension funds because these investments are distinct and unlikely to result in learning benefits.

on 4-digit SIC classification) as those firms in our CVC dataset who also patented over the time period 1969-1999.

The HJT datasets contain detailed information on almost 3 million U.S. patents granted between 1963 and 1999, all citations made to these patents since 1974 (over 16 million), and a match of patents to Compustat. Standard & Poor's Compustat database was used to provide annual firm-level accounting and financial data thus limiting our sample to publicly traded firms. An automated, matching algorithm and hand-checking were used to link the VentureXpert data with the HJT patenting dataset and Compustat. Furthermore, while the HJT patenting dataset bases the ownership structure of firms to 1989, we manually matched up firms to US Patent and Trademark Office (PTO) assignee codes to ensure we capture the patenting activity of all firms.

The resulting sample included 2,289 firms and 45,664 observations. 262 firms (11.4%) of these firms invested corporate venture capital some time during the period 1969-1999. For each of these firms, we collected annual financial data such as research expenditures and book value of assets for the years 1969 to 1999 from Compustat. Finally, we matched this data with the Carnegie Mellon Survey (CMS) of Research and Development (Cohen, Nelson, and Walsh, 2001). This survey provided our measures of industry-level appropriability. Since the survey covered only a subset of the industries collected in our initial data collection, our final sample was reduced to 749 firms and 14,972 firm-year observations. 115 firms (15.3%) of these firms invested corporate venture capital during our thirty-year panel.

Measures

Our dependent variable is annual CVC investments in millions of dollars (*CVC*). This variable is calculated as the sum of all investments (disbursements) via all venturing funds by a

firm in a year. Note, these amounts represent the actual dollar value invested during a given year, and should not be confused with dollars committed to venturing activity (usually reported in the professional media), which represent the total dollar amount a fund has committed to invest over the fund's life. We believe the former measure is more appropriate for two reasons. First, not all firms who pursue corporate venture capital set aside a dedicated amount for this activity. The measure funds committed may therefore be under-estimating firm's CVC. Second, we explore the effect of changes in industry and firm factors has on firm's corporate venturing. If some or all of these factors change *after* the funds have been committed, it may affect subsequent CVC investments. The use of funds committed rather than funds disbursed does not make use of this most interesting information.

There are two groups of independent variables. The first group is comprised of industry level measures such as a measure of technological ferment, strength of appropriability regime, and the importance of complementary assets. *Tech Opportunity* is defined as the average number of citation-weighted patents applied to by firms in a given year in a given industry defined by each four-digit Standard Industrial Classification (SIC). This measure captures time-variant differences in the level of technological opportunities across industries. In other words, *Tech Opportunity* gauges the level of innovative, or quality patenting, for a given industry in a given year. Because, we are interested in the level of technological ferment in the focal year, we peg patents by their application date, rather than by the grant date. By including *Tech Opportunity*, we attempt to address the fact that some industries at some points in time may experience greater technological ferment that may drive both the opportunities to invest in new ventures and the opportunities to innovate internally (Klevorick, Levin, Nelson and Winter, 1995).

Admittedly, this measure might be noisy due to citation ‘inflation’ in certain industries. In addition, this variable is biased downward in recent years as firms have not had the opportunity to cite more recent patents. Hall, Jaffe and Trajtenberg (2001) report that the distribution of forward lag in citation (i.e., the number of years between patent’s application date and later citing-patents application date) is about 3 to 4 years. This downward bias should work against us finding a result as this period is also the period in which we see a massive increase in CVC investment. Finally, because this measure is highly skewed, we employ the natural logarithm of *Tech Opportunity* in the regression analysis.

