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WHEN DO FIRMS UNDERTAKE R&D BY INVESTING IN NEW VENTURES?

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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 weak intellectual property protection and, to some extent, in industries with high technological ferment and where complementary distribution capability is important. Furthermore, we find that the greater a firm's cash flow and absorptive capacity, 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.

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, 2005).

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 is 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

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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 concerns (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 percent 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, 2005). 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 it is even more difficult to determine their cost. For example, what price does one place on maintaining personal ties with star scientists (Cohen *et al*., 2002)? Data on the cost of maintaining R&D alliances are 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 1000 U.S. public firms during the time period 1990–99. Primary data were gathered from Venture Economics' 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 Tratjenberg, 2001), and the Carnegie Mellon Survey (CMS) of Research and Development (Cohen, Nelson, and Walsh, 2001).

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 absorptive capacity, 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 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

A number of scholars have advanced the idea that entrepreneurial ventures are likely to be the source of highly valuable and innovative ideas (Tushman and Anderson, 1986; Kortum and Lerner, 2000; Shane, 2001a). At the heart of this argument is a consideration of the ability of firms to employ star scientists in internal labs. Amit, Muller, and Cockburn (1995) propose that the decision to start a new venture is undertaken when the value of self-employment is higher than the opportunity cost (i.e., lost salary from incumbent). In the later half of the 20th 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).

Following this line of reasoning, researchers will opt away from fixed salary (i.e., remaining a corporate employee) and toward 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, Kortum and Lerner (2000) observe that entrepreneurial, human-capital intensive ventures generate higher levels of patenting output than established firms. Shane (2001a) provides empirical evidence that the decision to form a new venture is associated with underlying entrepreneurial inventions that have high economic value.

This line of reasoning suggests that the marginal R&D productivity of new ventures is likely to be higher than established firms. While this may suggest that established firms will thus favor CVC investment over internal R&D, we must recognize that there are potential costs to incumbents using CVC investment as a vehicle to tap these innovative ventures. 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 only in technological domains where 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 1990s, 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 1990s, 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; Ernst & Young, 2002; Winters and Murfin, 1988). Yost and Devlin (1993) report that 93 percent of corporate venture capitalists in their sample view strategic objectives as one of their main objectives. Siegel *et al.* (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 Winters and Murfin (1988) and more recently in a survey of more than 40 corporations (Ernst & Young, 2002). Further support is provided by recent empirical work examining the relationship between CVC investment and firm innovation (Dushnitsky and Lenox, 2005).

Industry drivers

First, we examine the degree to which general industry and technology characteristics may drive the decision to invest in new ventures within a particular sector. We propose that firms will most likely invest in sectors 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 from investments in ventures from industries with rich technological opportunities—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 *et al*., 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 inventions 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. Thus, all else being equal, firms will be more likely to invest in sectors with rich technological opportunity.

Hypothesis 1: The greater technological opportunities in a sector, the greater a firm's investment in new ventures within that sector.

The innovative benefits of CVC investment will be more pronounced the weaker the intellectual property (IP) protection of the sector invested. We define a weak IP regime as one where ventures struggle to protect their inventions from imitation through legal mechanisms such as patents (Cohen *et al*., 2001). In such environments, CVC serves as an effective channel for learning from quality ventures (Dushnitsky and Lenox, 2005). 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. 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 spillovers to investors when patent protection is weak, thus increasing the incentives of incumbents to seek CVC investment over internal R&D.

Given the greater access investment may provide, we expect firms to be more likely to invest in sectors with weak IP regimes. We point out that if firms are pursuing CVC purely for the narrow financial returns from future sale of ownership stakes, we would expect the opposite to hold. Strong intellectual property protection would allow ventures to appropriate more value from their innovations, increasing the value of the venture and hence the returns to CVC investors. Only to the extent that firms are pursuing CVC as a form of external R&D do we expect to see Hypothesis 2 hold.

