

More Than Words:

Is Startup's Propensity to Patent and Publish Sensitive to Investor Characteristics?¹

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ABSTRACT

Over the last decade, corporations became an increasingly important source of financing for innovative startups across a wide array of industries. This paper investigates the consequences of Corporate Venture Capital (CVC) investments: Do strategically-oriented CVCs affect startups' research productivity? Do CVC-backed startups overemphasize basic over applied research? We study these questions using a longitudinal sample of 574 U.S. biotechnology ventures founded from 1990 to 2003. We find that CVCs foster publications more than VCs, especially when the CVC parent firm shares industry niche with the venture. And while CVCs also foster the venture's patents more than VCs, the effect is stronger when the CVC parent firm is in a different industry niche. In summary, our findings highlight the innovation implications of different investor types.

“Corporate venture funding, the investment of corporate funds into external endeavors, is expected to become a much more crucial source of funding to the industry, with 30 percent of CEOs surveyed saying they will tap corporate venture capital as a finance source in the next 12 months, versus only 10 percent who did so in the past 12 months.”

PwC 2012 CEO survey of California Biomedical Industry (in collaboration with CHI and BayBio).

INTRODUCTION

Innovation is one of the cornerstones of today’s economy, and as such policy makers and researchers seek to provide incentives to fund it, and to better understand the consequences of that innovation on firms and the economy. Because entrepreneurial ventures are an important source of innovative ideas and products (e.g., 1988), the question of how to fund innovative ventures is at the center of the larger issue (Hall, 2002).

It has been argued that venture capital (VC) stimulates the innovation of the entrepreneurial ventures they back (Kortum & Lerner, 2000; Samila & Sorenson, 2010). And yet VCs are only one source of funding. Increasingly, corporate investors, also known as corporate venture capitalists (CVC), are becoming an important alternative (Dushnitsky, 2011), which like VCs, pursue financial but also strategic objectives (Dushnitsky & Shaver, 2009; Gompers & Lerner, 1998). This study seeks to understand the implications of CVC investment on entrepreneurial innovation: Do strategically-oriented CVCs affect startups' research productivity? Do CVC-backed startups overemphasize basic or applied research?

The purpose of this paper is to study the impact on entrepreneurial ventures’ innovativeness, comparing CVC-backed ventures to those funded by VCs. To that end, we study the research output (both basic and applied) of CVC-backed ventures and further explore whether such output is affected by the competitive position of the CVC-venture pair (i.e., do they target the same industry niche?). Specifically, we focus on the two main types of innovative outcomes: (1) patents, as a result of applied research, that

award monopoly commercialization rights, and (2) scientific publications, which are the result of basic research that is far from a commercial application, and generate knowledge spillovers.

Corporate venture capital investment is on the rise. The reason is threefold. First, there is a relative decline in VC investment. The financial crisis constrains VCs' ability to raise capital from pension funds, endowments and other traditional financiers. This, in turn, leads to lesser availability of venture capital, and therefore increases the relative attractiveness of CVCs. Second, entrepreneurial ventures recognize that established corporations offer not only financial capital but also access to valuable complementary assets (e.g., corporate manufacturing facilities, or distributions channels). There are some industries, such as the pharmaceutical industry, where corporate complementary assets are highly valued, and thus CVC-backing is particularly attractive. Third, more and more corporations understand the value of having 'eyes and ears' in the world of innovative entrepreneurial ventures. Indeed, the number of CVCs has more than doubled in the past decade (Dushnitsky, 2011).

Because CVCs are affiliated with a large corporation, they are driven by a balance of VC-like financial objectives and corporate-oriented strategic goals. As a result, corporate venture capitals pose unique opportunities and threats to the much smaller entrepreneurial venture. The advantages include the aforementioned access to complementary assets: the corporation can be instrumental in speeding the time-to-market and reducing the commercialization costs of an entrepreneurial invention, as well as substantial endorsement effect and industry know-how (Stuart *et al.*, 1999). The disadvantages have to do with the fact that a large corporation is well-positioned to expropriate an entrepreneurial idea and commercialize it as its own (Dushnitsky & Shaver, 2009; Katila *et al.*, 2008).

