Contents lists available at ScienceDirect

Journal of Business Venturing

The influence of R&D investment on the use of corporate venture capital: An industry-level analysis

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A R T I C L E I N F O

Article history:
Received 6 September 2010
Received in revised form 25 November 2010
Accepted 6 December 2010
Available online xxxx

Keywords:
Absorptive capacity
R&D
Options
CVC
Exploration

A B S T R A C T

We consider how internal research and development (R&D) influences the use of corporate venture capital (CVC) and how this relationship varies across industries. We find that, in general, R&D investments increase the number of CVC deals in an industry. We also find that R&D investment has a particularly strong influence on the use of CVC in industries that are growing rapidly and changing technologically. Our analysis provides greater clarity on the relationships involving R&D and CVC in the presence of contingencies by integrating insights of absorptive capacity and real options reasoning.

1. Executive summary

Research and development (R&D) and corporate venture capital (CVC) are two major ways for developing new capabilities. CVC may substitute for or complement internal R&D in developing new capabilities. On one hand, access to new technologies can be gained in the venture capital marketplace instead of pursuing state of the art technology in house. On the other hand, internally-developed knowledge gained through R&D may increase the ability to both recognize the value of the technologies that reside in potential venture targets and exploit such technologies. There is some consensus in the literature that internal R&D generally supports greater use of CVC, as opposed to CVC substituting for internal R&D (Cassiman and Veugelers, 2002; Dushnitsky and Lenox, 2005; Gompers and Lerner 2001). However, there has been little consideration as to how industry conditions might influence the relationship between R&D investment and the use of CVC.

We propose that industry R&D investments create a capacity within the industry to identify and exploit technology from CVC targets. The extent to which this capacity is used in terms of CVC activity will depend on industry conditions. We argue that rapidly changing technology within an industry induces industry players to use the knowledge developed through R&D to search for and exploit CVC targets. In addition, a rapidly growing industry provides the opportunity and resources to use the knowledge derived from R&D to further find and exploit CVC targets. We test our hypotheses using a large sample of US manufacturing industries consisting of 400 industries that vary in terms of technological change and munificence in the industry environment.

We find that higher levels of industry R&D investment generally promote greater use of corporate venture capital deals. However, this relationship is stronger in the industries that are experiencing rapid technological change and higher levels of munificence. In sum, our results suggest that the absorptive capacity developed through internal R&D provides a foundation for CVC activity and industry conditions influence the relationship between R&D and CVC. We contribute to the literature by

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integrating the insights of absorptive capacity and real options reasoning to provide a more refined view of the influence of R&D on CVC in the presence of contingencies.

2. Introduction

Firms in a broad array of industries increasingly rely on corporate venture capital (CVC) as a means of developing new competencies (Gompers and Lerner, 2001; Dushnitsky and Lenox, 2005). Corporate venture investments are minority equity investments by established firms in entrepreneurial ventures. From 1980 through 2003, established firms in various industries invested over $40 billion in entrepreneurial ventures (Venture Economics, 2005). In 2003, venture-backed firms employed 10.1 million people, generated $1.8 trillion in sales and represented 9.4% of the nation's jobs. Venture-financed companies in various industries had approximately twice the sales as compared to non venture-backed firms (NVCA, 2004).

The recent growth in CVC investment raises questions about why it has become so popular and how CVC activity is related to traditional R&D investments. CVC investment has increased in popularity because such investment can create important opportunities for continued growth through innovation (Folta and Miller, 2002; Kogut and Kulatilaka, 2001; McGrath and Nerkar, 2004). It is often difficult to build a sufficient portfolio of capabilities and technologies solely through internal R&D investments (Gompers and Lerner, 2001; Hagedoorn, 2002). Indeed, developing new capabilities through internal R&D is a relatively slow and inflexible process (Chesbrough and Tucci, 2004; Gompers and Lerner, 2001). In contrast, investing in entrepreneurial ventures can help established firms to quickly uncover new technologies and capabilities (Gompers and Lerner, 2001; Maula et al., 2003). Moreover, competencies generated through corporate venture capital deals tend to be more distinctive than those generated through internal firm processes (McGrath and Nerkar, 2004). Thus, CVC investments within an industry may comprise an alternative to industry R&D investments.

However, there is also growing evidence that CVC and R&D are complements rather than substitutes (Cassiman and Veugelers, 2002; Dushnitsky and Lenox, 2005; Gompers and Lerner 2001). Knowledge developed through R&D can increase the capacity to recognize valuable capabilities in new ventures and exploit those capabilities (Cohen and Levinthal, 1990; Kamien and Zang, 2000). This alternative view of the relationship between R&D and CVC suggests that there is a theoretical gap in the literature regarding the conditions when this capacity to evaluate and exploit CVC targets will be more or less proficiently used (Cassiman and Veugelers, 2002; Chesbrough, 2002; Dushnitsky and Lenox, 2005; Gompers and Lerner 2001).

We draw upon absorptive capacity and real options reasoning to develop a framework for examining the variance among industries in their use of CVC. We investigate the conditions when higher levels of R&D will be more strongly linked to higher levels of CVC. In some industries, pressure from rapid technological change can compel firms to search for emerging technologies external to the firms simply to maintain survival (Bettis and Hitt, 1995; Hannan and Freeman, 1989; Tushman and Anderson, 1986). In other industries, munificence in the industry environment may provide the resources and opportunities to pursue external venturing in a proactive manner (Ahuja, 2000; Basu et al., 2006). We argue that industries with rapidly changing technology and higher levels of munificence will be more engaged in CVC activities. We contribute to theory by integrating the insights from absorptive capacity and real options literatures and applying these insights to highlight the relationship between R&D and CVC. We propose that industries that are munificent and experiencing rapid technological change use the expertise derived through R&D to find and exploit CVC opportunities to a greater extent than relatively stable, low-growth industries do.