To test our hypotheses concerning the effect of intellectual property protection and complementary assets, we create two measures derived from the Carnegie Mellon Survey (CMS) of Research and Development (Cohen, Nelson, and Walsh, 2001). The CMU survey of R&D explores the effectiveness of various mechanisms in protecting profits due to invention. The questionnaire was administered in 1994 to a random sample of U.S. manufacturing R&D labs drawn from the Directory of American Research and Technology. Overall, 1,478 R&D unit managers answered about mechanisms they use in order to protect profits due to inventions in their focal industry. These included a variety of mechanisms such as trade secrets, patents, complementary assets due to sales, and complementary assets due to manufacturing. A comparison of CMS results with the earlier Yale survey (Levin et al, 1987) suggest that industry appropriability conditions as well as the importance of complementary assets are relatively stable over time.³ Variables similar to the ones delineated below have been employed by Shane (2001a, 2001b), with the exception that his measures were based on the earlier Yale survey, as the CMS was not yet available.

³ With the exception that larger firms rely on patents somewhat more nowadays than in the early 1980’s.

The variable *IP Regime* reflects the relative importance of patenting as a way to protect intellectual property. *IP Regime* is derived from the CMU survey measure of the mean percentage of innovations for which patenting was considered as an effective mechanism in protecting intellectual property within an industry. The higher the value of *IP Regime*, the more effective are patents in protecting inventor's profits. *CA Importance* reflects the relative importance of complementary assets in bringing an innovation to market. *CA Importance* is taken directly from the CMU survey measure of the reported importance of distribution and sales capabilities within an industry. (For presentation purposes solely, we divide these variables by 100 to create a 0 to 1 scale.) Note, by construction, these two variables vary across industries but are time-invariant.

The second group of independent variables consists of firm level measures such as cash flow and absorptive capacity. These variables are defined at the firm level and are time-variant. In particular, we define *Cash Flow* as income before extraordinary items (i.e. income after interest and taxes) plus depreciation and amortization (Fazzari, Hubbard and Petersen, 1988; Hall, 1992; Himmelberg and Petersen, 1994; Gilchrist and Himmelberg, 1998). Since firm treat R&D as an expense, some studies have added R&D back into the usual accounting definition of cash flow. Because we control for R&D expenditure separately, we did not follow this procedure.

We capture the absorptive capacity of the firm by measuring the stock of patents a firm has been granted (*Patent Stock*). It is a common practice to capture firm absorptive capacity with its R&D expenditure. Unfortunately, this may bias our results. The relationship between internal and external R&D is very much an open question in the literature. While the two compete for corporate resources (implying a substitution effect), some studies suggest they are

complements. Some studies find internal R&D increases the effectiveness of external R&D (Pisano, 1991); others reports external R&D increases the effectiveness of internal R&D (Veugelers, 1997); and yet others indicate a simultaneous effect (Colombo and Gerrone, 1996). Thus, R&D expenditure may likely be correlated with the error term, and hence, violate the regression assumptions.

To avoid this concern, we employ firm stock of prior patents as a proxy. It is highly correlated with R&D expenditure (see Table 1), but is not likely correlated with the error terms. On a theoretical level, we believe *Patent Stock* may be a more attractive construct for firm absorptive capacity (Silverman, 1999). Each dollar spent on internal R&D may not generate the same amount of knowledge stock. Some research is likely to be unproductive and should not be weighed equally to that which is successful (Hall, Jaffe, and Trajtenberg, 2001). According to Hall et. al. (2001), patents (and by extension patent stocks) should be a good proxy for knowledge capital because it represents the success of an R&D program.

Following Blundell, Griffith and Reene (1995), we calculate *Patent Stock* by calculating the depreciated sum of all patents applied from 1963 to the current year.⁴

$$Patent\ Stock_{it} = Patents_{it} + (1-\delta) Patent\ Stock_{it-1}$$

We assert that this measure helps capture the previous innovative efforts of the firm and reflects their ability to absorb new knowledge. Previous studies examining patenting rates have used a similar measure (Cockburn and Henderson, 1998; Stuart, 2000).