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

The discussion above raises an interesting conflict. While the contribution of CVC to firm innovative output is directly related to the quality of the funded ventures, 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 invention. These benefits include complementary capabilities in manufacturing, distribution, and marketing that new ventures are often lacking. Based on a survey of more than 100 entrepreneurial ventures, Gans, Hsu, and Stern

(2002) 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, 2004). Second, it can extend unique services, which capitalize on corporate resources. For example, investing firms may provide (1) the right to use the firm's complementary assets such as laboratories, (2) access to the firm's network of customers and suppliers, (3) a readily available beta site, and (4) access to domestic and foreign distribution channels (Acs *et al*., 1997; Maula and Murray, 2001; Pisano, 1991; Teece, 1986). Finally, the fact that a focal venture is chosen by an industry incumbent acts as an endorsement effect toward 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 potential 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 *et al*., 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 within a sector, the greater a firm's investment in new ventures within that sector.

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 (i.e., firm cash flow).

Interestingly, contrary to prediction, scholars report low sensitively 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 expenditures) 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 cooperative 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 cooperative R&D, while cooperation may also stimulate in-house R&D. Thus the authors conclude that internal R&D and external R&D (i.e., cooperative 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, 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 a firm's inclination to pursue external innovative inputs. Specifically, we explore the varying levels of firm CVC investment within particular sectors 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 a similar industry during the period 1990–99. 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 1990–99. The panel includes all public firms that were in industries where at least one firm invested corporate venture capital during this period. The database contains information on firms' venturing activity collected from Venture Economics' VentureXpert database, patenting activity from the Hall *et al.* (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 and Development. The resulting dataset includes 1171 firms and 60,444 firm-year-sector observations.

To construct our sample, 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

[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, 1988; Gompers, 1995).

funds.[2] For these firms, we collected data on the annual amount of venturing investments (i.e., disbursements). We added to our sample all U.S. firms within the same industries (based on 4-digit SIC classification) as those firms in our CVC dataset. The resulting sample includes firms from across a vast number of industries. Figure 1 provides a breakdown of total CVC investment by investing firm sector (see the pie chart on the left of Figure 1).

To complete our dataset, we augmented our CVC data with data from a number of sources. Patenting data were pulled from the NBER version of the U.S Patent Office database (Hall *et al*., 2001). 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. While the HJT patenting dataset pegs the ownership structure of firms at 1989, we manually matched up firms to U.S. Patent and Trademark Office (PTO) assignee codes to ensure we captured the patenting activity of all firms. Finally, we used the Carnegie Mellon Survey (CMS) of Research and Development (Cohen *et al*., 2001) to provide our measures of industry-level appropriability and complementary assets. The resulting sample includes 1171 firms and 10,074 firm-year observations; 115 of these firms invested corporate venture capital some time during the period 1990–99.

Firms may either invest in ventures that operate in their own sector or other sectors. For example, nearly 50 percent of all CVC investments by chemical and pharmaceutical companies went into ventures within those sectors, while 19 percent and 17 percent went into ventures in the devices and software sectors, respectively (see Table 1). To test our industry-specific hypotheses (Hypotheses 1–3), we expanded the dataset such that each observation

[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.

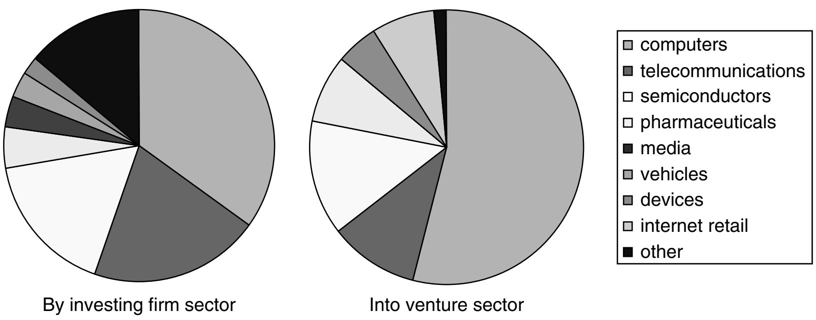

Figure 1. Total CVC investment by sector (1990–99)

Table 1. Percentage CVC investment in venture sector by firm sector (1990–99)