We test these hypotheses using a large sample of US manufacturing industries. Firms in an industry often share attributes allowing for the aggregation of firm effects and development of a composition model at the industry level[3] (Dansereau and Yammarino, 2000; Klein et al., 1994; Kozlowski and Klein 2000, p. 33). Aggregating R&D investments to the industry level is particularly appropriate. R&D activities and consequent outcomes for individual firms often spill over to other firms within the industry (Henderson and Cockburn, 1996; Jaffe, 1986). Firms within an industry learn about each other's technological developments through trade shows, industry conferences, trade publications, reverse engineering, and employee mobility (Appleyard, 1996; Henderson and Clark, 1990). Because of the knowledge spillover within an industry, the R&D efforts of each firm contribute to an industry-level pool of knowledge accessible to all firms in the industry (Henderson and Cockburn, 1996). Thus, we maintain that the aggregate R&D activity within an industry creates a general capacity to evaluate and exploit potential CVC targets and will influence overall CVC activity within the industry (Fig. 1).

3. Theory and hypotheses

3.1. Background

Real options theory highlights the value of managers' flexibility in responding to evolving market or technological conditions (Reuer and Tong, 2005; Trigeorgis, 1996). Real options are limited investments that allow managers to exploit potential opportunities in a contingent fashion (Bowman and Hurry, 1993; Kogut and Kulatilaka, 2001). Real options give managers the right but not the obligation to undertake various actions in the future (Folta and Miller, 2002; McGrath and Nerkar, 2004). Through real options, managers gain a privilege to enhance their commitment of resources and managerial attention when uncertainty is

[3] Entities embedded at any level of analysis can be viewed using the notions of homogeneity, independence, and heterogeneity (Klein, Dansereau, and Hall, 1994; Dansereau and Yammarino, 2000). We use these notions to view firms embedded at industry level of analysis. Industry is a collective, group level entity composed of a number of firms and industry level effects can be disaggregated into across firm effects and within firm effects.

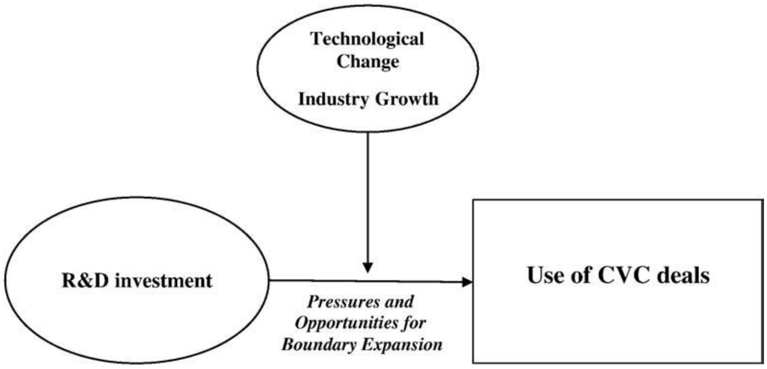

Fig. 1. Forces driving the uses of corporate venture capital.

relatively resolved without getting fettered by large obligations from the beginning (Dixit and Pindyck, 1994; Tong and Reuer, 2007; Trigeorgis, 1996). The flexibility conferred by real options reduces downside risk while maintaining upside opportunities (Bowman and Hurry, 1993; Kogut and Kulatilaka, 2001). Such flexibility can be particularly valuable in rapidly changing technological environments characterized by high degrees of uncertainty. Because CVC investments are limited commitments to potentially valuable technologies that offer an opportunity to invest more at a later point in time, real options logic is particularly applicable in this context.

The value of the flexibility allotted by CVC investments will vary depending on industry conditions (Basu et al., 2006; Sakakibara, 2002; Schilling and Steensma, 2001). Technological uncertainty and munificence vary across industries and provide differential pressures, inducements and opportunities for strategic partnerships and external venturing (Boyd, 1990; Dess and Beard, 1984; Sakakibara, 2002; Schilling and Steensma, 2001). Similarly, the variance in prior R&D investments across industries contributes to differences in the capacity to identify, evaluate, assimilate and apply knowledge from the environment for commercial outputs (Cohen and Levinthal, 1990; Lane et al., 2006). This enables firms to identify, acquire and exploit novel technologies and innovations from the market (Cohen and Levinthal, 1989, 1990, 1994; Tsai, 2001; Zahra and George, 2002). Such absorptive capacity may provide a foundation for investing in potentially valuable technologies with CVC investments.

By conceptualizing CVC as a flexible investment and integrating insights of real options and absorptive capacity perspectives, we can consider not only how industry conditions directly influence CVC activity, but also how such conditions might alter the relationship between industry-wide R&D and CVC activity.

3.2. R&D and CVC

CVC investment has become popular for two reasons. First, CVC provides a means to spread investment for pursuing innovations across multiple new ventures. By spreading their investment across multiple new ventures, firms reduce their overall risk associated with their quest for new capabilities. Spreading investment and reducing risk is a particularly useful tactic in dynamic environments where technologies can quickly become obsolete. CVC limits the commitment to R&D investments in emerging technologies that have an uncertain future while maintaining the potential to increase involvement as the markets evolve and the viability of the emerging technologies becomes more clear (Basu et al., 2006; Kann, 2000; Maula et al., 2003). In essence, CVC provides the latitude to use a 'step-by-step investment' process, which limits huge losses at any step, while maintaining the option to further commit to the investment if prospects for the venture appear to be attractive (McGrath and Nerkar, 2004).

Second, CVC activity in related businesses can also strengthen a firm's ability to create new business opportunities. Investor firms gain access to proprietary technologies of the new venture that they can then combine with existing technologies to create valuable new products and processes (Deeds, 2001; Gompers and Lerner, 2001; Kann, 2000).

R&D investment within an industry enables its firms to learn about external technology and keep abreast of the latest developments in the marketplace (Cohen and Levinthal, 1989; Lane, Koka and Pathak, 2006). Conducting successful R&D often requires researchers to scrutinize external sources of complementary technology in order to complete various in-house projects (Deeds, 2001). Through these efforts, researchers develop a particularly keen sensitivity to scientific development in general and a capacity to effectively evaluate and potentially integrate external technology (Lavie and Rosenkopf, 2006). Firms in industries that typically have high levels of R&D investment tend to be quite familiar with the latest developments in the field due to their association with universities, academies, dedicated R&D labs and new ventures in the market that are engaged in the cutting edge research (Chesbrough, 2002; Gompers and Lerner, 2001; Zahra and George, 2002).