In a nutshell, our analysis pivots on three elements. We explore whether (a) the research output of entrepreneurial ventures (i.e., patents or publications) is sensitive to (b) investor identity (i.e., VC or CVC), and (c) the relative market positioning of the venture-investor pair (i.e., whether or not the venture operates in the same industry niche as the CVC). Our findings present evidence of a division of labor.

Specifically, CVC-backed ventures exhibit greater publications and patents compared to VC-backed ones. Interestingly, the impact of same-industry-niche CVC investor diverges: it is associated with the highest increase in a venture's publications, yet the lowest impact on patents.

We investigate these issues by studying 574 biotechnology ventures founded between 1990 and 2003, of which 198 ventures are backed by a corporate venture capital and the remainder are VC-backed. The biotechnology industry is an ideal setting to test our hypotheses: (a) it is capital intensive and requires VC or CVC-backing, (b) it is a field where basic and applied research are highly intertwined, leading firms to invest in both (Rosenberg, 1990), and (c) it provides well-accepted measures of basic-research outcomes (i.e., scientific publications) and commercial applied- research outcomes (i.e., patents). The empirical strategy seeks to identify the treatment and selection effects, using structural models and leveraging the variation in the availability of CVC funding. The results suggest that inventor type affects the ventures' innovation trajectory. CVC-backing promotes ventures' publications more than VC-backing does; the effect is even greater when the CVC parent firm is in the same industry niche as the venture. We also find that CVCs foster patenting more than VCs, especially when the CVC and the startup compete in different industry segments, suggesting that CVCs nurture the patenting but also internalize part of the innovation outcomes of the startup. The results are economically important, leading to increases of more than 50% on the rate of patents and publications.

This study makes several contributions. First, it adds to a growing literature that documents innovation implications of different investor types. We focus on the biotechnology industry, where VCs and CVCs are commonplace. Second, it is the first paper, to the best of our knowledge, to investigate the consequences of different investors along different innovative outcomes. Whereas prior work focuses on commercialize-able innovation (i.e., patents), we also consider the impact of ventures' basic research (i.e., scientific publications). We therefore shed light on the way in which investor characteristics contribute to knowledge spillovers.

TYPES OF INNOVATIVE OUTCOMES

It is commonplace to distinguish between two archetypes of innovation activity: basic and applied research. The National Science Foundation defines basic research as “systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind”, and applied research as “systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.”² Economists and management scholars use similar definitions. For instance, Stern (2004: 837) defines “participation in science to be distinguishable from commercially motivated knowledge production, involve the formulation and testing of theories (which may, but need not, result in commercial spillovers), and result in public disclosure in academic journals.”

In the biotechnology industry, patents are particularly instrumental in appropriating commercial value (Cohen *et al.*, 2002; Levin *et al.*, 1987; Shan *et al.*, 1994). The technology that results from the applied research efforts is typically protected through patents, which are externally validated through the patent examination process (Griliches, 1990), and are indicators of commercialize-able new products (Basberg, 1987; Hagedoorn & Cloudt, 2003). Entrepreneurial ventures tend to patent their innovations so as to secure the commercial monopoly rights associated with them. In contrast, basic research has no direct commercial application and is typically disseminated through scientific publications and academic conferences. It is a public good and plays an instrumental role in applied research and technology (Cohen *et al.*, 2002; Gambardella, 1995; Gittelman & Kogut, 2003; Powell *et al.*, 1996; Zucker *et al.*, 2002). Public institutions invest in this public good, but interestingly, firms do as well, as a means to improve their productivity in their applied research activities, and as an incentive for their scientists (Stern, 2004).

With the passing of the Bayh-Dole act in 1980, patenting in the universities became prevalent, raising the question of whether academic publications were diminished in turn. One stream of literature

² As defined by the National Science Foundation (<http://www.nsf.gov/statistics/randdef/fedgov.cfm>, accessed on 1/1/2012)

has sought to analyze the extent to which science and technology in the universities act as substitutes (Agrawal & Henderson, 2002; Azoulay *et al.*, 2009; Goldfarb, 2008; Goldfarb *et al.*, 2009; Larsen, 2011; Mowery & Ziedonis, 2002), and the role of institutions in shaping this interaction (Furman & Stern, 2011).

