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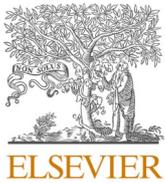
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Access to the Corporate Investors' Complementary Resources: A Leverage for Innovation in Biotech Venture Capital-Backed Companies

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ABSTRACT

Entrepreneurial companies are a vital source of innovation and are financed by investors with different profiles. We examine whether the innovative outputs of entrepreneurial companies are responsive to access to complementary resources from different types of venture capital (VC) funds: “independent venture capital (IVC) and corporate venture capital (CVC)”. We then delve deeper and examine the mechanisms by which we measure if access to investors' complementary resources has an influence on the innovation performance of the companies they fund. Our sample consists of 1547 U.S. biotechnology companies founded between 1998 and 2013 and financed by IVC or CVC funds. We find that CVC-backed companies display higher rates of innovation output, as measured by their patenting outcomes, than their IVC-backed counterparts. We specify three mechanisms that affect the influence of complementary resources of corporate investors compared to those of IVC: (1) absorptive capacity enhances the ability of the company to grasp and utilize investor knowledge; (2) business similarity helps nurture the technologies of innovative companies, and (3) geographic proximity enables approachability.

1. Introduction

One external means for equity financing, economic growth, and innovation is venture capital (VC) investment, which has become highly influential in the funding of entrepreneurial companies (Cavallo et al., 2019; Vanacker et al., 2013; W. Zhang et al., 2020). Entrepreneurial companies receive backing from different types of investors with different profiles in the funding landscape (Chemmanur et al., 2014; Kaminski et al., 2019). According to Hellmann (2002), the most critical distinction related to VC is that between corporate venture capital (CVC) and independent venture capital (IVC).¹ Chemmanur et al. (2014) define IVC funds as limited partnerships that seek purely financial returns. CVC investments, whereby incumbent firms take minority equity stakes in private startups (Dushnitsky, 2008), is an investment made by large established firms that seek strategic advantages in addition to financial returns (Röhm et al., 2017). An extraordinary record participation in CVC in terms of both deal count and deal value was reached in 2020, with 4000 deals and \$125 billion, respectively (NVCA, 2021). According to PitchBook-NVCA Venture Monitor Q1 2021, CVC

investment activities in 2020 accounted for more than 25% in value (\$) and 50% in number of the overall US VC deals, with 2021 showing an even stronger trend.

Braune et al. (2019) demonstrate that “the returns on CVC investments are satisfactory for information technology companies, which tend to renew their CVC investments each year”. Such deals benefit corporate investors as they gain insight into emerging technologies (Maula et al., 2013). Lerner (2012), in describing the architecture of innovation, shows that the available corporate model may not be the best organizational structure for nurturing innovation. Additionally, he notes that, while IVC firms may have numerous innovative ideas, they have only performed well in some targeted businesses. Increasingly, corporate investors are proving to be an essential alternative to IVC as outlined by Dushnitsky (2012). Lerner (2012) suggests that the best design to drive innovation is possibly a “hybrid” model, such as a CVC program that merges characteristics of venture-backed companies with those of corporate research laboratories “within a powerful system that consistently and efficiently produces new ideas”.

New ventures often lack the necessary resources and expertise to

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¹ In order to distinguish between CVC and IVC, we use Appendix A to make a comparison, to identify areas of identical investment and shared institutional characteristics.

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innovate on their own. The assistance of their parent companies provides access to complementary knowledge and resources to raise their chances of survival and of innovation success (H. D. Park and Steensma, 2013). While corporate investors share several behaviors with IVC, the latter lack the comprehensive collection of complementary firm resources that corporate investors have (Maula, 2007). Examples of these resources are the involvement of in-house specialists, manufacturing positions, information and marketing and regulatory experts. These complementary resources may provide CVC-backed companies with new knowledge of the business and technology used by the corporate investor, a dimension which is lacking in IVC (Alvarez-Garrido and Dushnitsky, 2016). The literature indicates that there is usually potential for value creation when the complementary resources of entrepreneurial companies and large firms are affiliated (Laamanen and Autio, 1996; Rothwell, 1983).

Tece (1986) illustrates that to succeed, entrepreneurial companies need certain vital complementary resources typically owned by big firms. Rothwell (1983) argues that one of the reasons small companies enter into partnerships is to enhance their innovative skills by leveraging the complementary resources of large firms. To transfer essential resources, corporate investors and entrepreneurial companies build investment relationships. Davidson (1991) finds that small and large firms possess complementary resources well adapted to facilitate the innovation process. Still, how the different resources of small and large firms are combined in collaborative innovation within industries is a matter that has not received extensive treatment in the literature in the context of CVC investments. The objective of this study is to improve our understanding of how companies' innovation outputs are affected by having access to the complementary resources provided by venture capitalists. We start from the consideration that there is distinct diversity in the profiles of the complementary resources of investors. We construct our research questions: When are some venture capitalists better than others in the innovation value creation path? How are complementary resources accessed to release innovative synergies? We examine whether the innovative outputs of VC-backed companies are responsive to the complementary resources of different types of venture capitalists. We then delve deeper and examine the tools by which we measure if access to investors' complementary resources has an influence on the innovation output of the funded companies. Here, we employ three mechanisms expected to impact on this ability: absorptive capacity, business similarity and geographic proximity.

To test our hypotheses, we construct an unbalanced panel of 1547 biotechnology companies in the U.S. backed by CVC and IVC investors between 1998 and 2013. The biotechnology sector provides a suitable background to examine our assumptions, as recommended by the literature (Gurău and Dana, 2020). First, biotechnology is resource-intensive and requires considerable investment (Rosenberg, 1990). Second, biotechnology is a sector where innovation is essential and patents and citations are highly valued (Stokes, 1996). Firms typically apply individual innovation strategies to cope with the high levels of uncertainty and complexity prevalent in knowledge-intensive technological areas such as biotechnology. Alliances in biotechnology have been analyzed in a number of studies (Gay and Dousset, 2005; Zidorn and Wagner, 2012) that have found that they have a positive effect on a firm's performance, especially if the innovative potential of project partners is high (Shkolnykova and Kudic, 2021). By focusing on the biotechnology industry, we reduce the importance of factors (e.g., differences in the determinants of venture capital backing and in the use and valuation of patent) that could not be easily controlled for if we considered a multitude of different industries (Cohen et al., 2000). Moreover, in this industry, patents are an important protection device for inventions (Hall et al., 2009; Levin et al., 1987).

Our study aims to contribute to the literature through three essential approaches. First, our study contributes to the continuing discussion about the best structure for nurturing innovation in entrepreneurial companies (Alvarez-Garrido and Dushnitsky, 2016; Chemmanur et al.,

2014; Sargon and Katircioğlu, 2019; Wallmeroth et al., 2018). Corporate investors are better at nurturing innovation than IVCs in companies within specific innovative sectors where the funded companies can access the complementary resources of the corporate investor. In addition, the absorptive capacity of the funded companies enables them to better leverage the complementary resources of the corporate investor. They will be able to create innovation when they can assimilate and grasp the knowledge of the firm, especially if there is a strong link between the business areas of the partners. Finally, a close business fit and geographic proximity between the corporate investor and the entrepreneurial company facilitate the transfer of knowledge, R&D capabilities and corporate personnel. By identifying absorptive capacity and business similarity as an influential dyadic antecedent and by exploring relevant geographic fit as a boundary condition for their influence, we respond to the call by (Basu et al., 2011) to further study relational antecedents of CVC investment relationships.

Second, our empirical conclusions bring new insights to the theoretical literature on the role of financial intermediaries in fostering innovation and corporate innovation. They also extend the existing empirical literature on corporate investors (Anokhin et al., 2016; Baierl et al., 2016; Baldi et al., 2015; Basu et al., 2011; J.-H. Park and Bae, 2018). We find that for a CVC-backed company to progress, it is important for it to access the complementary resources of its corporate investor along the industry value chain. We point to three influential mechanisms – absorptive capacity, business similarity and geographic proximity – that support the superiority of CVC financing over IVC financing in increasing the innovation productivity of entrepreneurial companies. Third, we participate in the growing discussion in the literature on entrepreneurial finance about the character and outcomes of various investor types (Benson and Ziedonis, 2009; Dushnitsky and Lenox, 2005; Dushnitsky and Shapira, 2010; P. A. Gompers, 1995; Sapienza, 1992; Wadhwa and Kotha, 2006). Although prior research assumes that all incumbent firms are equally likely to engage in misappropriation when there are incentives to do so (Diestre and Rajagopalan, 2012), our study unpacks this assumption and finds that incumbent firms differ in their opportunistic propensities, and that new ventures vary in their abilities to distinguish incumbents of questionable character. As such, our study responds to the call for more research on the heterogeneity of VC investors (Dushnitsky and Shaver, 2009) and contributes to research on business similarity or relatedness and geographic proximity between new ventures and incumbent firms more broadly.