The capacity to understand and evaluate external technology is particularly helpful when reviewing the technology of new ventures and potential investment options. Industry knowledge gained through R&D activity reduces the difficulty in evaluating relatively unfamiliar technology within the CVC target (Cohen and Levinthal, 1989, 1990; Keil, 2002; Lane et al., 2006). Because industry knowledge is generally accessible to all members of the industry (Henderson and Cockburn, 1996), firms in R&D intensive industries become generally adept at forecasting technological trends and making informed investment choices among emerging ventures in the market. A number of firms in the R&D intensive telecommunication industry attribute their success in understanding and evaluating the value proposition of emerging technologies for CVC investments to the evaluative capacity cultivated by R&D investments over the years (Covin and Miles, 2007).

Hypothesis 1. Industry R&D expenditures increase industry corporate venture capital activity.

3.3. Technological change

The pace of technological change varies across industries (Klepper, 1996). Some industries, such as the timber industry, are relatively stable. Others, like the software industry, are in constant flux (Agarwal and Bayus, 2005; Henderson et al., 2006). Industries come under significant pressure as technologies change and disrupt the underlying equilibrium of an industry (Schumpeter, 1942). Rapid technological change can render firms' existing capabilities obsolete (Leonard-Barton, 1992). As a result, rapid technological change can act as an impetus to search for new and better technologies in the market (Anderson and Tushman, 1990; Schumpeter 1942).

Because the growth and trajectory of emerging technologies are highly unpredictable (Arthur, 1988; Henderson and Clark, 1990), rapid technological change creates uncertainty with regard to future market demand, technological trajectories, and the likely dominant design (Anderson and Tushman, 1990). A portfolio of investment options garnered through CVC hedges against such uncertainty by providing a window on multiple emerging technologies (Folta and Miller, 2002; Keil, 2002; Steensma and Corley, 2001). Such a portfolio also provides opportunities for learning, sharing resources and distributing risks across multiple young ventures pioneering new technologies. In contrast, when technological change is limited, there is little pressure for external venturing. Firms within an industry simply pursue routine incremental activities using internal R&D.

Hypothesis 2. Higher levels of technological change in an industry lead to higher levels of corporate venture capital activity.

3.4. Technological change and R&D

Rapid technological change also enhances the complementary relationship between R&D and CVC activities. Industry R&D increases the capabilities of industry members to evaluate and exploit new venture opportunities. Rapid technological change further enhances the value of such capabilities. When technological trajectories are shifting, predicting the future potential of technological options is more difficult. Rapid technological change provides impetus for using the evaluating and exploiting capabilities derived through R&D activities to form linkages with promising young ventures (Kogut and Kulatilaka, 2001).

When uncertainty is limited due to stable technological progression, absorptive capacity will lie supine and be underutilized in terms of exploring new options and external venturing opportunities. The relationship between R&D and CVC will be relatively weak.

Hypothesis 3. The influence of R&D on CVC is more strongly positive in industries where the levels of technological change are high than in industries where the levels of technological change are low.

3.5. Environmental munificence

A munificent industry environment where sales growth is substantial generates a greater abundance of resources while reducing both the competition for resources and resource dependencies (Boyd, 1990; Dess and Beard, 1984). A surfeit of resources can be used for a variety of strategic initiatives such as CVC that go beyond basic operations of managing products and services. Indeed, industry participants require excess resources in order to pursue new ventures (Gompers and Lerner, 2001). Using these excess resources, firms can monitor a variety of emerging technologies and market trends. As a result, firms in resource-rich environments are aware of and able to explore new technologies, trajectories and competencies in the market—this process generally starts with exploration in related domains[4] (e.g., sub-sectors or closely related sectors) because of greater awareness and knowledge regarding emerging technologies in related areas (Gompers et al., 2005; Henderson and Cockburn, 1996). Moreover, excess resources and the resulting exploration capabilities can fuel industry-wide innovation races by increasing the competition among industry participants to discover and exploit new opportunities (Smit and Trigeorgis, 2004). Thus, a munificent environment reduces the tendency for organization inertia (Aldrich, 1999; Hambrick and Finkelstein, 1987) and enhances the pursuit of bold initiatives such as CVC.

In contrast, in less munificent environments where sales growth is limited, there is less focus on future growth because increasing competition for shrinking resources threatens the survival of firms within industry (Castrogiovanni, 1991). Firms in such industries focus on maintaining stable operations, legitimacy, and reducing costs while trying to understand and manage threats to their survival (Hannan and Freeman, 1989; Khandwalla, 1973).

Hypothesis 4(a). Higher levels of munificence in industry environment will lead to higher levels of corporate venture capital activity.

However, it is plausible that less munificent environments may promote greater search for new options via external venturing.[5] Indeed, poor performance can motivate firms to pursue novel solutions while success can breed complacency and risk avoidance (Cyert

[4] We thank an anonymous reviewer for bringing this aspect to our attention.
[5] We thank an anonymous reviewer for mentioning this argument.

and March, 1992). Thus, in the less munificent environments where sales growth is limited, the pressure for engaging in CVC activity for exploring new options could be greater. This would especially be the case when the firms decide to conduct their search for new competencies outside of the 'less munificent' industry environment in trying to build a new portfolio of growth options. Moreover, firms with excess resources tend to expend them in imprudent ways that can undermine innovative efforts (Nohria and Gulati, 1996). Thus, a competing hypothesis to the Hypothesis 4(a) is as follows:

Hypothesis 4(b). Lower levels of munificence in industry environment will lead to higher levels of corporate venture capital activity.

3.6. Environmental munificence and R&D

A munificent industry environment may also increase the complementary relationship between R&D and CVC activities. When munificence is high, resources are available for a variety of strategic initiatives, organizational inertia is low, and opportunities for growth are plentiful. In addition, absorptive capacity developed through R&D provides a foundation for exploring new technologies and building a portfolio with potentially valuable technologies. The foundation provided by absorptive capacity could enable firms to exploit the opportunities presented by munificent environment more efficiently. Under such conditions, the absorptive capacity can be targeted toward exploring new competencies and developing options for future growth via CVC investment. In resource-rich industries, firms will have greater discretion to use their capacity to absorb external knowledge through CVC activity. They may begin with exploring new competencies in related domains and further use such opportunities to learn about radically different technologies for developing a fresh portfolio of options.