While universities have a central role in science, firms also engage in basic research and share their results through academic publications. The rationale for such investment is that basic research partly leads to applied research, because it increases the absorptive capacity of the firm (Cohen & Levinthal, 1989, 1990; Rosenberg, 1990), but also because it provides an incentive for scientists (Dasgupta & David, 1994; Stern, 2004). Lim (2004) shows that this close industry relationship between science and technology is stronger in pharmaceuticals than in other fields, such as semiconductors. Indeed, much of the work on the science-technology relationship focuses on the life sciences fields (e.g., Azoulay *et al.*, 2009; Murray & Stern, 2007; Stern, 2004).

It follows that patenting and publications are distinct, but they are highly intertwined, underscoring the need to study both types of research if we are to analyze the dynamics of entrepreneurial venture's innovation. And while extant work has focused on the basic-applied research output from universities, there has been little work on the basic-applied balance in the private sectors, and specifically on that of entrepreneurial ventures. There is no work that we are aware of on the impact of different investors on this balance.

CORPORATE VENTURE CAPITAL AND STARTUP INNOVATIVENESS

In recent years, an incipient stream of literature has begun to analyze the role of investors on the venture's innovative outcomes. In addition to some work on the role of government investment (Svensson, 2007), the main focus is on venture capitalists. Kortum and Lerner (2000) show that VCs have spurred patenting across industries in the U.S. Furthermore, the presence of venture capitalists increase

the effect of knowledge spillovers from research centres and universities on the rates of patenting of firms (Samila & Sorenson, 2010).

Yet, to the best of our knowledge, past work has focused on one type of investor –VCs- and on one type of innovative outcome –patents. This paper takes two steps further, studying the effect of corporate venture capitals as compared to venture capitalists, on the two types of outcomes – patents and publications. The key insight is that as financial investors, the VCs benefit when the ventures they back are successful at creating and commercializing innovation. As strategic investors with existing products and services of their own, corporations may have a different approach. In what follows, we expand and hypothesize on these issues.

CVCs and Ventures' Publications

As the investment arm of a corporation, corporate venture capitalists may provide additional resources and knowhow to the entrepreneurial ventures, but may also have interests in them beyond mere financial success. In addition, both VCs and CVCs select the ventures they invest in. Hence, to understand how CVCs impact innovation differently from VCs we need to understand not only how CVCs select ventures, but also the interest that CVCs have on the innovation outcomes of the venture, and the means by which they can affect the innovation processes.

Previous research has emphasized that both VCs and CVCs select the ventures they invest in, and that they naturally prefer those that are more innovative and promising. To the extent that publications signal how promising the venture is, or the knowledge and innovative capabilities of its scientists, it is possible that both VCs and CVCs prefer ventures with more scientific publications. However, because publishing is costly, once the VC or CVC invests it has to choose to nurture, or not, future scientific publications of the venture. The question, then, is whether there are incentives to foster publications, and whether there are resources that can be leveraged to foster them.

There are two broad motives for ventures to engage in publications. As a “ticket of admission,” the research leading to scientific publications increases the absorptive capacity of the venture and, in turn, its research productivity (Arora & Gambardella, 1994; Cohen & Levinthal, 1989, 1990; Rosenberg, 1990). Besides, publications are valued by scientists and provides them with an incentive to engage in the R&D activities that will lead to the discovery of a technology (Dasgupta & David, 1994; Stern, 2004). For these reasons, both large corporations and entrepreneurial ventures engage in research that leads to publications in addition to patents.

Extant work indicates that entrepreneurial ventures are specifically a source of highly valuable and innovative ideas (Kortum & Lerner, 2000; Shane, 2001; Zingales, 2000). According to this line of reasoning, star scientists/innovators will opt away from fixed salary (i.e., as an employee in a corporate R&D lab) and towards profit sharing (i.e., founding their own new venture) when they have an idea that is highly lucrative (Anton & Yao, 1995; Gans & Stern, 2003). Thus, we expect to observe the formation of new ventures primarily when entrepreneurs have highly innovative ideas (Aghion & Tirole, 1994).