Into By	Chemicals/ Pharma	Computers	Electronics/ Semis	Devices	Telecom	Internet Retail	Software	Other
Publishing	0%	3%	0%	0%	9%	12%	64%	12%
Chemicals/Pharma	46%	0%	4%	19%	0%	0%	17%	13%
Computers	0%	18%	20%	0%	15%	3%	43%	2%
Electronics/Semis	0%	18%	29%	4%	9%	5%	23%	12%
Devices	30%	4%	4%	33%	0%	0%	15%	15%
Telecom	0%	10%	27%	2%	8%	7%	37%	8%
Software	6%	5%	9%	5%	12%	5%	50%	8%
Media	0%	0%	0%	0%	7%	21%	50%	21%
Other	9%	2%	9%	2%	15%	17%	39%	7%

captures the amount invested by a single firm (i.e., a corporate venture capitalist) in a single sector (i.e., aggregate investment in ventures that operate in that focal sector) in a given year, resulting in 60,444 firm-sector-year observations.

Finally, by including measures from the CMU survey, we limit our sample to investments in the following sectors: chemicals (including pharmaceuticals), industrial machinery (including computers), electronics (including semiconductors and telecom equipment), medical and measurement devices, and computer software. These sectors are the target of over 90 percent of all CVC investments during the time frame of our sample (see pie chart on right of Figure 1). The only significant sector that is not included in our sample is Internet retailers such as Amazon.com (approximately 8.5% of all CVC investment). As a robustness check, we ran our model sans the CMU variables (thus allowing us to capture 100% of the sectors who receive CVC funding) and found consistent results.

Measures

Our dependent variable (*Firm Sector CVC*) is annual firm CVC investment in millions of dollars in ventures within a given sector.[3] Since these ventures are not yet publicly traded companies, they are typically not associated with a SIC code. To identify the sector of a particular venture, we make use of the venture's Venture Economics Industry Classification (VEIC), a Venture Economics proprietary industry classification scheme. We manually assign a sector to each venture using a two-step process.[4] In particular, we assigned an SIC code to more than 2000 entrepreneurial ventures that received CVC backing between 1990 and 1999. If a firm is not found to have invested in any ventures assigned to a given sector with a given year, that firm is assign a zero for *Firm Sector CVC*.

There are two groups of independent variables. The first group is comprised of venture sector-level measures. *Tech Opportunity* is defined as the average number of citation-weighted patents applied for by firms in a given year in a given sector defined by each 2-digit Standard Industrial Classification (SIC). This measure captures time-variant differences in the level of technological opportunities across sectors. 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 *et al.*, 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 *et al.* (2001) report that the distribution of forward lag in citation (i.e., the number of years between a patent's application date and later citing-patents application date) is about 3–4 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

[3] 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 underestimating a firm's CVC. Second, we explore the effect that changes in industry and firm factors have 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.

[4] Coding each venture involved the following steps: (1) identify all ventures in Venture Economics (VE) that ever pursued a public offering (IPO); (2) record their VEIC code as available through VE; (3) identify them through Compustat and record their SIC code; (4) generate an initial mapping of VEIC to SIC; (5) for a given VEIC code, identify all IPOed ventures and their SIC codes; (6) review relevant information about them from the VE database; this includes the following VE fields: Company Business Description, Company Competitors, Company Customers, Company Internet Tech Group, Company Primary Customer Type, Company Product Keywords; (7) for each of the non-IPOed ventures, review the same VE fields and assign an appropriate SIC code; (8) triangulate venture's line of business through other databases (e.g., Dun & Bradstreet, Lexis-Nexis).

assets, we create two measures derived from the Carnegie Mellon Survey (CMS) of Research and Development (Cohen *et al.*, 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, 1478 R&D unit managers answered questions 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) suggests that industry appropriability conditions as well as the importance of complementary assets are relatively stable over time.[5] 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.

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 inventors' 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 0–1 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 *et al.*, 1988; Hall, 1992; Himmelberg and Petersen, 1994; Gilchrist and Himmelberg, 1998). Since firms 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 in a number of ways. To capture the absolute level of absorptive capacity, we measure 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 report external R&D increases the effectiveness of internal R&D (Veugelers, 1997); and yet others indicate a simultaneous effect (Colombo and Gerrone, 1996).