The next sections present the literature review and the development of hypotheses. Next, we present the methodology and dataset in addition to the estimation approach used to test our hypotheses empirically. We then proceed with a description and discussion of the principal results ending with the conclusion and contributions.

2. Theory and hypotheses

2.1. Theoretical development

Resources are often firm-specific and heterogeneously distributed because their development consists of time-consuming, path-dependent processes (Dierickx and Cool, 1989). This makes market trading for such resources quite difficult (Pfeffer and Salancik, 1978). The logic of resource dependence theory emphasizes the importance of an alliance to overcome threats and avoid failures in new venture companies by reducing the uncertainties associated with innovation. Resource dependence theory provides insights into which collaborative strategies organizations will apply and how these may vary over time. When innovation and the transfer of knowledge are problematic and uncertain, organizations try to build CVC investment linkages or strategic partnerships to acquire access to knowledge and to avoid organizational restrictions (Pfeffer and Salancik, 1978). Resource dependence theory has two premises. The first is that new venture companies are restrained

by and depend on other firms in control of critical resources. The second, proposed by resource dependence scholars, is that managers exercise strategic preferences to diminish and control innovation uncertainty, given the restrictions imposed by a strategic alliance (Hrebiniak and Joyce, 1985). In this research, this theory could explain why new venture companies involve a venture capitalist in their activity and why the impact of such a strategy on innovation performance may be contingent on the investment's complexity.

According to the resource-based view, firms are bundles of tangible and intangible resources (Wernerfelt, 1984). Valuable, rare, inimitable, and non-substitutable resources are sources of competitive advantage and economic performance for firms (Barney, 1991). Investment links enable partners to quickly access needed resources, increasing the learning rate in businesses and the speed of resource recombination and development (Hamel et al., 1989). Resources include all processes, experiences, capabilities, tangible assets, and knowledge managed by the firms (Barney, 1991). In the case of newly backed ventures, usually described from the resource-based view (Barney, 1991; Wernerfelt, 1984), researchers claim that the level of innovation in these ventures is closely associated with their venture capitalists' knowledge and resources. Resource-based theory emphasizes the value of investment by venture capitalists as an opportunity to benefit from the innovative strengths of the newly backed ventures. The resource-based CVC formation argument posits that a new venture company joins the parent's resources and maximizes innovation by pooling and using valuable resources that a new venture firm cannot create by itself (Das and Teng, 2000). CVC investment provides financial resources and synergistic advantages through the cooperation experience when based on complementarity. The resource-based view of alliance collaboration argues that links are formed when firms have sufficient inducements to collaborate (Ahuja, 2000). Inducements refer to the incentives firms have to partner with other firms and result from a firm's need to access specific competitive resources that it does not possess and the costs of doing so (Ahuja, 2000).

Teece (1986) explains that alliances may give small companies access to complementary resources that are often required to capitalize on innovations while Forrest and Martin (1992) confirm that this is true in technology-intensive businesses. Stein (1997) explains that from the resource-based perspective, the primary argument in support of an alliance structure is that it allows firms to build a real advantage in inter-organizational relationships by better leveraging their own resources with complementary resources. To facilitate the transfer of essential resources, corporate investors and entrepreneurial companies build investment relationships. Through the CVC channel, corporate investors provide complementary resources in addition to financial ones to the entrepreneurial companies, which in turn confer strategic and financial advantages on the corporate investors. And while they share many practices with IVCs, corporate investors have access to a wide set of complementary corporate assets that independent VCs do not (Dushnitsky, 2012; P. Gompers and Lerner, 2000; Maula, 2007).

(King et al., 2003) demonstrate that technological innovation often results when the resources of a small firm are combined with those of a large one. This is because small and large firms typically possess complementary resources which, when combined, can facilitate innovative success (Lorenzo & Vrande, 2019). Complementary innovation-producing resources held by small and large firms help to explain the patterns of interaction among firms in dynamic, technology-based industries (Katila et al., 2008; Lorenzo and Vrande 2019). (Sok et al., 2016) argue that enterprises must possess both resources and capabilities at a superior level, and that those resources and capabilities must be complementary with one another to achieve superior performance. (Katila et al., 2008; Lorenzo and Vrande 2019). Kim et al. (2019) demonstrate that new venture companies often innovate by building on their parent companies' assets and rely on the sources of innovation held by their parent companies.

Resource-based theory and resource-dependence theory propose that

new venture companies depend on a venture capitalist to provide resources as well as the knowledge to reduce and handle innovation uncertainties (Harrison et al., 2001). From an investor's perspective, CVC relationships provide innovative new ventures with the means of quickly accessing external resources (Keil, 2002) and a way of exploiting internal resources (Maula, 2007). We build on this framework by examining the conditions under which corporate investors form new partnerships through their CVC investments in the biotechnology sector, an area which requires considerable resource investment (Rosenberg, 1990). Access to the corporate investor's R&D personnel and labs contributes greatly to the innovation outputs of the backed ventures especially in the biotechnology sector which has a high demand for knowledge. New research requires advanced equipment that can be either costly or scarce and proximity to the firm's R&D department facilitates access to its laboratories and R&D personnel (Fleming et al., 2007). The literature shows that boosting innovation has a robust regional nature (Jaffe et al., 1993). From the perspective of corporate investors, these complementary resources are critical and this point is key to validating our hypotheses.

2.2. The type of VC fund and innovation performance

Alvarez-Garrido and Dushnitsky (2016) and Scotchmer (2006) outline that entrepreneurial companies can use organizational laboratories and research tools. These resources can be utilized to support, advance and examine additional encouraging inventions (Reichardt and Weber, 2006). As a result, corporate investors can leverage the firm's resources during the development phase. This special access can stimulate companies' research and innovation. Merck's Global Health Innovation Fund declares the following: "For the entrepreneur, going through the corporate venturing unit brings access to Merck's product line and research and development..." (Global corporate venturing, 2018). In parallel, to better understand the channel of communication between the CVC-backed company and the corporate investor, we share another quote from a biotechnology company funded by Merck's Global Health Innovation Fund. Kevin FitzGerland, CEO of F-Star, states the following: "Our relationships with Merck Serono have given us the opportunity to meet with senior representatives from relevant research areas within the pharma organization" (Global corporate venturing, 2018). From the Ernst and Young report (2009), Steve Tregay of Novartis Venture Funds stated that such advantages are to be expected by CVC-backed companies: "You can help develop your technology platform at a lower cost because you are offsetting some of the costs through collaboration".

Alvarez-Garrido and Dushnitsky (2016) examine two determinants influencing the ability to leverage complementary corporate assets. They find that access to the firm's Food and Drug Administration approval capabilities and corporate R&D abilities are some of the advantages gained from the investor's complementary resources. Analyzing forty US telecommunications equipment manufacturers, Wadhwa et al. (2016) found that the depth of knowledge resources made available influences organizational innovation. Maula et al. (2009) find that in corporate ventures, since investing firms have more extensive resources for experimentation, the knowledge flow from the investor to the company is a valuable asset. The CVC program can leverage the competences, capacities and assets of the investing firm, which, in turn, promotes and facilitates the evolution of the company (Block and MacMillan, 1993). Based on these insights, we expect the CVC-backed companies to be more innovative than the IVC-backed companies if they are able to access and leverage the complementary resources of the firm providing the CVC funding. Using market tools to obtain resources is not always straightforward in a new venture's early stage and startups need to work with VCs because of their need for additional funding (Amankwah-Amoah and Hinson, 2019; Gloor et al., 2020; König et al., 2019). CVC investment is an attractive path to access resources due to their technological flexibility and potential to reduce innovation risk.

A new venture can obtain financial backing from multiple sources,

including IVC and CVC investors. New ventures typically receive financing from IVC investors prior to receiving funding from a CVC investor (P. A. Gompers and Lerner, 1998). The primary motivation for IVC investors is potential capital appreciation of their investment. In contrast, corporate investors tend to view CVC deals more strategically, as an opportunity to learn and open a window on new technology (Dushnitsky and Lenox, 2006; Keil et al., 2008; Maula et al., 2013). In return, CVC investors can provide their investees not only with financing but also with complementary assets, such as product test sites, marketing expertise, and access to distribution channels (H. D. Park and Steensma, 2013). CVC activity is particularly prevalent in industries characterized by technological ferment and the need for sophisticated distribution capabilities (Dushnitsky and Lenox, 2005). Technological ferment creates an environment where new ventures, rather than incumbent firms, are often at the cutting edge. The need for complementary resources entices high quality new ventures to partner with incumbent firms. Likewise, industries where the technological and market directions are highly uncertain have also been shown to have higher levels of CVC activity (Tong and Li, 2011). CVC investments can be an attractive way of contending with uncertainty because they demand relatively low commitment and require little integration (Basu et al., 2011). Building on these insights, we would expect that corporate venture-backed companies with access to the complementary resources of their corporate investors will show higher innovation output than those backed by IVC funds.