Accordingly, large corporations engage in corporate venture capital activities as a vehicle to gain a window into cutting edge and high potential research developed by high-technology entrepreneurial ventures (Dushnitsky & Lenox, 2005a; Wadhwa & Kotha, 2006). Strategic investors are, therefore, interested in promoting publications at the venture, because they drives the future commercial success of the ventures innovation (Rosenberg, 1990), but also because it keeps scientists engaged and motivated (Stern, 2004), and this is particularly relevant in a small and young organization that can offer fewer extrinsic rewards.

The question that follows is whether the CVC can offer resources and capabilities that could be valuable for the venture’s R&D activities. One of the mechanisms is the provision of financial resources. Financing is a typical constraint that researchers in high technology industries face. Another mechanism has to do with access to management talent. Professionalizing the venture (Hellmann & Puri, 2002) may

also prove relevant to the R&D processes, because lower-quality management may detract attention from the R&D processes to focus on day-to-day problem solving activities. In addition to these mechanisms (Block & MacMillan, 1993; Dushnitsky & Lenox, 2005a), a CVC may also take advantage of the resources and knowledge from its parent corporation: providing unique services that build on corporate resources, including access to corporate laboratories, knowledge of navigating regulatory demands and FDA processes, as well as access to their suppliers and distribution networks, or access to their patent lawyers (Acs *et al.*, 1997; Zucker *et al.*, 1998). These resources can be used to help develop and test promising new inventions (Scotchmer, 2004).

It follows that CVC parent firms have both the incentive and the resources to support and stimulate basic research conducted by the entrepreneurial venture. In comparison, VC-backed ventures are privy to business advice, yet do not experience the same level of scientific conversations. Consequently, we expect CVC-backed ventures to create more scientific knowledge of the type published in academic journals.³

Hypothesis 1. All else being equal, the publication outcomes of CVC-backed ventures increase above and beyond those of VC-backed ventures.

The implications of CVC-backing may be sensitive to the degree to which the corporation and the venture compete in the same industry niche. The topic of knowledge-sharing, including the effect of resource complementarities and complexities inherent to knowledge transfer (e.g., Dyer & Singh, 1998; Hamel, 1991; Sampson, 2007), has been examined in the framework of strategic alliances and may be exacerbated in the context of corporate venture capital where the entrepreneur's main asset is knowledge based.

³ Note that there is no incentive to keep the scientific discovery secret. The scientific process requires validation of the results, which in turn requires publicity (Kuhn, 1962). Besides, scientists pay to be scientists because instead they are rewarded by the public recognition of their scientific achievements. Therefore, even if CVC enterprises would prefer to keep the scientific discovery secret to reduce external spillovers, the nature of such discovery requires publicity.

In high technology fields, innovation is a lengthy process and firms often specialize in different stages of the innovation chain. There is, then, certain division of labor, with startups often focused on the early stages of the process and incumbents farther down the chain. The biotechnology and pharmaceuticals are the archetypical examples in the literature (Galambos & Sturchio, 1998; Pisano, 1991, 2006). It follows that CVC parent firms in the same industry niche as the startup have additional incentives to foster publications, because the knowledge outcomes of such research are of great value to their R&D projects. In essence, CVC parent firms explore by investing in the venture's scientific publications (Cohen & Levinthal, 1990; Dushnitsky & Lenox, 2005a; Wadhwa *et al.*, 2009).

An industry-niche overlap will also enhance the parent's ability to accurately evaluate and potentially commercialize an innovation. The degree to which a firm learns from a venture depends in part on its absorptive capacity (Cohen & Levinthal, 1990; Pisano, 1991; Veugelers, 1997). Recent work highlights the 'relative' nature of absorptive capacity, that is, a firm's ability to learn from another firm is contingent on domain similarities (Ahuja & Katila, 2001; Lane & Lubatkin, 1998). Overlap in knowledge domains allows a firm to better gauge the value of its prospective partner's invention. Essentially, CVC parent firms in the same industry niche possess resources and knowledge that are more complementary to the ventures' than those of CVCs in a different industry niche, and as a result the former are better equipped to aid the venture.