To avoid this concern, we employ firm stock of prior patents as a proxy. It is highly correlated with R&D expenditure (see Table 2), 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, 1996). Each dollar spent on internal R&D may not generate the same amount of knowledge stock. Some R&D is likely to be unproductive and should not be weighed equally to that which is successful (Hall *et al.*, 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 a 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.[6]

$$\mathit{Patent\ Stock}_{it} = \mathit{Patents}_{it} + (1-\delta)\mathit{Patent\ Stock}_{it-1}$$

We assert that this measure captures the previous innovative efforts of the firm and reflects its

[5] With the exception that larger firms relay on patents somewhat more nowadays than in the early 1980s.

[6] We adopted a depreciation rate of 30 percent as in Blundell *et al.* (1995). At a depreciating rate of 30 percent, patents granted prior to 1963 have little impact on 1969 *Patent Stock* especially given the 1- to 4-year lag between patent application and granting.

Table 2. (a) Descriptive statistics

Variable	Description	Mean	S.D.	Min.	Max.
Firm Sector CVC	Log of total annual CVC dollars invested in a particular sector ($ million)	0.009	0.142	0.000	5.878
Tech. Opportunity	Log of average citations within a sector in each year	2.946	1.944	0.000	5.413
IP Regime	Relative effectiveness of patenting within each sector	0.295	0.130	0.121	0.429
CA Importance	Relative importance of sales and distribution within each sector	0.508	0.092	0.401	0.633
Firm Cash Flow	Log of income after interest and taxes plus depreciation and amortization ($ million)	2.222	2.474	0.000	9.538
Firm Patent Stock	Log of depreciated count of patents issued to a firm from 1963 until year *t*	1.792	1.813	0.000	8.730
Proximity	Relative technological proximity between firm and a particular sector	0.179	0.315	0.000	1.000
Firm Advertising	Log of total annual advertising expenditures by firm ($ million)	0.605	1.534	0.000	8.217
Firm Internal R&D	Log of total annual R&D expenditures by firm ($ million)	1.869	2.031	0.000	8.778
Firm Size	Log of total assets of firm ($ million)	4.820	3.067	0.000	13.512
Other CVC	Log of total annual CVC dollars invested in other sectors ($ million)	0.046	0.319	0.000	6.265

$n = 60,444$

(b) Pairwise correlations

	1	2	3	4	5	6	7	8	9	10	11
Firm Sector CVC	1.00										
Tech. Opportunity	0.05*	1.00									
IP Regime	−0.03*	0.19*	1.00								
CA Importance	0.03*	−0.22*	−0.85*	1.00							
Firm Cash Flow	0.08*	−0.02*	0.00	0.00	1.00						
Firm Patent Stock	0.06*	0.04*	0.00	0.00	0.47*	1.00					
Proximity	0.05*	0.05*	0.14*	−0.17*	−0.03*	0.03*	1.00				
Firm Advertising	0.08*	0.03*	0.00	0.00	0.39*	0.28*	−0.01	1.00			
Firm Internal R&D	0.09*	−0.01	0.00	0.00	0.51*	0.70*	0.04*	0.35*	1.00		
Firm Size	0.09*	0.02*	0.00	0.00	0.73*	0.46*	−0.03*	0.38*	0.65*	1.00	
Other CVC	0.11*	−0.14*	0.02*	−0.01*	0.15*	0.08*	−0.02*	0.12*	0.14*	0.17*	1.00

* $p < 0.01$

ability to absorb new knowledge. Previous studies examining patenting rates have used a similar measure (Cockburn and Henderson, 1998; Stuart, 2000).

Absorptive capacity, as originally conceived, is not a state variable; rather, it is domain-specific (Cohen and Levinthal, 1990). A firm may possess absorptive capacity in one domain of knowledge but lack absorptive capacity in another domain. To address the domain-specific nature of absorptive capacity, we adopt an alternative measure based on the technological proximity between an investing firm's domain of expertise and the domain of expertise of the firm's portfolio ventures. In particular, we follow Jaffe (1986) and examine the extent of technological overlap between a firm and a sector in which a firm may potentially invest in entrepreneurial ventures. We believe this measure is more appropriate for our analysis than cross-citation measures of technological overlap (Mowery, Oxley, and Silverman, 1996).[7]