Finally, we include a number of controls. *Internal R&D* is equal to the annual expenditures on research and development, for each firm, as it appears in Compustat. *Firm Size*

⁴ We adopted a depreciation rate of 30% as in Blundell et. al. (1995). At a depreciating rate of 30%, patents granted prior to 1963 have little impact on 1969 *Patent Stock* especially given the one to four year lag between patent application and granting.

is measured as total firm assets in millions of dollars. Larger firms possess greater resources for investing in research and thus are more likely to pursue more internal R&D as well as external CVC (Schumpeter, 1942; Henderson and Cockburn, 1996; Cohen and Levinthal, 1990). We also include year dummy variables to account for macro economic changes such as stock market fluctuations. The dependent variable as well as all relevant independent and control variables (*Cash Flow*, *Internal R&D* and *Firm Size*) are adjusted to 1999 dollars. These variables also exhibit high level of skewness. Following common practice in the literature, we employ the natural logarithm in the regression analysis.

Analysis and Results

Table 1 presents summary statistics and correlations for the measures in our study. Of the 749 firms in our sample, 115 (15.3%) firms invest in new ventures at some point during the thirty-year time frame of study. The amount of CVC invested in our sample varies from zero to \$523 million (in absolute terms). We observe that firms in our sample, on average, have an annual cash flow of \$9.5M. The average internal R&D expenditure is \$10.9M, or about 4.5% of the average firm size of \$242M. To allay fears of multicollinearity between firm size and R&D expenditures, we estimated each of our models using intensities and found consistent results. Please note that Table 1 reports the natural log of each of our variables.

Insert Table 1 about here

Figure 1 presents a summary of annual corporate venture capital investment relative to the sum of CVC investment and internal R&D expenditures by sectors during the period 1969 to

1997.⁵ We observe three wave of corporate venturing across sectors: the first in the early 1970's, the second beginning in 1979 in response to legislation which fueled a substantial growth of the venture capital market, and the third corresponding with the rise of the Internet in the mid-nineteen nineties. We also observe substantive differences across sectors in the level of CVC relative to all innovation investments. In 1999, the telecommunications and computer sectors invested 23% and 12% respectively of their innovation investments through CVC. In contrast, the chemicals and pharmaceutical sectors never invested more than 2%.

Insert Figure 1 about here

Table 2 presents the coefficients from our estimates of a number of specifications of our model of CVC investment. In Model 1, we adopt an OLS specification with year and firm dummies. We assume a contemporaneous relationship between our regressors and dependent variables. In particular, we use a log-log specification such that the coefficients represent the elasticities of our independent variables and firm CVC investment for every year in our sample. Because our measures of the strength of intellectual property protection and the importance of complementary assets are stable industry effects, they are subsumed by the firm fixed-effects and removed from the estimation presented in Model 1.

Insert Table 2 about here

⁵ Sectors were defined by SIC code as follows: chemicals (28** excluding 2834 and 2836, 29**, 3080), pharmaceuticals (2834, 2836), devices (38**), computers (357*), telecommunications (48**, 3663), and semiconductors (367*).

First, we find that the estimated coefficient to *Tech Opportunity* suggests a significant, positive effect on CVC investment as hypothesized. Second, we observe a significant positive effect of cash flow as we predict. Note, that the magnitude of this effect is very small, suggesting an increase in 1% in firm's cash flow is associated with an increase of only 0.015% in corporate venture capital. However, we believe that this result underestimates the effect of cash flow because at any given year only 10% of the firms in the sample pursue external CVC. We report higher elasticity for models that control for this potential bias. Finally, as hypothesized, we observe a significant positive coefficient on *Patent Stock*, our proxy for the absorptive capacity of the firm. Neither *Internal R&D* nor *Firm Size* are found to be significant.

In Model 2, we adopt a random-effects specification that allows us to introduce our stable, industry effects – *IP Regime* and *CA Importance*. A random-effects specification assumes that individual specific constant terms are randomly distributed across cross-sectional units (Greene, 2000). This assumption seems reasonable since we are sampling on a larger population of firms. By construction, the random-effects specification assumes that the individual effects are uncorrelated with the other regressors. In Model 2, we observe a negative, significant coefficient on *IP Regime* and a positive, significant coefficient on *CA Importance* – both as hypothesized. In other words, firms in industries with weak intellectual property protection and where complementary assets are important are more likely to invest in CVC. While we continue to find a positive coefficient for *Tech Opportunity*, the significance of the coefficient dropped to the ($p < 0.05$) level. This is not surprising given that we now incorporate additional industry-level information (i.e. *IP Regime* and *CA Importance*). We continue to find significant, coefficients on *Cash Flow* and *Patent Stock*.