In contrast, when resources are tight, the focus of attention shifts to short-term resource acquisition, immediate competition and survival (Aldrich, 1999; Deeds, 2001). When environmental munificence is low, the capacity to absorb external knowledge through CVC may be underutilized, and the relationship between R&D and CVC will be relatively weak.

Hypothesis 5(a). The influence of R&D on CVC is more strongly positive in industries where the levels of environmental munificence are high than in industries where the levels of munificence are low.

Alternatively, it is plausible that the complementary relationship between R&D and CVC activities will be particularly strong for industries with limited munificence and resources.[6] When sales growth and resources are limited, firms will target their capacity to absorb knowledge toward exploring new options and opportunities in more conducive environments. Under such conditions, CVC activity will be particularly attractive. In contrast, when there are excess resources, firms may become complacent (Cyert and March, 1992). In their complacency, the capacity to absorb knowledge will be underutilized in terms of pursuing CVC opportunities. Thus, a competing hypothesis to the Hypothesis 5(a) is as follows.

Hypothesis 5(b). The influence of R&D on CVC is more strongly positive in industries where the levels of environmental munificence are low than in industries where the levels of munificence are high.

4. Methods

We gathered data on every U.S. manufacturing industry at the four-digit SIC level. After eliminating those industries for which data are not available for every variable (some four-digit industries have so few firms that data for them are not reported), we were left with 400 industries for our models. Our database contains information on firms' venturing activity collected from Venture Economics' VentureXpert database, financial and industry-level data from Standard & Poor's Compustat database, and the U.S. Census Bureau and Bureau of Economic Analysis's Industry Economic Accounts Databases.

4.1. Dependent measures

4.1.1. Corporate venture capital activity

We measure corporate venture capital activity as the aggregate count of corporate venture deals by each investor firm in each manufacturing SIC for 1997–1999. We searched the population of all private equity deals and investments by specific firms and their funds for 1997–1999. We identified the population of firms engaging in corporate venturing activity through the VentureXpert[7] database for 1997–1999. We searched the population of all private equity deals for any investments by firms and their funds. We used Compustat, Factiva and VentureXpert to identify an investor's primary SIC. We traced funds to their parent firm using Factiva and Lexis–Nexis search databases. For example, Intel has a corporate venture capital division called Intel Capital. We include any corporate venture investment by 'Intel' and by 'Intel Capital' in the semiconductor industry segment. For these firms, we collected data on the numbers of corporate venture deals. We assigned SIC codes to each of these using Compustat and Factiva databases. If no firm is found to have invested in any ventures in a SIC for 1997–1999, that SIC gets a count of zero.

[6] We thank an anonymous reviewer for highlighting this argument.

[7] We include 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.

Dushnitsky and Lenox (2005) use a similar algorithm for corporate venture investments. We normalized our count of venture investments by dividing the total number of deals by the number of firms in the industry.[8] Our measure is indicative of the intensity of corporate venture investments for each industry for 1997–1999. We also created a baseline database for 1990–1999 and found that measures for 1997–1999 were significantly correlated with the baseline ($r=.85$, $p<.01$).

4.2. Independent measures

4.2.1. R&D intensity

R&D intensity was defined as R&D investment expressed as a percentage of net sales for each industry. We relied on data published by Schonfeld and Associates (1994, 1995, 1996). Schonfeld calculates industry R&D/sales as a weighted average, based on the sales of each company in the industry. Schonfeld's data are obtained from government filings and published financial records (Siegel and Hambrick, 2005). These numbers provide the most complete R&D intensity data for each four-digit SIC code (Swan and Ettlie, 1997).

4.2.2. Technological change

We measured technological change using the growth in total factor productivity (TFP) (Schilling and Steensma, 2001). TFP growth is a version of the Solow residual and measures industry-level rates of technological change (Solow, 1957). A series of studies of economic growth conducted at the National Bureau of Economic Research showed that the historic rate of economic growth in GDP could not be accounted for entirely by growth in labor and capital inputs. A consensus has emerged that the residual largely captured technological change (Crafts, 1996; Terleckyj, 1980) and a number of researchers have used TFP growth at the industry level (e.g., Griliches and Lichtenberg, 1983; Jorgenson, 1984; Siegel and Griliches, 1991).

The Bartelsman–Gray manufacturing productivity database tracks TFP growth for every four-digit manufacturing SIC code from 1958–1994. This measure is based on a five-factor production function: capital, production worker hours, non-production workers, non-energy materials, and energy. The TFP growth index is calculated as the growth rate of output (real shipments) minus the revenue-share-weighted average of the growth rates of each of the five inputs (Bartelsman and Gray, 1996). The measure used in this study is the average TFP growth rate (as reported in the Bartelsman–Gray database) from 1985–1994 at the four-digit SIC level.

4.2.3. Environmental munificence

Munificence in industry environment provides greater decision-making freedom to the managers in that industry for making bold strategic decisions such as CVC (Finkelstein and Boyd, 1998; Datta and Rajagopalan, 1998; Hambrick and Finkelstein, 1987). Consistent with the literature, we measure the presence of munificence in industry environment in terms of growth in sales (Boyd, 1990; Dess and Beard, 1984; Keats and Hitt, 1988). Following the methodology employed by Keats and Hitt (1988), we acquired industry sales for the years 1992 to 1996 from US Census Bureau's Annual Survey of Manufacturers. The natural logarithms of these sales figures were entered into quasi-time series regressions with time serving as the independent variable. The antilogs of the resulting regression slope coefficients were then used to capture the presence of munificence in an industry environment.