Hypothesis 1: The innovation output of CVC-backed companies is higher than that of IVC-backed companies.

2.3. Possible mechanisms to leverage investor complementary resources: absorptive capacity, business similarity and geographic proximity

2.3.1. Absorptive capacity of the entrepreneurial company

Following review of the knowledge-based view and the organizational learning insights, we find that scholars rely heavily on absorptive capacity as an essential concept in learning, knowledge creation and innovation (Cohen and Levinthal, 1990; Lee and Kang, 2015; Zahra and George, 2002). Cohen & Levinthal (1990) describe absorptive capacity as the “ability to recognize the value of new external information, assimilate it, and apply it to commercial ends.” Their finding is that inter-organizational learning is most efficient when there is sufficient commonality in the fundamental knowledge of the partners to enable efficient interaction, but simultaneously, there is enough heterogeneity in the unique knowledge of each one to be mutually stimulating. Based on these insights, we use the absorptive capacity as a determinant that enhances the innovation outputs of the CVC-backed companies.

The company’s ability to assimilate knowledge is dependent on its power to absorb, realize and apply new technology, resources and information. Cohen & Levinthal (1990) find that while a company may have the opportunity to benefit from the firm’s complementary resources, if it cannot grasp and embrace new technology and resources, it may not be able to create innovation. The company needs to assimilate additional information and apply it to improve its innovation process. In this study, we test the impact of what the company already knows on its ability to grasp and stratify new external knowledge which will be converted to innovation production as it accesses the corporate investor’s complementary resources after receiving CVC funding. We expect that a company’s absorptive capacity will serve as an essential determinant in generating innovative output. A company with high absorptive capacity may be better placed to produce a higher number of patents and a higher quality of innovation than a company without experience and knowledge of the investor’s business domain. Consequently, we can assume that the company’s absorptive capacity plays a role in facilitating the company’s ability to leverage the corporate investor’s knowledge resources to increase the company’s innovative output.

Hypothesis 2. The innovation output of CVC-backed companies with

absorptive capacity is higher than that of CVC backed companies without absorptive capacity.

2.3.2. Business similarity between the investor and the entrepreneurial company

We define business similarity as the level of relatedness between the core business of the partners (Villalonga and McGahan, 2005). The Strategic Management field has investigated relatedness and value creation in more depth (Piscitello, 2004; Rumelt, 1974; Seth, 1990). Seth (1990) emphasizes the value of knowing how synergies are achieved and their influence on the innovation output. An essential factor driving the potential synergies that can be realized is the “strategic fit” between the linked firms. Similar cognitive structures, shared languages, and shared skills enable technical learning and communication (Kogut and Zander, 1992). Application or assimilation of the new knowledge is likely to be difficult and resource-consuming if the knowledge bases are unrelated (Haspeslagh, 1991).

Coase (1937) and Oxley & Sampson (2004) discuss relatedness between the focal firm and the investing partner. A combination of resource-based and transaction-cost arguments implies that more relatedness means a lower integration cost because of economies of scale within the organization. Relatedness enhances the ‘integration potential’ of an acquisition (Larsson and Finkelstein, 1999). Technological relatedness implies that the parties share complementary and similar knowledge bases and produce economies of scale and scope in the R&D process by eliminating duplication of efforts and introducing operational improvements (Hagedoorn, 2002; Makri et al., 2010). Moreover, they can provide access to unique co-specialized complementary assets that the acquirers need to commercialize their innovations (Teece, 1986).

Additionally, in high-tech industries, firms frequently engage in acquisitions to increase their technical abilities and improve their innovation performance (Cassiman et al., 2005; Hagedoorn and Wang, 2012; Stiebale, 2013; Villalonga and McGahan, 2005). Prior research on technology acquisitions has suggested that the level of relatedness between the acquirer’s and target’s business is an important predictor of post-acquisition innovation performance (Ahuja and Katila, 2001; Cassiman et al., 2005; Cloudt et al., 2006). To date, this research stream has focused on understanding the extent to which business relatedness is beneficial for future synergy creation (Bena and Li, 2014; Sears and Hoetker, 2014). These studies show that technological relatedness between parties enhances innovation output (Ahuja and Katila, 2001; Cassiman et al., 2005; Makri et al., 2010; Sears and Hoetker, 2014).

Cassiman et al. (2005) argue that the impact of M&A on R&D and innovation depends on the relatedness of the entities. Technological relatedness can be assessed along the lines of business similarity and complementarity (Cassiman et al., 2005). Similarly, Makri et al. (2010) found that technological complementarity between partners leads to higher quality and more novel innovations. They contend that business relatedness affects the relationship between acquisition and innovation. As for innovation outcomes, efficiency synergies emerge from both technological and market relatedness (Cassiman et al., 2005). Howell (2020) demonstrates that industry relatedness has a positive effect in each phase of innovation. M&A literature suggests that acquisitions contribute to innovation performance while relatedness increases the ‘integration potential’ of acquisitions and enhances the scope to exploit efficiency synergies in the innovation process. (Cefis et al., 2020) confirm that acquirers can achieve better innovative performance in the case of high business relatedness when learning capabilities through both internal R&D and acquisition experience are high. We assume that CVC-backed entrepreneurial companies with business similarity will experience better innovation outcomes than will both IVC-backed companies and CVC-backed companies without business similarity.

Hypothesis 3. The innovation output of CVC-backed companies with business similarity is higher than those of IVC-backed companies and CVC-backed companies without business similarity.

2.3.3. Geographic proximity between the investor and the entrepreneurial company

Polanyi (1967) argues that tacit knowledge "knowing more than we can tell" is the most helpful form for firms because it is unbounded and thus can provide a competitive advantage from the knowledge-based perspective. The geographic distance between the investor and the company has been studied in the past, as proximity facilitates interaction and the flow of information (Stuart and Sorenson, 2003; Tian et al., 2020). Stuart and Sorenson (2003) note that relationships are more likely to be formed when there is close geographic proximity. Doloreux (2002) states that faster communication between actors and a lower cost associated with exchanging knowledge and information occur with closer geographical distance between partners. Investors often base their investment decisions on the "twenty-minute rule" which claims that if a start-up seeking VC funds is more than a twenty-minute drive from the VC firm, then it will not be funded (Simmie, 2003). The venture capital literature, and the investment literature more broadly, has documented a "home (local) bias" phenomenon—when investment is made in companies that are geographically closer, IVCs are better able to resolve the information asymmetry problem and conduct more efficient monitoring (Bernstein et al., 2016; D. Cumming and Dai, 2010; Hochberg and Rauh, 2013). Ma (2020) examined whether CVCs are more or less likely to invest in geographically close firms and found that CVCs tend not to show a preference for investment in "home" companies. Peri (2005) and (Matray (2021) find that CVCs seem to have a "reverse home bias" and are less likely to invest in companies in their geographic areas, as CVC parent firms can acquire innovation knowledge from startups in the same zone through local innovation spillover which decreases the marginal benefit of making a CVC investment in them (Ma 2020).

Gaba & Meyer (2008) studied a sample of Fortune 500 firms active in the information and telecommunications sector to analyze the style of CVC adopted. They found that firms launch a CVC program if they are geographically proximate to a VC cluster (e.g., Silicon Valley) and when the success of venture capitalists is prominent. According to Catalini

(2017), the probability of consolidation is higher for partners that are located near each other. Modern fieldwork demands equipment and labs that are scarce and expensive. Geographic proximity solves the problem of having to acquire sophisticated equipment and R&D personnel. The smaller the geographic distance between corporate investor and firm, the higher the ability of the CVC-backed company to access the complementary resources. We expect that a company funded by a distant corporate investor will have poorer innovative practices and will have less access to laboratories and R&D personnel. Consequently, the distant CVC-backed company will have a similar profile in terms of complementary resources as a company supported by an IVC fund investor whose objectives do not include obtaining strategic benefits from the companies it invests in. We expect that CVC-backed companies with close geographic proximity will produce more innovation output than either IVC-backed companies or distant CVC-backed companies.

Hypothesis 4. The innovation outcomes of CVC-backed companies are higher than those of IVC-backed companies and CVC-backed companies without geographic proximity.