Interestingly, we find a significant, positive coefficient on *Internal R&D*. This would suggest that internal R&D and CVC investment are in fact complements not substitutes. This would follow from our absorptive capacity hypothesis. Note that *Patent Stock* and *Internal R&D* are correlated at 65%. To the extent that internal R&D is undertaken for the explicit purpose of helping source external knowledge (and not generate innovations directly), *Patent Stock* would only partially reflect the absorptive capacity of the firm. *Internal R&D* may be picking up this addition component of absorptive capacity.

We should be cautious in our confidence in these results. Less than 10% of the firms invest in ventures in any given year. In particular, our data are likely left-censored – we observe zero investment amongst all firms who fail to clear a threshold level to do so even though their individual propensity to invest may differ. As a first attempt to address this issue, we perform two estimations. First, we adopt a random-effects probit specification to predict the likelihood that a firm pursues any level (non-zero) of CVC investment. Second, we limit our sample to only those firms who invest CVC and re-estimate the specification from Model 2.

While less significant in some cases, our results are consistent with our previous estimates. In Model 3, we estimate a significant, positive coefficient for *CA Importance*, *Cash Flow*, and *Patent Stock*. We also continue to find a significant, negative effect from *IP Regime*. We no longer find that *Tech Opportunity* is significant at the ($p < 0.05$) level. This may in part be due to lost information as a result of using a binary measure of investment. We continue to find a positive relationship between *Internal R&D* and *CVC investment*, though we are only confident in this estimate at the ($p < 0.10$) level.

Model 4 presents the estimates from our reduced sample of firms who pursue non-zero levels of CVC investment. We continue to observe significant, positive coefficients on *Cash*

Flow and *Patent Stock*. Note that the coefficient for *Cash Flow* has more than doubled, and is more likely to capture the correct elasticity of external CVC to firm's availability of internal capital the same year. While no longer significant at the ($p < 0.05$) level, *Tech Opportunity* (+), *IP Regime* (-), and *CA Importance* (+) are of similar signs to previous estimates. The loss in confidence is not surprising given that limiting the sample as we have likely reduced the variation across these dimensions. With respect to the control variables, *Internal R&D* is positive but insignificant while *Firm Size* is significant and positive.

Please note the substantial increase in the overall model fit in Model 4. While the previous models are significant (see the results of our F-test and χ^2 test), they were only able to explain a small percentage of the overall variation in CVC investment (between 6.9% and 9.1%). The addition of stable industry effects in Model 2 increased the overall fit of our model and not surprisingly increased the between explained variance from 9.2% to 16.6%. However limiting our sample in Model 4, led to estimates that help explain more than 20% of the overall variation in the magnitude of CVC investments for those firms who choose to pursue CVC at any non-zero level. This restricted sample model also increased the explain variance within (20.8%) and between (24.9%) firms. This substantial increase is likely due to the fact that only a small proportion of our sample pursues equity investment in any given year.

However, removing firms who never invest CVC from our sample, throws away valuable information. In Model 5, we adopt a random-effects Tobit specification to address the censoring issue and to make use of all our observations. We estimate a Tobit with a lower limit of zero using the same set of independent variables and sample of Model 2. Our estimates are consistent with previous models. We find a significant positive coefficient on *CA Importance*, *Cash Flow*, and *Patent Stock*. We observe a significant, negative coefficient on *IP Regime*. The fact that

both *IP Regime* and *CA Importance* return to be highly significant supports our conjectures that the smaller sample size and the lack of variation are associated with their lack of significance in the previous model. We are no longer confident in our estimates of *Tech Opportunity*.