4.3. Control variables

4.3.1. Heterogeneity of demand

In highly differentiated industries with heterogeneous demand, firms have relatively higher freedom to create options for growth using strategies such as outsourcing, alliances or CVC for meeting the demands of diverse set of customers (Porter, 1980; Schilling and Steensma, 2001). Firms have the opportunity to explore multitude of ways to meet changing market and customer preferences rather than relying on past routines and standard practices prevalent in relatively undifferentiated industries. To measure heterogeneity of demands for each industry, we used the U.S. Bureau of Economic Analysis's Benchmark Input–Output Accounts for 1997. The benchmark input–output data captures, at a very detailed level, how each industry uses various outputs of other industries. It is the most carefully and consistently measured data on the outputs used by each industry (Schilling and Steensma, 2001). To create this measure, we first identify all the commodity categories produced by each industry. Then, for each of those commodity categories, all purchasing industries for the commodity were identified. The resulting count measure thus includes every industry customer of every commodity category produced by each industry. Our measure explicitly considers industry differentiability by tracking sales relationships.

4.3.2. Heterogeneity of inputs

Industries vary in the general complexity of production (e.g., automobiles, consumer electronics, appliances versus logging, primary aluminum, raw cane sugar etc.). As the variety of inputs increases, so does the number of potentially valuable configurations that can be created by young ventures in the market. Diversity of inputs or subsystems also implies that new technologies can emerge in each of these subsystems. To measure input diversity for each industry, we used the 1997 Benchmark

[8] In our sample, fifty-four industries used CVC at the four -digit SIC level for 1997–1999. This is 12.8% of all the US manufacturing. This percentage is similar to the percentage of firms/sectors in other studies (Basu et al., 2006; Dushnitsky and Lenox 2005). Dushnitsky and Lenox (p.953, 2005) present a pie chart on the breakdown of total CVC investment by investing firm sector for 1990–1999. In our sample, the total number of deals is 1497. US manufacturing sector consisted of 450 industries at SIC 4-digit level with 357,984 firms.

Table 1
Intercorrelation matrix for dependent, independent, and control variables[a]

	Variables	Mean	S.D.	1[a]	2	3	4	5	6	7	8	9
1.	CVC deals per firm per industry	.004	.02	–								
2.	R&D	2.318	2.42	.241**	–							
3.	Firm assets	11.197	26.38	.044	.004	–						
4.	Industry size	795.520	2060.53	.009	−.041	−.110**	–					
5.	Slack	2.269	.525	.004	.328**	−.147**	−.107*	–				
6.	Heterogeneity of inputs	63.184	60.39	.035	.041	.114**	.081*	−.054	–			
7.	Heterogeneity of demand	1268.23	1109.92	.041	.064	−.062	.060	.118**	.281**	–		
8.	Standard	0.568	0.49	.089*	.162**	.042	−.118**	.146**	.074	.042	–	
9.	Technological change	0.007	0.016	.305**	.129**	.039	−.034	.000	.023	−.017	.079	–
10	Environmental munificence	1.058	.0514	.132**	.200**	−.015	.059	.032	.223**	.203**	.049	.134**

[a]N = 400; †$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$.

Input Output data.[9] These tables provide data on every commodity category input used by an industry. We used counts of every commodity category used by that industry to capture the diversity of inputs. Using count of categories for diversity is valid in similar fashion to the study by Lubatkin et al. (1993) who found that a simple count of the number of SIC codes that the firm operates in captures diversification as well as any of the weighted measures commonly used.

4.3.3. Slack

Slack is an important determinant of external venturing using CVC (Chesbrough and Tucci, 2004). When firms in an industry have extra resources, they spend more on CVC deals (Anokhin, 2006). Slack serves as a cushion of extra resources that can be used in a discretionary manner (Bourgeois, 1981). Higher slack creates an environment conducive for experimentation and innovation while low slack makes firms conservative. When firms have no extra resources, they may cut back on venturing. We operationalize slack as current ratio or the ability of firms in the industries to meet current obligations for 1996 (current assets divided by current liabilities).

4.3.4. Industry standards

The development of technology standards within an industry further facilitates ongoing exploration using strategies such as outsourcing, alliances and CVC (Schilling and Steensma, 2001). Standards mitigate fear and confusion regarding new technological trajectories, reduce barriers to entry and develop common platform for collaborative partnerships via corporate venture capital (Sahaym et al., 2007). We used a database of standards organizations provided by the American National Standards Institute (ANSI)[10] to capture whether standards are available in the industry. A dummy variable (0, 1) was employed to indicate whether the industry has a registered member of the ANSI that develops and administers standards.

4.3.5. Average firm size

We control for average firm size of the industry measured as average assets held by firms in each industry. This measure parses out the amount of variance in internal R&D investment and external venturing that could be present due to firm's scope and scale. Average firm size in terms of assets is based on data from NBER-US Census Bureau.

4.3.6. Industry size

We control for industry size in terms of the number of firms in each industry. This measure parses out the amount of variance in internal R&D investment and external venturing that could be present due to the size of industry in terms of number of firms. We acquire this data from the U.S. Census Bureau's CenStats databases.

5. Results

Table 1 reports the means, standard deviations, and correlation coefficients between the dependent, independent, and control variables. Because the *corporate venture capital activity* dependent variable is constrained and a number of observations have a value of zero, we used Tobit to estimate these models. Tobit is designed explicitly to account for left-censored dependent variables. The independent variables in Tobit affect both the probability that dependent variable exceeds zero (or a given threshold value), and the value of the dependent variable if it exceeds zero (Bowen and Wiersema, 2004; Helfat, 1994). To avoid multicollinearity between the predictors and the interaction terms and enhance the interpretation of the main effects, we centered all variables involved in the interaction terms (Aiken and West, 1991). Table 2 presents the results of the analysis.

[9] The BEA uses a six-digit industry coding system that is different from both the 1987 SIC system and the NAICS system. Therefore, all BEA industry categories were matched to 1987 SIC codes using the BEA's concordance tables.

[10] In the US, ANSI is responsible for aggregating and coordinating the standards creation process. ANSI is the only organization that can approve standards as American national standards. While they do not create any standards themselves, they are a conduit for federally-accredited organizations (e.g. IEEE) in the field that are developing technical standards.