Our research model presenting our hypotheses and the variables used in the analysis is illustrated in Fig. 1.

3. Methods

3.1. Sample and data

We construct an unbalanced panel of 1547 U.S. biotechnology companies between 1998 and 2013. The biotechnology sector is a suitable background to examine our assumptions, as recommended by the literature (Guräu and Dana, 2020). First, biotechnology is resource intensive and needs considerable investment (Rosenberg, 1990). Second, biotechnology is a sector of essential innovations in which patents and citations are privileged (Stokes, 1996). Our conclusions call attention to the mechanisms by which entrepreneurial biotechnology companies profit from access to firms' complementary resources. We focus

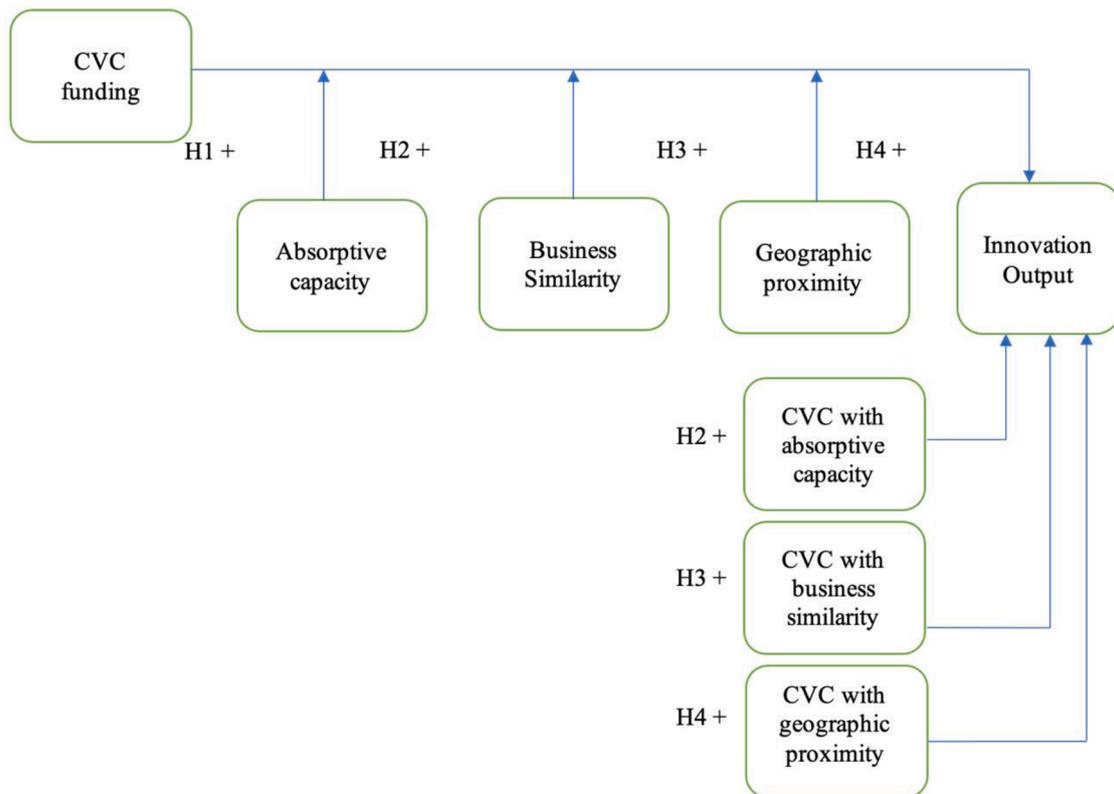


Fig. 1. Research Model (The Determinants of CVC-backed Companies' Innovation Performance).

on companies funded by two leading venture capitalists: IVC and corporate investors. Our sample consists of VC-backed companies where 39% are CVC backed. This kind of sample enables us to examine the marginal impact of CVC funding compared to only IVC funding.

We obtain complete investment information from VentureXpert, an extensive database on venture investments that has been broadly applied in prior studies (Titus and Anderson, 2018; Wadhwa et al., 2016). To obtain the necessary financial and accounting information, we use Standard and Poor's Compustat database. The United States Patent and Trademark Office (USPTO) database is used to obtain patent application information. To capture the time of knowledge creation, we use the application date of the granted patent. Finally, Bloomberg, our fourth database, is used to find the ticker symbols, which help us obtain data from Compustat because of the differences in the names of companies in the databases. To combine the data from the Thomson One, USPTO, and Compustat databases, the names of the companies were hand-matched in all the databases. We choose 1998 as the start of our study period because it corresponds to the increase in CVC investment among firms and companies, and we end the sample at 2013 because of the lag between the patent application date and its granting. We construct a sample of corporate investors as reported by the Thomson VentureXpert database. The Standard Industrial Classification codes (SIC) data of the firms are collected from Standard and Poor's Compustat and VentureXpert databases. We obtain our final sample at the company level. A brief description of the variables used in running the estimations and building the models is presented in the Appendix.

3.2. Variables

3.2.1. Dependent variables

Citations and Patents. Following the literature, we create patent variables based on the year of patent application because it is nearer to the event of the exact innovation, which is outlined by Griliches (1990). Our first proxy that captures the quantity of the innovation output is the natural logarithm of one plus the patent count for company (i) at year (t), $\ln(1 + Patents_{i,t})$, denoted as $\ln(Patents_{i,t})$ to fix the skewness problem for better empirical properties (Ma, 2020). Particularly, the variable $\ln(Patents_{i,t})$ includes the number of patent applications filed in the granting year (L. Zhang et al., 2019). We build the second proxy, which indicates the patent quality (Chemmanur et al., 2014) by including one plus the number of citations collected by each patent $\ln(1 + Citations_{i,t})$ denoted as $\ln(Citations_{i,t})$.

3.2.2. Independent variables

Dummy CVC. The primary independent variable of concern measures whether a company obtains funding from corporate investors or IVC. To determine the fund type, we obtain the list of investor fund types provided by the VentureXpert database. Applying the keywords on the kind of investor from the Thomson One database, we have 652 corporate investors in our combined sample. In line with Chemmanur et al. (2014), we construct the dummy variable CVC to take the value of one if a company has at least one corporate investor and zero if it is funded solely by IVC.

Patent stock. According to Cohen and Levinthal (1990), the patent stock of a company is employed as an index of the company's absorptive capacity. It is measured by estimating the depreciated sum of all patents for which a company has applied at time (t) at a depreciating rate λ of 30% (Blundell et al., 1995; Dushnitsky and Lenox, 2005).

$$Patent Stock_{it} = \ln(patents)_{it} + (1 - \delta) Patent Stock_{it}$$

CVC with patent stock. It is a dummy variable that is equal one if the company is funded by a corporate investor and has absorptive capacity.

CVC without patent stock. It is a dummy variable that is equal one if the company is funded by a corporate investor and has no absorptive

similarity.

Business similarity. Designed on the SIC codes of the companies and their funding firms, we construct business similarity, which measures the degree of relatedness in the core business between the partners. Business similarity is based on the four-digit SIC code that overlaps between the investor and its funded company. This index takes the value of 1 in the case of a matching SIC code and zero in the case of an entirely different SIC code. In prior research, very similar measures have commonly been used to measure industry relatedness. We divide firms into 17 industries using the classification given by Kenneth French on his web site (Rosen, 2006).²

CVC with business similarity. It is a dummy variable that is equal one if there is a business similarity between the corporate investor and the CVC-backed company.

CVC without business similarity. It is a dummy variable that is equal one if there is no business similarity between the corporate investor and the CVC-backed company.

Geographic proximity. It is measured based on the North America Metropolitan Statistical Area (MSA), which is a variable that will capture the geographical operating location for the area of the firm and the company. It is equal to 1 if both the company and the venture capitalist are geographically in the same area and zero otherwise.

CVC with geographic proximity. It is a dummy that equals one if an entrepreneurial company is backed by a CVC fund and the company is located in the same geographic area of the corporate investor and zero otherwise.

CVC without geographic proximity. It is a dummy equal to one if an entrepreneurial company is backed by a CVC fund and the company is not located in the same geographic area of the corporate investor and zero otherwise.

3.2.3. Control variables

Multiple CVC. Kaplan and Schoar (2005) show that the syndicate size reflects the level and quality of the framework of the partners who control the fund. A larger value of the variable prominent CVC implies that there are more corporate investors in the company. We control for multiple corporate investors in the syndicate size with this dummy; when multiple corporate investors are in the investment syndication, the variable takes the value of 1.

Number of rounds. Greater round numbers are expected to add more investment (Hand, 2005). For this reason, we add the control variable round number, which is the count of all rounds of investment for each company during the investment period.