Discussion

In support of Hypothesis 1, we find some evidence that firms are more likely to invest CVC in industries where there is greater technological opportunity. The absence of a more consistent finding across industries may reflect the fact that our measure of *Tech Opportunity* is biased in most recent years in a way that decreases the likelihood of finding a relationship. Consistent with Hypotheses 2 and 3, we find strong evidence that firms in industries with weak intellectual property protection and where complementary distribution capability is important are more likely to invest CVC.

We also find support for our predictions concerning firm drivers. We find that firms that have a history of generating innovations are more likely to invest in new ventures. We interpret this as support for our absorptive capacity hypothesis (Hypothesis 5). In support of Hypothesis 4, we find that cash flow has a positive effect on equity investment. The relatively moderate elasticity of cash flow to external CVC need not reflect that the latter is of no economic significance. Rather, it is more likely to capture the fact that it is leading firms who choose to pursue CVC. As such their annual cash flow is greater by an order of magnitude compared to the supply of investment opportunities in high-quality entrepreneurial ventures. Even Intel, who invested hundred of millions in new ventures, committed no more than 10% of its cash flow in any given year towards equity investments.

In addition to our hypotheses, we also observe an interesting relationship between CVC and R&D choices. We find in at least one specification a significant, positive relationship

between internal R&D and CVC investment. If a firm views one innovative input as a substitute for the other, we would expect to find a negative relationship, as they compete for the same corporate resources. However, we did not observe a negative coefficient for internal R&D in any of our specifications. We speculated that firms are pursuing different types of innovation between internal R&D and CVC. If we believe that new ventures are the source of more radical, innovative ideas, then firms may pursue CVC for its more far-reaching projects while continue internal R&D to help with incremental innovations in their core technologies. Numerous firms have made a similar point when announcing their CVC programs. This result also echoes recent work on complementarity in firms' innovative strategies (Cassiman and Veugelers, 2002). We leave further exploration of the variance in project type whether funded externally or internal to later study.

We should point out that many, but not all, of our findings could be indicative of firms trying to capture a high return on investment from new ventures independent of any learning or innovation benefit. Firms with substantial cash flow may be tempted to try their hand investing in equity markets. Firms in industries with high technological ferment will have greater opportunity to realize positive returns from CVC investment. Firms with complementary capabilities and a history of generating innovations may provide valuable knowledge and skills to the venture themselves, helping those ventures to survive and prosper.

While this is an alternative underlying explanation for our results, there are reasons to be skeptical of this logic. First, as discussed earlier, previous work suggests that firms are more often looking for a window on technology than purely a high return on investment. Second, previous empirical work casts doubt on the logic of CVC as a pure financial play (Gompers and Lerner, 1998). In particular, there are reasons to be skeptical of firms being more effective than

venture capitalists in picking high payoff ventures. Third, and perhaps most importantly, the logic concerning IP regime would be reversed if in fact firms were pursuing CVC purely for narrow return on investment.

As we argue in Hypothesis 2 , under a weak IP regime, CVC provides greater access to ventures compared to other mechanisms for scanning, identifying and sourcing external knowledge (e.g., reading publications and patent applications). However, for that same reason, a venture's survival is adversely affected by weak IP protection. Even if it survives, the lack of ability to protect propriety IP is likely to lead to a decrease in the venture's valuation as competitor's imitate them. Form the perspective of a financial investor, a weak IP regime should discourage equity investments. In other words, innovation-motivated-CVC would favor a regime of low IP protection, but for that same reason, financially-motivated-CVC is likely to decline in these regimes. Hence, our finding of a significant and negative coefficient for *IP Regime* is consistent with the innovation-driven view of corporate venture capital.

As with all studies, we should be cognizant of the limitations of our analysis. One possible source of bias in our results is that there might be unobserved heterogeneity across firms that affect the desire to pursue CVC investment. We attempt to control for such unobserved heterogeneity by including year-effects and firm-effects as well as firm size and R&D expenditure. However, there might be additional firm-specific, time-variant factors that affect the desire to pursue CVC investment. If as we conjecture, firms self-select to invest CVC based on the attributes of the industry sector they operate in as well as on various firm-level attributes, these factors may result in a self-selection bias of our estimates.