Table 2
Hierarchical moderated Tobit regression models for corporate venture capital 1997–1999[a]

Variables	Model 1	Model 2	Model 3
Constant	−.217***	−.272*	−.070
Control variables			
Average firm size by assets	.000**	.000*	.000*
Industry size	.000***	.000***	.000***
Slack	.026*	−.016	−.017†
Heterogeneity of inputs	.000†	.000	.000
Heterogeneity of demand	−.000	.000	−.000
Industry standards	.050***	.042**	.044**
Direct effects			
R&D intensity		.010***	−.033
Technological change		.566*	−.128
Environmental munificence		.143	.036
Two way interactions			
R&D × Environmental munificence			.039†
R&D × Technological change			.100†
Log likelihood	−26.261	4.264	6.048
Chi-square	34.712***	95.763***	99.333***
Change in chi-square		61.051***	3.57*

[a] $N = 400$; † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$.

In Model 1 of Table 2, we entered the control variables. In Model 2, we entered the main effects of R&D intensity, technological change and industry munificence. The addition of these variables significantly enhanced our models ($p < .001$).

Hypothesis 1 proposes that internal R&D enhances the use of corporate venture capital deals. The coefficient associated with internal R&D in Model 2 of Table 2 is significant ($p < .001$). Hypothesis 1 is supported.

In Hypothesis 2, we argue that higher levels of technological change increase the levels of CVC activity. The coefficient associated with technological change in Model 2 of Table 2 is significant and positive ($p < .05$). Hypothesis 2 is supported.

In Model 3 of Table 2, we add the associated interactions between R&D and technological change and between R&D and environmental munificence. The addition of these variables significantly enhanced our models ($p < .05$).

In Hypothesis 3, we contend that the influence of industry R&D investment on CVC deals is enhanced when the levels of technological change are high. The interaction term is positive and significant ($p < .10$, Model 3, Table 2). Hypothesis 3 is supported. To further explore the nature of these relationships, we plot the relationship between the dependent variable (CVC deals), R&D intensity (one standard deviation above and below the mean) and technological change (one standard deviation above and below the mean) (Fig. 2). As predicted in Hypothesis 3, the relationship between R&D intensity and exploration via CVC deals is more strongly positive when levels of technological change are high than otherwise. Hypothesis 3 is supported.

In Hypothesis 4(a), we argue that higher levels of environmental munificence lead to higher levels of CVC activity. A competing hypothesis to Hypothesis 4(a), Hypothesis 4(b), proposes that the CVC activity will be higher when the levels of munificence are

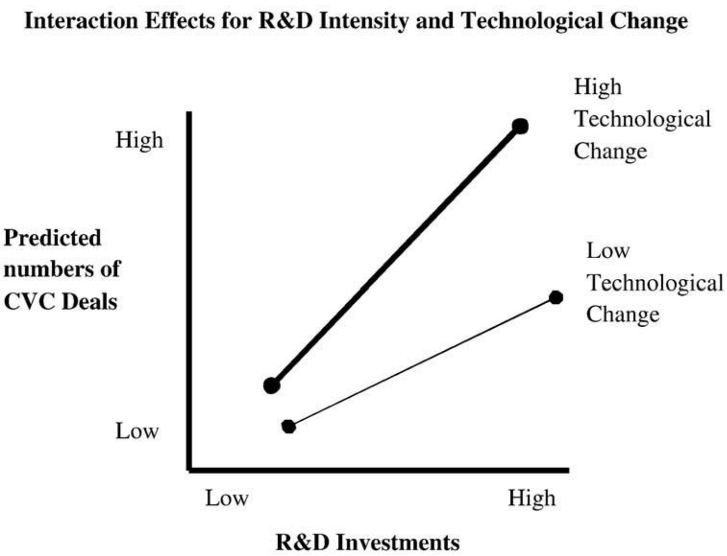

Fig. 2. Interaction effects for R&D intensity and technological change.

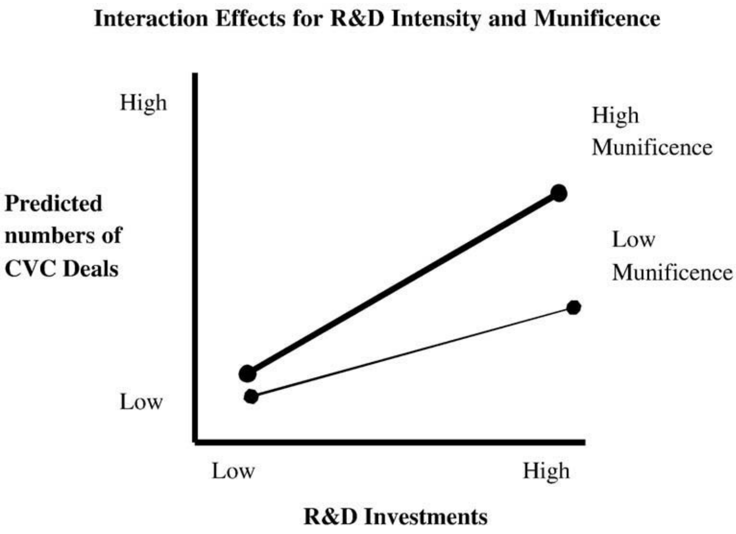

Fig. 3. Interaction effects for R&D intensity and munificence.

low. Our results show that the coefficient associated with environmental munificence in Model 2, Table 2 is positive but not significant. Thus, neither Hypothesis 4(a) nor Hypothesis 4(b) is supported. However, environmental munificence is positively and significantly correlated to the levels of CVC activity ($p<.01$, Table 1).

In Hypothesis 5(a), we argue that the influence of R&D investment on CVC deals is strengthened by the level of environmental munificence. The interaction term is positive and significant ($p<.10$, Model 3, Table 2) showing support for Hypothesis 5(a). Alternate Hypothesis 5(b) which proposes that the influence of R&D on CVC is stronger in industries when the levels of environmental munificence are low is not supported. To further explore the nature of these relationships, we plot the relationship between the dependent variable (CVC deals), R&D intensity (one standard deviation above and below the mean) and munificence (one standard deviation above and below the mean) (Fig. 3). As predicted in Hypothesis 5(a), the relationship between R&D intensity and exploration via CVC deals is more strongly positive when levels of munificence are high than otherwise. In essence, Hypothesis 5(a) is supported.