Consistent with the prediction in hypothesis 1, we argue that both CVCs in the same and in a different industry niche will nurture publications more than VCs.

Hypothesis 2. (a) All else being equal, the publication outcomes of ventures backed by same-industry-niche CVCs increase above and beyond those of VC-backed ventures.

(b) All else being equal, the publication outcomes of ventures backed by different-industry-niche CVCs increase above and beyond those of VC-backed ventures.

CVCs and Ventures' Patents

Investors, be that a CVC or an independent VC, also affect a venture's patenting outcomes. Moreover, it is well known that ventures invest in patents as a signal of quality, among other things to attract investors, and that both VCs and CVCs prefer ventures with more patents (Amit *et al.*, 1990; Hsu & Ziedonis, 2011). Kortum and Lerner (2000) found that even after controlling for selection, VCs foster patenting after the investment. Therefore, as in the case of publications, there is still the question of whether VCs and CVCs have the same incentives and capabilities to nurture the firm's innovative processes.

A key observation is that investors' objectives shape the value they assign to patents. One might argue that VCs, as financial investors, view patents as a means-to-an-end (i.e., they allow a venture to access more capital, either through further fundraising, licensing or eventually, IPO or trade sale), whereas for strategic CVCs patenting is a goal in and by itself. Specifically, corporate venture capitalists invest in entrepreneurial ventures because they provide a "window" into different technologies, hence allowing them to learn and explore (Dushnitsky & Lenox, 2006; Wadhwa *et al.*, 2009). For VCs, however, patents are a quality signal for high-technology ventures that increase the value of their investment, especially when the venture is young and the information asymmetries are greater (Hsu & Ziedonis, 2011). Also, both CVCs and VCs can aid the venture in their R&D processes, but as in the case of publications, CVCs have a greater array of resources and knowledge that complement those of the venture, and as a result they are better positioned than VCs to foster patenting outcomes.

This line of reasoning suggests that CVCs foster patents more than VCs. The picture is, however, more complex, because CVC parent firms have the infrastructure, and possibly the incentives, to internalize the venture's technology. It is therefore necessary to analyze the dynamics of technology appropriation between the established corporation and the venture.

Both VCs and CVCs have an incentive to foster the venture's patenting outcomes, which as a signal of quality lower the information asymmetries (Hsu & Ziedonis, 2011), making the entrepreneurial venture more attractive to later stage investors and also to the stock market investors or corporations, facilitating further rounds of investment, and IPO or a trade-sale. Furthermore, patents can be licensed or sold, and this is for the most part the main source of profits for early stage ventures that still lack a commercial product. In essence, by fostering patents, corporate and independent VCs enable the financial success of the entrepreneurial venture in their portfolio.

But the resources and knowledge-base of the CVC parent firm provide the entrepreneur with an alternative to the costly and time-consuming patenting process. Through the corporation, the venture has access to distribution channels and so it may be possible to avoid (or at least keep a trade secret and postpone until commercialization is more certain) the patent application and subsequent licensing agreements. Moreover, many ventures reach licensing and/or commercial agreements with the CVC parent corporation in a way that allows the venture to capture part of the rents associated with the innovation, while leaving the costly commercialization phase to the corporation. Finally, it is also possible that the corporation takes advantage of their privileged position, to expropriate the technology of the startup. In this case the effect of CVC-backing would not necessarily translate into more patents for the venture, even though it may translate into more patents for the CVC if they want to fully expropriate the technology.

Overall, we argue that CVCs possess resources and knowhow that complement those of the venture, and hence may foster patenting outcomes more than VCs. However, CVCs may also reduce the patenting outcomes of the venture by providing an alternative avenue to the venture or by expropriating its technology. Because it is an empirical question whether CVCs foster patents more than VCs or not, we propose the two effects on hypothesis 3 (a) and (b).

Hypothesis 3. (a) All else being equal, the patenting outcomes of CVC-backed ventures increase above and beyond those of VC-backed ventures.

(b) All else being equal, the patenting outcomes of CVC-backed ventures decrease compared to those of VC-backed ventures.