Conclusion

In competitive markets, incumbent firms are inclined to innovate in order to sustain profitability in the face of imitating rivals (Schumpeter, 1942; Arrow, 1962; Roberts, 1999; Hamel, 2000). Consequently, the selection and coordination of innovative inputs is critical to firm survival. An extensive literature looks at the antecedents and consequences of one input – *internal* R&D expenditures. Scholars have studied the determinants of firm R&D expenditures (Hall, 1992; Himmelberg and Petersen, 1994), as well as its effect on subsequent firm innovativeness (Griliches, Pakes and Hall, 1987; Griliches, 1990). More recent work looks at the relationship between alternative – mainly *external* – sources of ideas, and firm innovation rates (Ahuja, 2000; Henderson and Cockburn, 1994; Stuart, 2000).

This paper explores the antecedents to one such *external* innovative input, corporate venture capital. We explored the effect of industry and technological conditions as well as own-firm attributes on firm's corporate venture capital investment, by analyzing a sample of more than twenty hundred U.S. public firms for the period 1969-1999. We find that CVC investment is greater in industries that are characterized by weak patent effectiveness and where complementary assets are important. We also report that there are firm level factors driving the decision to pursue external CVC. We observe a positive relationship between firm annual equity investments and firm stock of patents as well as the magnitude of firm's internal cash flow.

We believe these findings advance a view of the firm as being highly sensitive to the relative marginal contributions of external innovative inputs to internal innovative inputs. Firms shift greater attention and corporate resources towards external repositories of knowledge when their marginal contribution to the firm's innovative output is higher. Consequently, external investment rises during times of technological ferment and when new knowledge is less likely to

be made public. Consistent with the notion of absorptive capacity, we also report that firms' inclination to pursue knowledge that resides outside its boundary increases in the presence of strong in-house research capabilities.

To conclude, we believe this paper helps advance our understanding of the way firms manage their innovative toolkit. Interestingly, we find that firm external CVC investment does not seem to compete with internal R&D funds. This is an important finding, as it suggests that there are some complementarity between external CVC and internal R&D. On the one hand, the modern firm is highly sensitive to the marginal contribution of various innovative strategies. On the other hand, it seems that there are latent inter-dependencies between these strategies that remain to be uncovered.

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Figure 1. Relative CVC investment per sector per year (1969-1999)