[7] The measure proposed by Mowery *et al.* (1996) is a strong indicator of a technological bond between two firms. However, it may underplay information about the similarities of firms that do not cite each other (a likely event given that entrepreneurial

Generating *Proximity* involves a number of steps. First, each firm's technological portfolio is determined by measuring the distribution across patent classifications of the patents associated with its businesses using Silverman's (1996) concordance between SIC codes (i.e., line of business) and patent classes (i.e., domain of expertise). Next, for each sector in which a firm may potentially invest in entrepreneurial ventures, we identify ventures' domain of expertise using the same methodology. Finally, the overlap in technological portfolios (i.e., activity in the same patent classes) is calculated for each firm–venture sector pair. We favor this approach since it does not rely on the firm to actually invest in ventures within that sector.

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. *Advertising* is the annual expenditures on advertising, for each firm, as it appears in Compustat. We include this variable as a control for the ability of the firm to offer potential complementary marketing and sales expertise. *Firm Size* 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 and investing firm industry dummy variables to control for unobserved inter-sector variance. Finally, we include the total dollars invested by a firm in a given year in other sectors (*Other CVC*) to control for firm-level investment across firm-sector-year observations. The dependent variable as well as all relevant independent and control variables (*Cash Flow, Internal R&D, Advertising, Firm Size*, and *Other CVC*) are adjusted to 1999 dollars. These variables also exhibit a high level of skewness. Following common practice in the literature, we employ the natural logarithm in the regression analysis.

ventures have not been around for a long period of time). The extent to which similar patent classes are used by the two firms, irrespective of whether or not they cite each other, is consistent with the conceptual construct of firm's absorptive capacity.

ANALYSIS AND RESULTS

Table 2 presents summary statistics and correlations for the measures in our 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 \$9.5 million. The average internal R&D expenditure is \$10.9 million, or about 4.5 percent of the average firm size of \$242 million. To allay fears of multicollinearity between firm size and R&D expenditures, we estimated each of our models using intensities and found consistent results. Note that Table 2 reports the natural log of each of the relevant variables.

Table 1 provides a summary of the percentage of total corporate venture capital investment that went to ventures with an individual sector broken down by firm sector. Not surprisingly, we find that many firms invested in sectors similar to their own. For example, nearly half of all CVC investments by chemical and pharmaceutical companies went into ventures within those sectors. An additional 19 percent went into medical devices. Electronics and semiconductor firms most often invested in electronics and semiconductor ventures, but were also active investors in computer hardware and software. Two of the more interesting sectors were publishing and media, which both invested heavily in computer software ventures and Internet retail ventures (such as Amazon.com) during the 1990s. This reflects the growth of the Internet during this time period and attempts by many traditional publishing and media concerns to offer online content.

Table 3 presents a number of specifications of our model of CVC investment. In each of the models, we adopt an OLS specification with year and investing firm industry 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. Finally, we include firm-sector random effects to deal with the unique structure of our panel. We adopt a random-effects rather than a fixed-effects specification because our measures of the strength of intellectual property protection and the importance of complementary assets are stable industry effects and would be subsumed by

Table 3. Firm equity investment in new ventures from 1990 to 1999 (Firm-sector random-effects OLS)

Model	1	2	3	4	5
Tech. Opportunity	−0.0005	−0.0005	−0.0006	−0.0008	−0.0009
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
IP Regime	−0.0392***		−0.0400***	−0.0343**	−0.0341**
	(0.0115)		(0.0115)	(0.0119)	(0.0119)
CA Importance	−0.0170	0.0400***	0.0047	0.0038	0.0037
	(0.0166)	(0.0093)	(0.0166)	(0.0166)	(0.0166)
Cash Flow	0.0014***	0.0014***	0.0017***	0.0017***	0.0014***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Patent Stock	0.0022***	0.0022***			0.0022***
	(0.0006)	(0.0006)			(0.0006)
Proximity			0.0227***	0.1210*	0.1249*
			(0.0026)	(0.0570)	(0.0570)
Proximity^2				−0.0935*	−0.1073*
				(0.0524)	(0.0542)
Advertising	0.0033***	0.0033***	0.0034***	0.0034***	0.0033***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Internal R&D	0.0015*	0.0015*	0.0026***	0.0027***	0.0014*
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0007)
Firm Size	0.0012***	0.0012***	0.0011**	0.0011**	0.0012**
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Other CVC	0.0225***	0.0225***	0.0231***	0.0230***	0.0228***
	(0.0019)	(0.0019)	(0.0019)	(0.0019)	(0.0019)
Year dummies	Included	Included	Included	Included	Included
Industry dummies	Included	Included	Included	Included	Included
Observations	60,444	60,444	60,444	60,444	60,444
Firm-Sector Pairs	7026	7026	7026	7026	7026
Firms	1171	1171	1171	1171	1171
Wald χ^2 test	1329.90***	1317.48***	1400.00***	1403.90***	1416.72***
Overall R^2	0.0295	0.0291	0.0319	0.0319	0.0325