Company age. The age of the company is a good proxy for company growth and is determined by the number of years since the company was founded (Chemmanur et al., 2014). It is an indicator of mature companies (Guo et al., 2015).

Investment duration. This variable represents the years that capture the length of investment at the time when we close the window of observation. The investment duration is the difference in days when the investment was received and the end of our consideration.

Investment amount. This variable is the dollar amount invested up to the close of our observation window. The investment or equity amount is the disclosed amount of the equity share of the investment round invested in the company at the round date. It is measured by adding the disclosed amounts of equity across all rounds in millions of dollars. Thomson One database provides the estimated and disclosed equity amount per round (Guo et al., 2015).

CVC Annual Availability. This variable measures the number of biotechnology ventures that receive CVC funding yearly and it is our instrumental variable (Alvarez-Garrido and Dushnitsky, 2016).

² The web address is mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html. Using 2-digit SIC codes to define industries gives less explanatory power, but similar results.

Research. Following the literature, we control for R&D expenses since we use the patenting output as the dependent variable (Alvarez-Garrido and Dushnitsky, 2016; Guo et al., 2015).

3.2.4. Estimation approach

We examine the innovation production of a company as a function of venture capitalists. As investors choose which companies to fund, our empirical approach considers nurturing and selection results. Our dependent variables are $Patents_{i,t}$ and $Citations_{i,t}$, which are count data related to the number of patent applications and citations of a company per year. We follow the literature (Alvarez-Garrido and Dushnitsky, 2016; Wadhwa et al., 2016) by using a negative binomial model, as our data take only integer, nonnegative values and exhibit significant overdispersion. The nonlinear model applied avoids heteroskedasticity, which is generalized from a Poisson model and allows for overdispersion by combining an individual, unobserved effect with the conditional mean. Since the mean and variance of the patent data are not proportional, we cannot apply a Poisson model, which cannot be used when the standard deviation of the dependent variable exceeds its mean value (Hausman et al., 1984). We run the Hausman test in Stata to identify which estimation we have to choose between fixed and random effects. Because the relationship between each of our dependent variables and the property effects of each variable are significant, the fixed effects estimation is suitable for our panel data. Our model considers two moments for the company in our sample. The first moment is at the first time of investment, which estimates the possibility that a corporate investor chooses a company to be funded, and the second moment is at the end of the observation window, which counts the number of annual patents and citations. This model enables us to examine the annual innovation production of companies that are CVC funded with those that are solely IVC funded. Before we discuss our regression results, we will address how we mitigate the potential endogeneity problem in our data. We address the problem created by the fact that the companies are not randomly matched with venture capitalists. Following (Dushnitsky and Shaver, 2009), we estimate the first stage, determining the probability of CVC funding at the time of investment, which is not influenced by the effect of the investor after the investment. We estimate our models by incorporating the residuals of the first stage as an additional regressor in the second stage.

4. Results and discussion

4.1. Descriptive statistics and correlations

Table 1 presents the pairwise correlations in addition to the descriptive statistics of the variables in our sample. The sample consists of 1547 companies, of which 603 (39%) are backed by a corporate investor. Regarding our dependent variables, the standard deviation is larger than the mean values for both patents (SD: 3.96, mean: 2.68) and citations (SD: 10.15, mean: 5.97), thus supporting our choice of a

Table 1
Descriptive Statistics for the Variables in the Models.

Variable	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10
1. Patents	2.68	3.96	0	42	1.00									
2. Citations	5.97	10.15	0	143	0.38*	1.00								
3. CVC	0.39	0.58	0	1	0.14*	0.20	1.00							
4. Patent stock	2.16	6.17	0	80	0.76*	0.18*	0.14*	1.00						
5. Business similarity	0.84	0.37	0	1	0.16*	0.05*	0.18*	0.17*	1.00					
6. Geographic proximity	0.74	0.44	0	1	0.20*	0.07*	0.14*	0.22*	0.58*	1.00				
7. Rounds	4.93	2.80	0	16.00	0.01	0.02	0.10*	0.04	0.08*	0.11*	1.00			
8. Investment duration	5.85	3.50	0	20.30	0.05*	-0.02	0.00	-0.03	0.05*	0.04*	0.34*	1.00		
9. Investment amounts	52.83	41.53	0	314.00	-0.09*	-0.06*	-0.02	-0.06*	0.04*	0.02	0.21*	0.41*	1.00	
10. Ln(R&D)	44.43	129.76	0	2666.00	0.38*	0.05*	0.18*	0.38*	0.28*	0.22*	0.08*	-0.06*	-0.15*	1.00

Standard errors are in parentheses;
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

negative binomial model regression. Concerning the innovation output, the companies are granted, on average, 2.7 patents yearly and receive approximately 6 citations per patent, with an average patent stock of 2. Table 2 shows the break down of our sample into CVC-and IVC- backed companies. We find that CVC-backed company has 4 patents per year where an average IVC-backed company has 1.67 patents. The average round number is 5, and the average duration of the investment is 5.8 years. The correlation results of our study show that patents and citations strongly correlate, having a correlation factor of 0.383. Similarly, both patents and citations correlate with CVC at rates of 14% and 20%, respectively.

4.2. Determinants of CVC Funding- First Stage regression

In the first-stage regression, we attempt to determine the match between companies and CVC or IVC funds using probit regression. The instrument, CVC annual availability, is positive and significant. We follow Dushnitsky & Shaver (2009)'s model to predict the likelihood of CVC funding. The dummy CVC is the dependent variable of the first stage. The additional variables should capture the company features that influence VC funding. Many circumstances determine the investor's decision on whether to fund a company, and the company is not randomly matched with venture capitalists. Many company characteristics determine whether there will be CVC funding. Referring to the available information in the Thomson One database, we retrieve a regression that reports the results of some explanatory indicators for the companies that receive VC financing. We check the stage at which the investment occurs, and we construct three indicators for the seed stage, early stage and expansion stage variables. In each indicator, the stage takes the value of one if it is the target stage and zero for the other stages. The investor may also examine the age of the company before deciding to invest; to track the impact of this variable on the probability of the choice of investment, we select the age of each company before receiving VC financing. Moreover, to check the quality of the CVC-backed companies, we add the patent stock variable, which is an indicator of the innovativeness of the company. Table 3 presents the results of the first-stage regression estimating the likelihood of being CVC-funded. The instrument CVC annual availability at time of investment by CVC or IVC is positive and significant.

Table 2
Full Sample Innovation Productivity.

	Mean	SD	N
Patents: full sample	2.68	3.96	1547
Patents: CVC-backed firms	4.03	7.38	603
Patents: IVC-backed firms	1.53	2.50	944
Citations: full sample	5.97	10.15	1547
Citations: CVC-backed firms	7.1	12.86	603
Citations: IVC- Backed firms	1.67	8.20	944

Table 3
CVC Fund Determinants-First Stage Regression.

CVC Dummy	Coefficient
CVC annul availability	0.76** (0.32)
Company age	0.014*** (1.19)
Seed stage	-0.425*** (3.92)
Early stage	-1.383*** (4.34)
Expansion stage	-1.612*** (7.34)
Geographic proximity	2.432*** (10.32)
Patent stock	0.427*** (13.42)
Constant	-4.36** (2.23)
Pseudo R ²	0.437
LR Chi ² (11)	1764.16***
Year fixed effects	Yes
N	1547

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.3. Companies' innovation performance and the related mechanisms to leverage complementary resources

4.3.1. Companies' innovation performance comparing CVC-and IVC-Backed companies

Table 4 shows the results of the second-stage fixed effects negative binomial regression model specifications using our first proxy for companies' innovation performance, citations. The unconstrained Model (1)

Table 4
Fixed Firm Effects – Negative Binomial Regression of Citations.