These positive and negative effects of CVC-backing are exacerbated when the CVC parent firm competes in the same industry niche as the entrepreneurial venture. Research in life sciences is a lengthy and complex process and as a result biotechnology ventures tend to focus more on the earlier stages of the process, while incumbents focus on the later stages (Pisano, 1991). When the CVC parent firm and the venture are in the same industry segment, there is a greater degree of complementarity between the resources and knowledge-bases of both. This greater complementarity of resources facilitates the commercialization of the technology through avenues different from the patent, also increasing the incentives of the corporation to expropriate and internalize the technology. In essence, even though there is a greater potential to nurture the applied research efforts, the CVC also offers a better alternative to patenting, either voluntarily by the entrepreneur or forced by the CVC parent firm. Therefore, we expect that the negative effect on patenting outcomes will be predominant when the CVC parent firm's and the venture's industry niches overlap (hypothesis 4.a).

In contrast, when the CVC goal is to expand the parent's product categories, and hence invests in a startup in a new (different) industry niche, they are less likely to internalize the innovation directly. In this case, the parent does not have the organizational structure in this business segment in order to directly exploit this technology, and it is more valuable to keep it in the startup. For instance, this is the case of the Novartis Option Fund, which seeks to "enabl[e] the development of novel programs and technologies that may be complementary to Novartis' research endeavors" and "is coupled with an option to [license] a specific therapeutic program giving early validation for the startup company's technology or programs by

a large Pharma.”⁴ In this case Novartis funds ventures in complementary (but different) areas and negotiates the licensing of the technology *ex ante*.

Even though both types of CVCs have complementary resources to foster patenting, the resources of same-industry-niche CVCs are more valuable. And even though both types of CVCs have incentives to foster patents, those in different industry niches have more incentives. While the mechanism may differ, we expect both types of CVCs to have an effect on patenting above and beyond VCs.

Hypothesis 4. (a) All else being equal, the patenting outcomes of ventures backed by same-industry-niche CVCs increase above and beyond those of VC-backed ventures.

(b) All else being equal, the patenting outcomes of ventures backed by different-industry-niche CVCs increase above and beyond those of VC-backed ventures.

METHODOLOGY

Empirical setting and sample description

We test our hypotheses using a sample of 574 U.S. biotechnology ventures founded during the period 1990 to 2003, and observed until 2005. Our sample brings together financial performance of these ventures as well as the investments they received, and a full history of their publications and patents. Venture Economics collects the data using a variety of sources, including the investment banking community, industry associations, or surveys of general partners and their portfolio companies. This database is widely used in previous research (Dushnitsky & Lenox, 2005a, 2005b; Gompers, 1995; Guler & Guillén, 2010; Sorenson & Stuart, 2001).

Biotechnology is an ideal setting to test our hypotheses. Being high-technology, innovation is valuable and ventures have a general desire to increase their innovative outcomes; as a result, patents and publications are good measures of innovation in this industry (Rothaermel & Thursby, 2007; Stuart *et al.*,

⁴ Source: Novartis website, <http://www.novartisventurefunds.com/index.php?id=234> (accessed Jan 17, 2012).

1999; Zucker *et al.*, 2002), Moreover, critical developments in the industry are strongly rooted in advancement of basic research, yet also require additional progress through applied research (e.g., Gittelman & Kogut, 2003; Huang & Murray, 2009; Lim, 2004). Finally, since innovation is costly, they rely heavily on external funding from corporate and independent VCs.

The main goal of this paper is to assess the effects on the innovation strategies of CVCs relative to VCs. To establish a baseline for comparison, we restrict the sample to those ventures that are VC-backed, and then analyze the effect of being CVC-backed. Each venture is observed since founding and until 2005, and they drop from the sample only in case of bankruptcy or acquisition. The rationale to close the window in 2005 stems from the time lag between filing and publication of patents. Collected in 2011, a six year lag is roughly the mean lag (4 years) plus one standard deviation (2 years), increasing our confidence that we observe most of the patents published by the ventures in our sample.⁵ Table 1 shows the distribution of founding years over the period of observation, generally increasing until the peak of the financial bubble in 2000, and drastically decreasing right afterwards.