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (standard errors are in parentheses)
Overall R^2 does not include the variance explained by the firm-sector effects.

the firm-sector fixed effects.[8] A Hausman test suggests that the coefficient estimates from the random effects are consistent.

In Model 1, the estimated coefficients of our firm-level variables, *Cash Flow* and *Patent Stock*, suggest each has a significant, positive effect on CVC investment as hypothesized (Hypotheses 4 and 5, respectively). Furthermore, we find support for our hypothesis that investment will be higher in sectors with weaker intellectual property protection (Hypothesis 2). We do not find support that sectors with rich technological opportunities (Hypothesis 1) and where complementary assets are more important (Hypothesis 3) are more likely to receive CVC funds. Finally, we find positive, significant coefficients for controls *Advertising*, *Internal R&D, Firm Size*, and *Other CVC*.

The lack of support for Hypothesis 1 may reflect the conservative nature of our sample. To further explore this hypothesis, we examined the occurrence of CVC investment as a function of sectors' technological opportunity for the *population* of industrial sectors, i.e., we do not limit our sample to industries that receive corporate venture capital. To this end, we calculated *Tech Opportunity* for all industries in the U.S. economy.[9] We find that corporate venture capital flows into sectors

[8] 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 a larger population of firms. By construction, the random-effects specification assumes that the individual effects are uncorrelated with the other regressors.

[9] We matched all the firms in the HJT (2001) NBER patent database with Compustat, which allowed us to connect each patent to an industry (SIC) and thus establish the patenting profile for every U.S. industry.

Table 4. Distribution of corporate venture capital across the population of U.S. industrial sectors, by the level of technological ferment in ventures' sector (1990–99)

CVC in year	Level of technological ferment in ventures' sector			
	Lowest 0–25%	Low 25–50%	High 50–75%	Highest 75–100%
1990	0%	6%	1%	93%
1991	0%	1%	8%	91%
1992	0%	0%	5%	85%
1993	0%	0%	0%	92%
1994	0%	0%	12%	69%
1995	0%	2%	6%	68%
1996	4%	0%	0%	67%
1997	0%	5%	1%	73%
1998	1%	2%	0%	80%
1999	3%	5%	0%	70%

The number of citation-weighted patents for each industry is used to determine its quartile in comparison to all other U.S. industries (including those that experienced CVC investment *and those that did not*).
The number in each box represents the proportion of annual CVC funds based on the level of technological opportunities in ventures' sector. For example, if CVC investments in 1990 totaled \$100 million, then \$6 million, \$1, million, and \$93 million were use to fund ventures in industries characterized by Low, High and Highest levels of technological ferment, respectively. Note that amounts may not sum to 100% when sectors that receive financing do not have patenting output (e.g., retail).

that exhibit the greatest technological opportunities. Table 4 illustrates a substantial amount of corporate venture capital flows into those industries that are at the top quartile in terms of technological opportunity. On average, 79 percent of CVC funds in any given year are aimed at entrepreneurial ventures that operate in sectors that are in the top quartile of citation-weighted patent applications.

One explanation for our lack of support for our complementary asset hypothesis (Hypothesis 3) is the high negative correlation between *CA Importance* and *IP Regime* (−85%). While it is not particularly surprising that complementary assets are more important in weak intellectual property regimes, the lack of a significant coefficient may reflect multicollinearity. In Model 2, we re-estimate Model 1 removing *IP Regime*. As suspected, we now find a positive, significant coefficient for *CA Importance*.