Among the control variables, industry standards ($p<.001$, Model 1, Table 2) and slack ($p<.05$, Model 1, Table 2) are the two notable variables that are significant along with others.

6. Discussion

The ongoing exploration of competencies within industries is vital to their health and survival. Firms in various industries maintain their survival and growth through CVC activity (Chesbrough, 2002; Covin and Miles, 2007; Dushnitsky and Lenox, 2006; Gompers and Lerner, 2001). CVC is used for learning about potentially valuable technologies that could be exploited in product-markets for competitive advantage. Though prior empirical research establishes that CVC investments represent real options to pursue potential innovation opportunities in the market, it has been limited in its typical focus on determining the nature of CVC investments and identifying reasons for the use of corporate venture capital (Chesbrough, 2002; Folta and Miller, 2002; Gompers and Lerner, 2001). For example, extant research shows that internal R&D is relatively slow and inflexible in terms of building a portfolio of novel technologies and competencies to meet future demands (Chesbrough and Tucci, 2004; Gompers and Lerner, 2001; Hagedoorn, 2002). CVC, on the other hand, is an effective mode for quickly developing a portfolio of new technologies and capabilities (McGrath and Nerkar, 2004; Maula et al., 2003). In addition, CVC often leads to a portfolio of new technologies and competencies that substantially vary from the selection firms already have and a new portfolio could be instrumental in meeting future demands (Covin and Miles, 2007; Dushnitsky and Lenox, 2006; Maula et al., 2003). CVC and other external modes enhance and complement internal innovation activities by tapping external knowledge sources (Cassiman and Veugelers, 2002; Keil et al., 2008).

However, some industries are more active in their use of CVC than others. Why do industries vary in their use of CVC? Substantial variance across industries suggests that the value of CVC depends on industry context and environment. In this study, we set out to better understand how industry R&D, technological change and munificence influence the use of CVC. We explore both the direct and interactive effects of industry context and environment on the use of CVC, thereby focusing on the contingent relationship between internal R&D and CVC.

We argue that industry R&D investments substantially increase the attractiveness of CVC by enhancing the capacity to recognize and exploit opportunities. We also contend that environmental pressures and opportunities associated with technological change and industry munificence create conducive conditions for the use of CVC. We find that industries with greater absorptive capacity developed by prior R&D investment and positive inducements in the form of technological change and environmental munificence display greater efforts towards pursuing innovations using corporate venture capital. Taken together, these findings suggest that the attractiveness of a CVC-based real options approach to strategy depends on industry characteristics.

Our finding that higher R&D investment in an industry promotes greater use of corporate venture capital deals suggests that the value of CVC-based real options depends on an industry's absorptive capacity. R&D investments can provide an important foundation of knowledge that facilitates the cognitive leaps that industry actors must make to identify, acquire and exploit new knowledge (Cohen and Levinthal, 1989, 1990, 1994; Tsai, 2001; Zahra and George, 2002). Thus, unlike the value of financial options, the value of CVC-based real options depends on more than supply and demand-based market conditions. Our results suggest that the value of CVC-based real options also depends on the assimilated knowledge and capabilities of industry actors. Thus, we maintain that absorptive capacity provides a foundation for investing in multiple (numbers and diverse) technologies as options for future growth and the relationship between R&D and CVC is complementary.

We also argue that technological change generally motivates exploration using corporate venture capital. Technological change induces exploration by disrupting industry equilibrium, bringing obsolescence to existing competencies and creating unpredictability about potentially dominant technological platforms in the future. In such conditions, the creation of a portfolio of real options by exploring multiple emerging technologies and cultivating new competencies can be a critical determinant of survival in subsequent rounds of the technological cycle. Thus, technological change has a direct effect on CVC investment.

Our results also show that technological change does not just have a direct, linear influence on the use of CVC. It also moderates the relationship between industry R&D investments and the use of CVC in an industry. Although industry R&D investments generally enhance the effective use and attractiveness of CVC-based real options, the positive influences of prior R&D investments are particularly valuable in dynamic technological environments. In the context of rapid technological change, the speed and efficiency with which industry actors can identify emerging technological advantages are particularly critical because early mover advantages, such as patents and brand equity, can lock out competition. In sum, technological change increases the positive effects of R&D investment on CVC activity.

We proposed and tested competing hypotheses about the direct relationship between environmental munificence and CVC activity. Our results did not demonstrate any significant direct relationship between environmental munificence and CVC activity. The argument that higher levels of environmental munificence lead to more CVC activity could not be confirmed. We also did not find support for the alternate argument that lower levels of munificence motivate more CVC. Given the lack of significant results, it is plausible that industry munificence simultaneously generates countervailing forces. Industry growth creates a pool of resources from which industry actors can finance CVC activity. However, industry munificence may also neutralize the industry-wide pursuit of CVC-based real options because industry actors are more likely to have achieved their aspirations without stretching.

We also developed competing hypotheses to examine moderating influence that environmental munificence may have on the relationship between R&D investment and CVC activity. Our results show that industry munificence significantly strengthens the positive influence of R&D investment on CVC activity. Industries where prior R&D investments have developed high absorptive capacity are better positioned for exploring new competencies using CVC when the levels of munificence are high in the industry environment. Munificence in the environment avails of abundance of resources and reduces inertia which provides opportunities for creating a portfolio of options with a number of potentially valuable new technologies. High levels of absorptive capacity provide a foundation for evaluation and exploitation of emerging technologies from a multitude of options in the market. Firms also have an opportunity for learning about the trajectories and technologies of future while evaluating new technologies for developing a fresh portfolio of options. They may build upon their prior knowledge base and use resources to begin exploring emerging technologies, trajectories and competencies in related domains. Moreover, foundational knowledge-base might nullify any countervailing effects of industry munificence (e.g., industry-wide satisficing) by shedding light on the potential for future growth with the abundance of innovation opportunities in the environment, thereby stoking the aspirations of industry actors.

We contribute to the literature by highlighting the conditions under which internal R&D can be complemented by CVC activity in the pursuit for innovation. Though scholars have previously mentioned that R&D investments assist in identifying potentially useful technologies (Afuah and Tucci, 2001, Chesbrough, 2002), this is one of the first papers that delves deeper into examining the influence of the foundation provided by absorptive capacity on the use of CVC for exploration under contingencies.