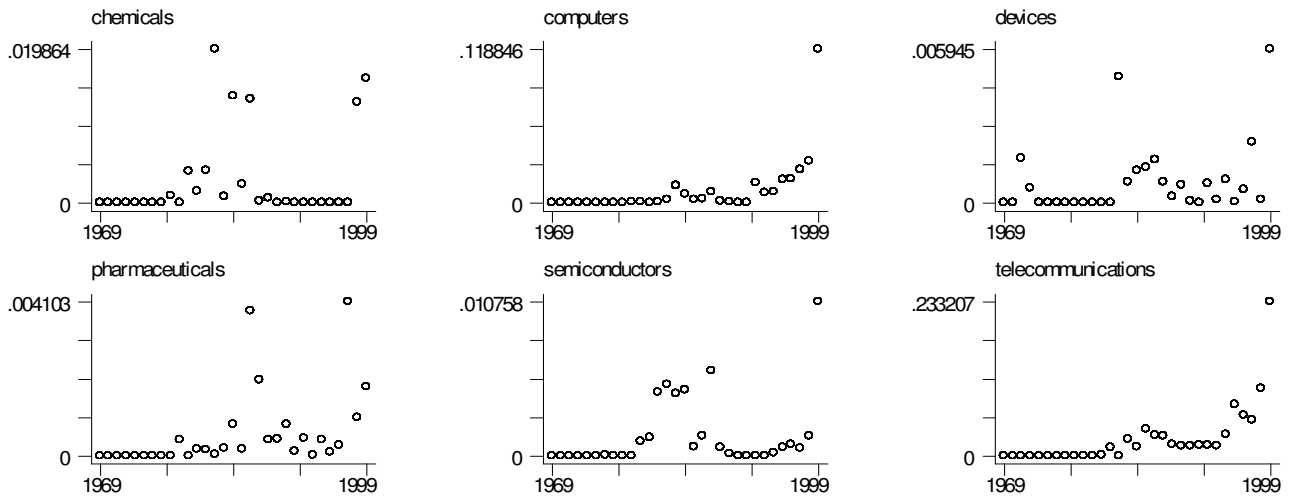


Table 1. Descriptive statistics for external venturing models

Variable	Description	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8
1. CVC Investment	Log of total annual CVC dollars invested (\$M)	0.039	0.297	0	6.265	1.00							
2. Tech Opportunity	Log of average citations within a 4-digit SIC classification in each year	4.828	1.768	0	8.133	-0.01	1.00						
3. IP Regime	Relative effectiveness of patenting within each industry	0.366	0.117	0.121	0.547	-0.03 *	0.28 *	1.00					
4. CA Importance	Relative importance of sales and distribution within each industry	0.455	0.070	0.316	0.633	0.03 *	-0.23 *	-0.30 *	1.00				
5. Cash Flow	Log of income after interest & taxes plus depreciation & amortization (\$M)	2.257	2.202	0	10.502	0.20 *	0.18 *	-0.03 *	-0.02	1.00			
6. Patent Stock	Log of depreciated count of patents issued to a firm from 1963 till year t	2.010	1.811	0	8.199	0.18 *	0.29 *	0.15 *	-0.08 *	0.53 *	1.00		
7. Internal R&D	Log of total annual R&D expenditures (\$M)	2.390	1.992	0	9.819	0.20 *	0.24 *	0.09 *	-0.10 *	0.57 *	0.64 *	1.00	
8. Firm Size	Log of total assets of firm (\$M)	5.490	2.096	0.139	12.553	0.19 *	0.16 *	-0.04 *	-0.04 *	0.77 *	0.56 *	0.73 *	1.00

$n = 14, 972$

* $p < 0.01$

Table 2. Firm equity investment in new ventures (1969-1999)

Model	1	2	3	4	5
Specification	Fixed-effects OLS	Random-effects OLS	Random-effects Probit	Random-effects OLS	Random-effects Tobit
Tech Opportunity	0.029 *** (0.004)	0.005 * (0.002)	0.040 (0.040)	0.014 (0.011)	0.048 (0.080)
IP Regime		-0.115 *** (0.035)	-2.120 *** (0.563)	-0.282 (0.187)	-3.405 *** (1.212)
CA Importance		0.163 ** (0.057)	3.444 *** (0.986)	0.130 (0.292)	7.107 *** (1.766)
Cash Flow	0.015 *** (0.002)	0.014 *** (0.001)	0.087 *** (0.024)	0.038 *** (0.007)	0.159 *** (0.068)
Patent Stock	0.026 *** (0.003)	0.017 *** (0.002)	0.236 *** (0.041)	0.023 * (0.010)	0.438 *** (0.296)
Internal R&D	0.005 (0.004)	0.009 *** (0.003)	0.078 (0.043)	0.013 (0.012)	0.120 (0.080)
Firm Size	0.007 (0.005)	0.001 (0.002)	0.109 * (0.046)	0.029 * (0.013)	0.320 *** (0.144)
Year dummies	included	included	included	included	included
Observations	14972	14972	14972	2965 ^a	14972
Firms	749	749	749	115	749
F-Test	30.74 ***	na	na	na	na
Wald χ^2 Test	na	1180.71 ***	998.02 ***	752.95 ***	9457.27 ***
Overall R ²	0.069	0.091	na	0.201	na
Within R ²	0.071	0.067	na	0.208	na
Between R ²	0.092	0.166	na	0.249	na

^a Sample limited to only those firms who invest CVC

^b Standard errors are in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$