Another possible explanation for our lack of support for Hypothesis 3 may be that merely the desire for ventures to seek complementary assets from corporate investors may be irrelevant if the firm itself lacks those complementary assets. To explore this possibility, we interacted *CA Importance* with various firm resources that may be desired by new ventures. We found a positive significant coefficient for both an interaction between *CA Importance* and *Advertising* and an interaction between *CA Importance* and *Internal R&D*. While suggestive, this does not represent a rigorous test without a fuller exploration of what constitutes a complementary asset in this setting.

In Model 3, we include our alternative measure of absorptive capacity, *Proximity*. We find a positive, significant coefficient for *Proximity*. In other words, the more closely aligned the domain of expertise of the firm and a particular sector, the greater the likelihood that the firm will invest in ventures in that sector. This is consistent with the sector statistics presented in Table 2. While this result is compelling, recent research on absorptive capacity suggests that there may be a concave relationship between technological proximity and learning (Dushnitsky, 2004; Lenox and King, 2004). Two explanations have been advanced: substitution and competition. Both suggest that little learning occurs when firms' knowledge bases are diverse due to a lack of absorptive capacity, but offer different reasons for lack of learning when knowledge bases overlap.

The first view suggests that as two agents become closely aligned in their knowledge sets their knowledge becomes redundant, and thus very little learning occurs (Mowery *et al*., 1998; Ahuja and Katila, 2001; Lenox and King, 2004). In the context of CVC, ventures and investing firms who are well aligned in their technological knowledge have little to learn from one another. As the divergence between knowledge sets grows, investing firms will be able to learn novel insights from their ventures. Eventually, however, this learning will diminish as the investing firm's knowledge is so divergent from the venture's knowledge space that the investing firm fails to assimilate knowledge from the venture.

The second explanation assumes that CVC investors are interested in learning but have little opportunities to do so given the actions of ventures.[10] While the greatest learning potential may

[10] To the extent that entrepreneurial startups may be a valuable source of innovations (Aghion and Tirole, 1994; Kortum and Lerner, 2000; Shane, 2001b), CVC investors may be interested in learning from those ventures that operate in the same technological domain. These ventures are likely to possess the cutting-edge technology within that technological field.

exist when two agents become closely aligned, competitive pressures may lead highly innovative entrepreneurs to avoid CVC investors: 'A small high-technology company might be reluctant to approach IBM or Sony directly for funding. Therefore, the very companies in which these corporations wanted to invest were usually the ones that never made it to their doorsteps' (Gompers, 2002: 1). Based on a large sample analysis, Dushnitsky (2004) concludes that ventures are most likely to be driven away from corporate investors when the two compete in the same product markets.[11] Consequently, CVC investors will not be exposed to novel technologies in their primary domain of expertise or will be privy only to lower-quality entrepreneurial inventions.

To test for concavity, we include the square of *Proximity* in Model 4. We find a significant, positive coefficient on *Proximity* and a significant, negative coefficient on *Proximity*^{2}. Thus, we find the concave relationship proposed. At low levels of technological proximity, firms are less likely to invest in ventures within a specific sector. As proximity increases, firms are more inclined to invest; however, eventually they begin to overlap too much and investment decreases. As a sensitivity test, we include both of our measures of absorptive capacity. In Model 5, we observe significant coefficients for both absorptive capacity measures, suggesting that the decision to seek external innovative inputs is a function of both the overall magnitude of focal-firm's knowledge base (captured by *Patent Stock*) and the relative positioning of firm–venture knowledge domains (captured by *Proximity*).

Across our models, 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 percent. 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 additional component of absorptive capacity.

[11] Dushnitsky (2004) also reports that competitive pressures diminish as the level of complementarity between the two increases.

We should be cautious in our results. Fewer than 10 percent 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 an attempt to address this issue, we perform three robustness checks (see Table 5). First, we limit our sample to only those firms who invest CVC and re-estimate the specification from Model 5. Second, we adopt a random-effects Probit specification to predict the likelihood that a firm pursues any level (non-zero) of CVC investment. Finally, we adopt a random-effects Tobit specification to address the censoring issue and to make use of all our observations.