The semiconductor industry is one such example where the environmental pressures and opportunities work in conjunction with the foundation provided by absorptive capacity leading to high use of CVC. Semiconductor industry has traditionally been an R&D intensive industry requiring high levels of investment over the years (Browning et al., 1995). In this industry, major firms invest individually in the in-house R&D as well as work together with the universities, government and other parties to develop industry-wide knowledge base—an example of such cooperation among competitors is SEMATECH (SEmiconductor MAnufacturing TECHnology). SEMATECH was jointly founded by 14 key firms in 1987 that then accounted for 80% of the U.S. semiconductor industry, U.S. government and academia (Browning et al., 1995). The purpose was to collaborate, sponsor and conduct research to build knowledge base aimed at assuring U.S. leadership in semiconductor manufacturing technology. Both the in-house R&D by major firms and industry-wide R&D efforts through consortiums like SEMATECH developed an industry-level pool of knowledge contributing to high levels of absorptive capacity in semiconductor industry. In addition to the high levels of absorptive capacity in this industry, the levels of technological change have remained consistently high over decades, and sales have grown exponentially with manifold increase in the use of semiconductors in the information age. Consistent with the findings of this study, such industry attributes and conditions have contributed in making the semiconductor industry a leader in exploring new competencies using CVC.

In this industry, firms such as Intel and Texas Instruments engage in exploration for the search of new competencies frequently. In one such case, Intel, a firm with high absorptive capacity cultivated upon heavy investment in R&D since its inception in 1968, decided to found Intel Capital, a separate arm dedicated to making corporate venture investments in 1991. A primary objective of Intel Capital is to seed and nurture those small ventures in market whose products and services could fill gaps of Intel product lines, capabilities, and capacity (www.intel.com/capital). Similar to other firms in the semiconductor industry, Intel invests heavily in the development of new technologies using both R&D and CVC (Burgelman, 2002; Burgelman and Grove, 2004). R&D and CVC are harnessed as complementary modes. On one hand, Intel keeps investing in R&D for building its absorptive capacity and developing new technologies; on the other hand, Intel keeps exploring the market in search for emerging technologies that could serve as options for future growth. This helps in developing new technologies as well as an ecosystem based on the partnerships with new ventures in the market.

7. Conclusion and implications

When does the evaluative and exploitative capacity developed by R&D investments serve as a foundation for exploring new competencies using CVC? What is the relationship between R&D and CVC? Our results suggest that the specific nature of the relationship between R&D and CVC depends on broader industrial context, however; the absorptive capacity developed by prior R&D investment serves as a foundation for exploring new competencies using CVC. We conclude that the pressures and opportunities provided by the industrial environment work in conjunction with the foundation provided by absorptive capacity to determine variance in the use of CVC deals for exploration across industries.

Assuming that pursuits for exploration create value and promote the health of firms, our results have implications for managerial decision making with regard to innovations. Both R&D and CVC play an important role in producing innovation outputs. It is important to pursue and enhance the complementary aspects of these two modes (Cassiman and Veugelers, 2002; Dushnitsky and Lenox, 2005; Gompers and Lerner, 2001). Discretionary managers should find an optimum balance between the two based on their industry environment. This would ensure proactive participation in both the evolution and exploration of competencies akin to ambidexterity (Hambrick et al., 2005; O'Reilly and Tushman, 2004).

Though not hypothesized, our results show that industry standards provide opportunities for exploration and directly promote the use of corporate venture capital deals. We maintain that industry standards create opportunities for exploration by creating a common language and platform for collaboration. Firms that can pursue an emerging technology and induce other firms in industry toward building a consensus around their technology as the industry standard evolve gain competitive advantage (Tanriverdi, 2006). Thus, firms may wish to engage actively in the sociopolitical process and complex negotiations that facilitate emergence of industry standards.

Our analysis has certain limitations because it was conducted at a relatively macro (i.e., industry) level assuming homogeneity among firms (Klein et al., 1994). A systemic longitudinal analysis at the firm level could bring new insights on the relationship between prior R&D investment and CVC under firm-specific contingencies (Covin and Miles, 2007; Dansereau et al., 1999; Keil, 2002). Similarly, studies exploring how firm heterogeneity may influence the relationship between R&D investment and CVC under contingencies would also be useful. Such research could draw upon resource-based and dynamic capabilities views as the proponents of these views argue that firm attributes and heterogeneity have a major influence on decisions regarding strategic partnerships and external linkages (Barney, 1991; Eisenhardt and Martin, 2000).

7.1. Future research and extensions

Future research on the effectiveness of various modes of exploration is a worthy area for investigation. Comparing and contrasting the effectiveness of R&D and CVC would take this research further. At a broader level, this line of inquiry would also benefit from exploring a variety of modes used for external venturing in industries with varying characteristics. Could there be a strategic fit between certain modes and industries in view of the nuances associated with these modes and industry attributes? Is there a variance among the modes in yielding superior performance (using different metrics of performance)? What are some of the conditions that could influence the relationship between such modes and select performance metric?

There is a dearth of literature on the use and application of learning gained from external venturing activities. It would be valuable to explore the ways in which firms apply the knowledge gained from their CVC activity. In addition, researchers can examine the influence of such applications on various measures of performance. This line of inquiry could readily be combined with the research on governance and top management team characteristics because exploration requires long term direction setting, support and encouragement from the management and their support influences performance. The role of managers in this context has not been adequately addressed in the literature. For example, understanding the role of managers and boards in using R&D and CVC programs vis-à-vis using R&D versus CVC programs for pursuing innovations and its performance implications would be valuable. Both managers and researchers would gain by developing an integrative view of corporate governance, innovation and contingencies for pursuing exploration using various modes.

Acknowledgements

The authors would like to thank Warren Boeker, Suresh Kotha, Nandini Rajagopalan, Robin Parry, Charles Waterson and anonymous reviewers from the AOM 2007 conference for their comments on the earlier versions of this manuscript. We also thank the editor and anonymous reviewers for their valuable insights and suggestions for improving the manuscript.

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