Dependent variable:&Citations	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
CVC _{t-1}		0.115*** (0.035)	0.102*** (0.031)	0.078** (0.031)	0.075** (0.032)	0.065* (0.034)
Patent stock _{t-1}			0.013*** (0.000)			0.012*** (0.000)
Business similarity _{t-1}				1.941*** (0.345)		1.220*** (0.260)
Geographic proximity _{t-1}					1.532*** (0.135)	1.122*** (0.172)
Number of rounds _{t-1}	0.015 (0.012)	0.008 (0.015)	0.009 (0.014)	0.011 (0.015)	0.003 (0.012)	0.006 (0.015)
Investment Duration _{t-1}	0.061*** (0.013)	0.059*** (0.013)	0.057*** (0.014)	0.047*** (0.013)	0.042** (0.014)	0.040** (0.014)
Company age _{t-1}	-0.139** (0.052)	-0.154** (0.055)	-0.153** (0.054)	-0.128* (0.050)	-0.132** (0.051)	-0.124* (0.049)
Investment amounts _{t-1}	0.005 (0.038)	0.010 (0.039)	0.011 (0.038)	0.018 (0.049)	0.001 (0.037)	0.004 (0.035)
Multiple CVC _{t-1}	0.099* (0.046)	0.101* (0.046)	0.119* (0.046)	0.060 (0.046)	0.091* (0.045)	0.085 (0.045)
Ln(R&D) _{t-1}	0.211*** (0.044)	0.190*** (0.044)	0.142** (0.045)	0.102* (0.044)	0.128** (0.044)	0.062 (0.044)
Constant	-1.782*** (0.171)	-1.936*** (0.168)	-1.827*** (0.171)	-3.454*** (0.289)	-2.938*** (0.219)	-3.467*** (0.264)
First-stage residuals		-0.45* (0.19)	-0.44* (0.18)	-0.48* (0.19)	-0.45* (0.17)	-0.42* (0.19)
Wald chi ²	58.99***	77.63***	144.98***	146.54***	178.44***	219.62***
Log likelihood	(5240.620)	(5198.670)	(5201.170)	(5090.980)	(5082.860)	(5073.140)
LR test	65.87***	86.77***	125.98***	208.41***	231.49***	288.69***
Number of observations	1547	1547	1547	1547	1547	1547

Bootstrap standard errors appear in parentheses;

*** $p < 0.001$,

** $p < 0.01$,

* $p < 0.05$.

presents the control variables without including the main independent variables. Model (2) includes CVC funding (Hypothesis 1), and Model (3) adds the patent stock to test Hypothesis 2. Model (4) presents the effect of business similarity (Hypothesis 3), and Model (5) presents the effects of geographic proximity (Hypothesis 4) on companies' innovation production.

Our first hypothesis predicts a positive impact of CVC funding on a company's innovative output. In Model (2), we add an independent variable, the CVC dummy, to test Hypothesis 1. The CVC coefficient has a significant positive sign, indicating that companies receiving CVC funds experience higher patenting production than companies that are backed only by IVC. Harmonious with Hypothesis 1, *the innovation production of CVC-backed companies is higher than that of IVC-backed companies*, we find evidence that CVC investment has a positive impact on the patenting output and impacts the number of citations. Corporate investors offer companies access to complementary resources that nurture innovative behaviors relevant to IVC. The coefficient of CVC is positive and significant in Models (2) to (6). Consequently, the empirical results uphold the first hypothesis.

We find that CVC-backed companies create more cited patents. The unique compensation composition of corporate investors may enable them to be more supportive of innovative activity which explains why corporate investors may be favored over IVC in nurturing innovation. First, IVC funds are structured as limited partnerships and are restricted by a contractually expected ten-year lifespan, whereas CVC funds are structured as subsidiaries of corporations. This means that corporate investors have more extended investment limits than do IVC. Second, corporate investors seek both financial and strategic purposes, whereas the investment goal of IVC is to deliver high financial interests. Third, the performance-based compensation arrangement experienced by IVC fund managers is usually not seen in CVC funds. Numerous differences as we have discussed earlier may support the greater introduction of

corporate investors to experimentation that is essential for driving successful innovation compared with IVC. Chemmanur et al. (2014) outline that the technical expertise and superior industry of corporate investors may improve their ability to handle the soft information they obtain about their funded companies' R&D projects more efficiently, thus enabling them to better nurture and assess these new companies' products and technologies. Alvarez-Garrido & Dushnitsky (2016), find robust evidence that CVC funding increases the innovative performance of the funded companies. We find that CVC funding is positively and strongly correlated with the levels of citations and the number of patents, which is in line with the finding as mentioned earlier.

4.3.2. The related mechanisms to leverage complementary resources: comparing CVC-and IVC-Backed companies

Patent Stock is an attractive construct for firm absorptive capacity. Each dollar spent on internal R&D may not generate the same amount of knowledge stock. According to Hall et al. (2001), patents should be a good proxy for knowledge capital because it mirrors the success of an R&D program, not just its input. We capture the absorptive capacity of the backed company in several ways. We apply firm stock of prior patents as a proxy for absorptive capacity. It is common to capture firm absorptive capacity with its contemporaneous R&D expenditure Cohen & Levinthal (1990). Since CVC funds and R&D labs likely compete for corporate resources and following (Dushnitsky and Lenox, 2005) we use the historical level of R&D as an alternative to test absorptive capacity. In particular, Past R&D measures the 3-year sum of past research and development outlays. That is, our second proxy for firm absorptive capacity is the sum of R&D in year $t - 2$ to year $t - 4$.

Our second hypothesis foresees a positive correlation between the company's ability to grasp knowledge and its innovative performance after it receives CVC funding; to avoid failing in the innovation creation process, the company should embrace new technology and resources. In Table 4, Model (3), we add the patent stock independent variable after controlling for the fund type (CVC dummy). The absorptive capacity of the company positively influences its innovation production. The effect of the patent stock is significant ($p < 0.001$) with a positive sign, and the patent stock has a strong impact on the patenting output. Previous research highlights the value of technological link between partners in interfirm connections (Dushnitsky and Lenox, 2005; Lane and Lubatkin, 1998; Zahra and Hayton, 2008). Zahra & Hayton (2008) demonstrate that absorptive capacity moderates the relationship between international venturing and firms' profitability and revenue growth. These results urge executives to build internal R&D and innovative capabilities in order to successfully exploit the new knowledge acquired from foreign markets. When a firm engages with entrepreneurial companies with connected technologies, the funded company can use the prior knowledge which is the absorptive capacity to understand the business potential and to assimilate the technology of the corporate investor.

In Table 4, Model (4) examines the effect of business similarity on companies' innovative performance when there is CVC funding. The effect of business similarity is significant ($p < 0.001$) with a positive sign. In addition, the result of the log likelihood test supports the model fit. Regarding the business similarity mechanism, we find that CVC-backed companies that operate close to the business area of the corporate investor (i.e., have a better "business fit" with the firm) are more innovative than IVC-backed companies. Our finding is in good agreement with Killen et al. (2008) who find that the core activity of senior management is to establish a business fit between the company and the firm. Our results are in line with (Ahuja and Katila, 2001; Bena and Li, 2014; Cassiman et al., 2005; Makri et al., 2010; Sears and Hoetker, 2014) who shed light on the importance of business relatedness and the innovation output. We find strong support for the impact of the business similarity between the company and the investor on increasing the patenting output of the company.

Model (5) examines the effect of geographic proximity on patenting output when there is CVC funding. The effect of geographic proximity is

significant ($p < 0.001$) with a positive sign. Interestingly, concerning the geographic proximity mechanism, we find that the innovation production of CVC-backed companies is higher than that of IVC-backed companies when there is geographic proximity between the corporate investor and the CVC-backed company. In line with Stuart and Sorenson (2003), we find robust support for the impact of geographic proximity between the investor and the company on increasing the company's innovation rates. Fleming et al. (2007) outline that a considerable amount of interpersonal communication aided by geographic distance is required for the recombination of novel ideas for research purposes. Thus, Hypotheses 3 and 4, which state that business similarity and geographic proximity impact the innovative performance of CVC-backed companies, are supported. In Model 6, we incorporate all the variables into a full model to demonstrate the effect of the predicted hypotheses on innovation production, i.e., citations, of companies, showing a positive and significant economic effect for all the independent variables.

Table 5 presents the analytical results with regard to our second proxy of companies' innovative performance, patents. As a robustness test, we also retrieve all the hypotheses and models above for this proxy. Additionally, with patents as the dependent variable, we estimate a fixed effect negative binomial regression. In Model (1), we present the control variables without including the CVC dummy as an independent variable. In Model (2), we add the CVC dummy as an independent variable and find a significant effect ($p < 0.001$) with a positive sign on the number of patents (Hypothesis 1). Consistent with the previous models in Table 5, our results for Models (2) to (5) show the strong impact of CVC funding on the innovation production of the company, providing strong support for Hypothesis 1. After controlling for the fund type, we add the independent variables of patent stock, business similarity and geographic proximity in Models (3), (4) and (5), respectively. We find a significant positive coefficient, showing that the abovementioned variables have strong effects on the level of patenting output (Hypotheses 2, 3 and 4).

4.3.3. Companies' innovation performance comparing CVC-Backed companies with and without business similarity and geographic proximity

In Table 6, Model (1) splits the CVC-backed companies into two groups. The first group is the companies that receive CVC funding and have business similarity with the corporate investor, while the second group is the companies that receive CVC funding and do not have business similarity with the corporate investor. The coefficient of CVC with business similarity is positive and significant, whereas the coefficient of CVC without business similarity is not significant. This result supports Hypothesis 3(b), which states that *CVC-backed entrepreneurial companies with business similarity are more innovative than both CVC-backed companies without business similarity and IVC-backed companies*.