While less significant in some cases, our results are consistent with our previous estimates with one notable exception. In both the Probit and Tobit specifications (Models 7 and 8 respectively), we find a significant, positive coefficient for *Tech Opportunity*. That is, within the group of industrial sectors that received CVC investment, the higher the level of industry's technological ferment the greater the amount it receives. This may reflect that the level of technological opportunities impacts not only *which* industrial sector receives corporate venture capital (see Table 4), but also *how* much is invested in each sector.

DISCUSSION

We find some evidence that firms are more likely to invest CVC in industries where there is greater technological opportunity (Hypothesis 1). We investigate the distribution of corporate venture capital across the *population* of U.S. industrial sectors and find that, consistent with our hypothesis, CVC investments concentrate in those sectors that exhibit the greatest technological opportunities. Further, the results suggest that the level of technological ferment not only explains the direction of corporate venture capital (i.e., which industries receive CVC investments), but also its magnitude (i.e., within those industries, which receives more and which receives less, Model 7 and 8).

Consistent with Hypotheses 2 and 3, we find evidence that ventures in industries with weak intellectual property protection and where complementary distribution capability is important are

Table 5. Firm equity investment in new ventures from 1990 to 1999

Model	6	7	8
Specification	RE OLS (Investors only)	RE Probit	RE Tobit
Tech. Opportunity	−0.0080 (0.0050)	0.2404** (0.0852)	0.3383* (0.1494)
IP Regime	−0.1945*** (0.0837)	−2.8876** (0.9672)	−5.6793*** (1.6308)
CA Importance	−0.0148 (0.1890)	0.3423 (1.1911)	1.2348 (1.9906)
Cash Flow	0.0059** (0.0022)	0.0209 (0.0202)	0.0414 (0.0335)
Patent Stock	0.0051 (0.0040)	0.0021 (0.0382)	−0.0251 (0.0686)
Proximity	1.0318*** (0.3167)	12.3914*** (3.0742)	19.2257*** (4.0844)
Proximity^2	−0.8378** (0.2983)	−10.1965*** (2.8748)	−15.2352*** (3.0843)
Advertising	0.0085*** (0.0025)	0.0753*** (0.0226)	0.1778*** (0.0384)
Internal R&D	0.0041 (0.0039)	0.0087 (0.0383)	0.0243 (0.0601)
Firm Size	0.0171*** (0.0035)	0.4503*** (0.0492)	0.8825*** (0.0777)
Other CVC	−0.0667*** (0.0060)	−0.0587 (0.0555)	−0.1917* (0.0981)
Year dummies	Included	Included	Included
Industry dummies	Included	Included	Included
Observations	8178	60,444	60,444
Firm-Sector Pairs	882	7026	7026
Firms	147	1171	1171
Wald χ^2 test	880.66***	343.04***	1427.15***
Overall R^2	0.1082		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (standard errors are in parentheses)
Overall R^2 does not include the variance explained by the firm-sector effects.

more likely to receive CVC. 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 percent of its cash flow in any given year toward equity investments.

In support for Hypothesis 5, we find that firms with greater absorptive capacity are more likely to invest in new ventures. This appears to be the case in both an absolute and relative sense. However, the relationship may be slightly more complicated. In particular, we present evidence of a concave relationship with the technological proximity between a firm and potential venture investments. Firms seem to seek out ventures in sectors that are similar but not identical to their own. We speculate that this may reflect either a substitution effect (firms have little to learn from closely affiliated ventures) or a competition effect (high-quality ventures will not accept corporate investment for fears of expropriation).

In addition to our hypotheses, we observe an interesting relationship between CVC and R&D choices. We find in a number of specifications 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 continuing 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 will have greater opportunity to realize positive returns from CVC investment in industries with high technological ferment. 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 pay-off 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 competitors imitate them. From 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 and industry dummies and firm-sector random 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 1000 U.S. public firms for the period 1990–99. We find that firms invest more corporate venture capital in sectors 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 internal cash flow. We also find that CVC investment is affected jointly by the absolute and relative absorptive capacity of the firm.

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 report that a firm's 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 is 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 interdependencies between these strategies that remain to be uncovered.

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