Model (2) splits CVC-backed companies into two groups. The first group is the companies that receive CVC funding and have geographic proximity with the corporate investor, while the second group is the companies that receive CVC funding and do not have geographic proximity with the corporate investor. The results support Hypothesis 4(b), which states that *CVC-backed entrepreneurial companies with geographic proximity are more innovative than CVC-backed companies without geographic proximity and that they are similar to IVC-backed companies in the absence of geographic proximity*. This result implies that access to corporate investor R&D support is an essential channel by which corporate investors boost companies' innovation. Additionally, Table 6 presents the analytical results with regard to the second proxy of innovative outcomes, patents, in Models (3) and (4). Model (3) examines the impact of the CVC-backed companies regarding business similarity with the corporate investor, and the results are compatible with those in Model (1). Model (4) echoes Model (2), giving added support for Hypotheses 3 and 4. We find that the gap in patenting outcomes between CVC-backed companies with geographic proximity and CVC-backed companies without geographic proximity is responsive to being located close to the corporate investor. As a result, CVC-backed

Table 5
Fixed Firm Effects – Negative Binomial Regression of Patents.

Dependent variable:&Patents	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
CVC_{t-1}		0.088*** (0.032)	0.097*** (0.038)	0.095** (0.041)	0.087*** (0.041)
Patent stock $_{t-1}$			0.002*** (0.000)		
Business similarity $_{t-1}$				1.338*** (0.342)	
Geographic proximity $_{t-1}$					0.981*** (0.234)
Number of rounds $_{t-1}$	0.007 (0.016)	0.002 (0.015)	0.003 (0.015)	0.000 (0.015)	0.005 (0.015)
Investment Duration $_{t-1}$	0.043* (0.020)	0.039* (0.020)	0.040* (0.020)	0.039* (0.020)	0.044* (0.019)
Company age $_{t-1}$	-0.092* (0.039)	-0.111** (0.039)	-0.108** (0.039)	-0.109** (0.039)	-0.112** (0.039)
Investment amounts $_{t-1}$	0.021 (0.038)	0.023 (0.038)	0.022 (0.038)	0.023 (0.038)	0.019 (0.038)
Multiple CVC $_{t-1}$	0.001* (0.050)	0.010* (0.050)	0.025 (0.050)	0.004* (0.050)	0.018 (0.049)
Ln(R&D) $_{t-1}$	0.112* (0.051)	0.100* (0.051)	0.081 (0.051)	0.084 (0.051)	0.103* (0.050)
Constant	-0.448* (0.189)	-0.583** (0.194)	-0.538** (0.196)	-1.799*** (0.353)	-1.452*** (0.270)
First-stage residuals		-0.19* (0.14)	-0.18* (0.13)	-0.16* (0.14)	-0.20* (0.13)
Wald chi ²	22.4***	34.73***	87.27***	55.41***	59.91***
Log likelihood	(2696.230)	(2687.790)	(2637.620)	(2643.340)	(2665.380)
LR test	27.16***	34.34***	72.05***	56.94***	181.12***
Number of observations	1547	1547	1547	1547	1547

Bootstrap standard errors appear in parentheses;

*** $p < 0.001$,

** $p < 0.01$,

* $p < 0.05$.

companies with geographic proximity are more innovative than CVC-backed companies without geographic proximity and are similar to IVC-backed companies in the absence of geographic proximity. Our findings are line with Catalini (2017), who finds that when the partners have geographic proximity, the possibility of creating an invention is more significant, and as a result, the company can benefit from the firm's complementary resources.

We split the CVC-backed companies into two groups. The first group is the companies that receive CVC funding and have absorptive capacity, while the second group is the companies that receive CVC funding and do not have absorptive capacity. In Table 6, Model (5), we observe that companies with absorptive capacity produce quality patenting after receiving fund from corporate investors. This finding is consistent with the theoretical prediction that *the innovation production of CVC-backed companies with absorptive capacity is higher than CVC-backed companies without absorptive capacity*. The economic magnitude is also significant at the 1% level. The companies with absorptive capacity and financed by CVC funds experiences an additional 75% increase in citations.

4.3.4. Robustness check

We investigate reverse causality through a robustness test. To support our finding that patenting is a result of CVC funding, we reverse the order of the independent and dependent variables. CVC funding is the dependent variable in Model (1) and Model (2), while the independent variables are patents in Model (1) and citations in Model (2). Then, we perform our regression analysis again with all the variables. Table 7, which displays the results of the two models, shows that there is no significant relationship between our variables once their positions are reversed. This result clarifies that the probability of a problem of reverse causality between CVC funding and patents and citations is negligible. We run the models using a Poisson specification as the second robustness test; the results are the same as those from the negative binomial model.

Similarly, we run the models again with random firm effects; the results are the same as those for fixed firm effects. As a robustness test on our second hypothesis, our second proxy for absorptive capacity is Past R&D. Estimating our model for CVC-backed companies with absorptive capacity, we find a significant positive relationship between CVC-backed companies and quality patenting. CVC-backed companies with absorptive capacity experience significantly higher innovation rates compared to similar companies without absorptive capacity and that do pursue CVC (Table 8).

5. Conclusions

The findings of this study show an important impact on the creation of innovation within the backed companies as an output of the CVC program. We observe that companies' innovation output is responsive to investor type: CVC-backed companies experience higher patent and citation output than are their counterparts financed solely by IVC. The innovation performance of CVC-backed companies is responsive to their ability to benefit from the firm's complementary resources. To address innovation concerns, we delve deeper into the potential mechanisms that open the doors for the funded companies to leverage complementary investor resources and create a difference in the nurturing effects of the investors. The absorptive capacity of the company facilitates its ability to grasp, utilize and comprehend the knowledge of the firm. Geographic proximity between the corporate investor and the company enables approachability to the complementary resources of the firm. Moreover, the business similarity between the corporate investor and the company helps nurture the technologies of the innovative companies.

Our study aims to contribute to the literature through three essential approaches. First, our study contributes to the continuing discussion about the best structure for nurturing innovation in entrepreneurial

Table 6
Fixed Firm Effects- Negative Binomial Regression of CVC Citations and Patent.

CVC-Backed Companies	Citations Model (1)	Patents Model (2)	Citations Model (3)	Patents Model (4)	Citations Model (5)	Patents Model (6)
CVCwith business similarity _{t-1}	1.34** (0.72)	1.24** (0.52)				
CVCwithout business similarity _{t-1}	0.98* (0.81)	0.87 (0.44)				
CVCwithgeographic proximity _{t-1}			1.62** (0.54)	1.32** (0.53)		
CVCwithout geographic proximity _{t-1}			1.25 (0.56)	0.98* (0.82)		
CVCwith absorptive capacity _{t-1}					0.75*** (0.62)	0.46** (0.47)
CVCwithout absorptive capacity _{t-1}					0.68* (0.39)	0.59* (0.39)
Number of rounds _{t-1}	0.05 (0.24)	0.17 (0.28)	0.04 (0.32)	0.16 (0.34)	0.03 (0.22)	0.14 (0.33)
Investment Duration _{t-1}	0.04* (0.07)	0.05 * (0.08)	0.06* (0.04)	0.07* (0.05)	0.02* (0.03)	0.05* (0.04)
Company age _{t-1}	0.03 (0.06)	0.02 (0.06)	0.04 (0.04)	0.02 (0.05)	0.04 (0.03)	0.03 (0.04)
Investment amounts _{t-1}	0.04* (0.01)	0.04* (0.01)	0.04** (0.01)	0.04** (0.01)	0.05** (0.02)	0.04** (0.01)
Multiple CVC _{t-1}	0.52* (0.35)	0.63* (0.33)	0.41* (0.32)	0.36* (0.34)	0.43* (0.33)	0.37* (0.35)
Ln(R&D) _{t-1}	0.62* (0.42)	0.63* (0.43)	0.63* (0.42)	0.63* (0.43)	0.64* (0.43)	0.65* (0.44)
Constant	-0.89** (0.33)	-0.77** (0.35)	-0.99** (0.31)	-0.91** (0.34)	-0.99** (0.31)	-0.89** (0.35)
Wald chi ²	145.8***	137.34***	84.27***	561.41***	82.39***	51.54***
Log likelihood	(5215.11)	(5086.92)	(2886.62)	(2685.34)	(3646.45)	(3668.33)
LR test	132.78***	217.78***	70.25***	57.84***	90.06***	88.87***
Number of observations	603	603	603	603	603	603

Bootstrap standard errors appear in parentheses;

*** $p < 0.001$.

** $p < 0.01$.

* $p < 0.05$.

Table 7
Reverse Causality Test.

Dependent variable:CVC dummy	Model (1)	Model (2)
Patents	0.019 (0.001)	
Citations		0.000 (0.000)
Patent stock	0.000 (0.000)	0.002* (0.000)
Business similarity	0.131 (0.146)	0.107 (0.145)
Geographic proximity	0.014 (0.127)	0.021 (0.118)
Number of rounds	0.109*** (0.031)	0.098*** (0.021)
Investment Duration	0.012* (0.001)	0.018* (0.001)
Company age	0.028 (0.013)	0.018 (0.016)
Investment amounts	0.011 (0.032)	0.012 (0.025)
Multiple CVC	0.089* (0.075)	0.078* (0.033)
Ln(R&D)	0.011 (0.019)	0.003 (0.029)
Constant	-0.430* (0.184)	-0.315* (0.167)
Number of observations	1547	1547

Bootstrap standard errors appear in parentheses;

** $p < 0.01$.

*** $p < 0.001$.

* $p < 0.05$.

Table 8
Past R&D robustness test.

&CVC-Backed Companies	Citations Model (1)	Patents Model (2)
CVC with Past R&D	0.64** (0.42)	0.36* (0.36)
CVC without Past R&D	0.21* (0.19)	0.17* (0.09)
Number of rounds	0.04 (0.35)	0.16 (0.34)
Investment Duration	0.03* (0.04)	0.04* (0.03)
Company age	0.02 (0.04)	0.03 (0.54)
Investment amounts	0.12** (0.03)	0.05** (0.02)
Multiple CVC	0.54* (0.34)	0.46* (0.43)
Ln(R&D)	0.64* (0.43)	0.65* (0.44)
Constant	-1.79** (0.43)	-1.68** (0.47)
Wald chi ²	72.45***	43.34***
Log likelihood	(3543.36)	(3367.34)
LR test	95.76***	92.47***
Number of observations	603	603

Bootstrap standard errors appear in parentheses;

*** $p < 0.001$.

** $p < 0.01$.

* $p < 0.05$.

companies. Our findings illustrate that CVC-backed companies are more innovative than IVC-backed companies. Second, our empirical conclusions shed light on the role of specific intermediaries in fostering innovation and corporate innovation. We point to three influential mechanisms – absorptive capacity, business similarity, geographic proximity– that support the superiority of CVC financing in increasing the innovation productivity of entrepreneurial companies over IVC. Third, we join the growing discussion in the entrepreneurial finance literature about the character and the results of various investor types.

Our findings raise a question “In the presence of such a benefit from corporate investors, why do companies continue to be funded by IVC only?” Corporate investors are better at nurturing than IVC in the following cases. First, corporate investors may be able to better nurture innovation in companies within specific innovative businesses where the funded companies can access the complementary resources of the corporate investor. Second, the absorptive capacity of the funded companies enables them to better leverage the complementary resources of the corporate investor. They will be able to create innovation when they can assimilate and grasp the knowledge of the firm especially if there is a strong business similarity in the business area between the partners. Finally, the presence of better business similarity and geographic proximity between the corporate investor and the entrepreneurial company, plays an essential role in facilitating knowledge transfer, R&D abilities, and corporate personnel.

One of our data limitations is that we are unable to identify all the mechanisms responsible for the impact of CVC. By concentrating on innovation production, we highlight the function of CVC in stimulating companies’ innovation. Although we examine a particular industry,

biotechnology, which limits the generalizability of our paper, this industry is appropriate for our research. In this sector, the amounts of knowledge involved matter a great deal, and this aspect is uniquely relevant to our investigation, given the predominance of biotechnology companies and the heterogeneity in their investor funds. We cannot generalize our results because these aspects may not match the characteristics of other high technology businesses. As with any research comparing two groups of companies funded by different investors, we encounter difficulties related to isolating the influences of choice and nourishing. The empirical hurdle stems from the fact that entrepreneurial companies and investors (IVC and CVC) are linked together. Admittedly, our conclusions support the view that corporate investors pick more innovative companies than do IVCs. As future work, it is essential to study the impact of the investment stage of the company on its innovative performance and the company needs from the investor at every stage. Future research can account for how the gap between CVC and IVC varies with regard to the knowledge or the experience of the leading fund in the syndicate. More research can study in depth the impact of fund reputation on this gap.

CRedit authorship contribution statement

Fatima Shuwaikh: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing.

Emmanuelle Dubocage: Conceptualization, Methodology, Validation, Supervision, Writing – review & editing.

Appendix A

Comparison between CVC and IVC Funds

Dimension	CVC fund	IVC fund	Reference
Definition	An established firm undertaking minority equity investment in entrepreneurial companies	An investor devoted to undertaking equity investment in entrepreneurial companies	(Alvarez-Garrido and Dushnitsky, 2016; Dushnitsky, 2012; Gompers and Lerner, 1998)
Description	A corporation whose investment liabilities are related to the CVC program	A dedicated financial investor	(Alvarez-Garrido and Dushnitsky, 2016; Dushnitsky, 2012)
Objective	To seek strategic gains, such as the improvement of new relevant business, and provide a window on technology. Less concerned with fast financial returns	Investment activity to achieve financial returns is the sole objective	(Gompers and Lerner, 2004)
Structure	Partnership form	A limited partnership	(Gompers and Lerner, 2004)
Lifespan	Long, unlimited period	Limited by ten years	(Chemmanur et al., 2014; Dushnitsky, 2012)
Structure of managers’ payments	Fund managers do not enjoy performance fees	Fund managers typically receive performance fees	(Meyer 2005)

Source: Elaborated by the author

Appendix B

Variables Description

Variable	Definition and construction	Data source
Patents	Number of patent application filed by a company in a given year. The natural logarithm of one plus the patent count for company (i) at year (t), $\ln(1 + Patents_{i,t})$, denoted as $\ln(1 + Patents_{i,t})$ is used in the paper.	USPTO
Citations	Citations of the new patents granted to the company per year. one plus the number of citations collected by each patent $\ln(1 + Citations_{i,t})$ denoted as $\ln(Citations_{i,t})$ is used in this paper.&	USPTO
CVC	Dummy variable to determine the type of fund (CVC or IVC).	VentureXpert
Stock of patents	Depreciated count of the patent granted to the company. $PatentStock_{it} = \ln(patents)_{it} + (1 - \delta)PatentStock_{it}$	USPTO

(continued on next page)

(continued)

Variable	Definition and construction	Data source
CVC with patent stock.	It is a dummy variable that is equal one if the company is backed by a CVC fund and has absorptive similarity.	USPTO
CVC without patent stock.	It is a dummy variable that is equal one if the company is backed by a CVC fund has no absorptive similarity.	USPTO
Geographic proximity	Data based on MSA, an indicator that is equal to one if both the company and the venture capitalist that finance the company are in the same area.	VentureXpert
CVC with geographic proximity	A dummy that equals one if an entrepreneurial company is backed by a CVC fund and the company is located in the same geographic area of the corporate investor and zero otherwise.	VentureXpert
CVC without geographic proximity	A dummy equal to one if an entrepreneurial company is backed by a CVC fund and the company is not located in the same geographic area of the corporate investor and zero otherwise.	VentureXpert
Business similarity*	Degree of business relatedness based on the SIC code. This index takes the value of 1 in the case of a matching SIC code and zero in the case of an entirely different SIC code.	Compustat VentureXpert Bloomberg
CVC with business similarity	A dummy that equals one if an entrepreneurial company is financed by a corporate investor with a business similarity and zero otherwise	Compustat VentureXpert Bloomberg
CVC without business similarity	A dummy that equals one if an entrepreneurial company is financed by a corporate investor without a business similarity and zero otherwise	Compustat VentureXpert
Multiple CVC	A dummy variable that is equal to 1 for multiple CVC in the syndicate size	VentureXpert
Number of rounds	The number of times a company has received an investment by round dates	VentureXpert
Company age	Number of years since the founding of the company	VentureXpert
Investment amount *	The summation of the disclosed amount of the equity amount invested in the company at the round date	VentureXpert
Investment Duration	The difference in days between the exit date and the first investment date received	VentureXpert
Research	Total annual research expenditures (USD Millions)	Compustat
Past R	The second proxy for firm absorptive capacity. It measures the 3-year sum of past R	Compustat
D	D outlays. is the sum of R D in year $t - 2$ to year $t - 4$.	

*Author's computation based on the mentioned data source

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