[Table 1 about here]

Empirical Strategy

The main econometric challenge of the paper is that CVCs choose the startups they fund. In fact, both corporate and independent VCs seek to invest in inherently innovative startups (Amit *et al.*, 1990; Eckhardt *et al.*, 2006; Sørensen, 2007), suggesting that the superior innovation outcome may be, at least in part, due to a selection effect. Because the focus of the paper is on the treatment effect of CVCs, it is critical to devise an identification strategy that addresses how CVCs select the ventures.

First we estimate a set of two-stage analyses that seeks to separate the selection from the treatment effects. Because in the first stage it is important to include exogenous variables that meet the exclusion restriction, we conducted an extensive search of the recent literature of corporate finance.

⁵ Note that we should only be concerned with the right tail of the distribution. Just as a reference, if the distribution were normal, this lag of mean+sd would cover roughly 85% of the patents.

Berger et al. (2005) instrument the selection of a bank with the availability of credit in a particular geographical area, and building on their paper, Bottazzi et al. (2008) instrument the experience of the investor with the local availability of investor experience. Likewise, Hellmann et al. (2008) utilize a combination of geographic availability with temporal availability of investors. Following a different approach Faulkender and Petersen (2006) utilize different measures of investor visibility and information availability, because the more visible firms are more likely to be selected, and those with more public information available are easier to be researched.

We need an instrument that is correlated with the investment of a CVC firm, but which does not lead to higher patents or publications of the venture. Building on Berger et al. (2005) and Bottazzi et al. (2008), we measure the availability of CVC investment for a particular type of biotech and also for a particular time. The former was calculated as the proportion of biotechnology ventures in a particular biotechnology field that obtain CVC funding. We also exploit the geographical distance between the investors and the biotechnology ventures. Past research has shown that independent VCs tend to invest locally (Sorenson & Stuart, 2001); CVC parents, however, choose a location for strategic considerations, and therefore may invest in entrepreneurial ventures that are located farther away from their main business. We expect that greater geographical distance between the venture and the investor will be associated with CVCs. It is plausible that distance mitigates the potential effect of the venture capitalists on the patents and publications; yet the direction of the effect would be opposite to the direction of the selection. Finally, following the specification by Dushnitsky and Shaver (2009), we also include an estimate of CVC size and the degree to which the CVC or the VC have industry experience.

We estimate the two-stage models in the cross-section formed by last year of observation for each of the ventures, which is when the information is more complete. Note that with count dependent variables it is not possible to implement a panel-data two-stage model. We estimate two different specifications: a treatment-effects model and a structural Poisson model. The former jointly estimates by maximum-likelihood a probit regression on the first stage, and an OLS regression on the second stage.

The latter estimates the same first stage regression, and a Poisson regression on the second stage. We include the residuals of the first stage on the second stage, calculating the correct standard errors using bootstrap. Note that by including the residuals, the Poisson is robust to overdispersion (Cameron & Trivedi, 2009: 592). Finally, we estimate the effect on the change in patents and change in publications, comparing the yearly patent and publication output at the time of investment by the VC and three years afterwards, and estimating a treatment-effects regression. Because the independent variables are 0 before the CVC enters, and 1 thereafter, it captures the change in the yearly patenting or publishing outcomes. As an additional robustness check, we also perform univariate analyses at the time of selection and four years afterwards, finding the same results. While each econometric approach has unique advantages, we further emphasize that our results are mainly consistent across all approaches.

The main strength of the two-stage models is that they better identify the selection and treatment effects. Yet they only allow for a cross-sectional analysis of count dependent variables, and they can only test the presence or absence of CVC, but cannot accommodate a more complex test of the industry overlap of such CVC.⁶ In order to test these issues, we specify fixed-effects Poisson models, estimated through quasi-maximum-likelihood, which is robust to overdispersion and to venture fixed-effects (Wooldridge, 1997). Robust standard errors were calculated using the `xtpqml` Stata command (Simcoe, 2007). Within the limits of the statistical technique, we control for different sources of endogeneity: a) including fixed-effects controls for all time-invariant sources of selection, such as the characteristics of the founding team, or the location of the venture; and b) to estimate publications (patents), we control for the lagged flow of patents (publications), which co-vary with the quality of the scientific team, and the research resources in general, hence reducing the concern with endogeneity in this set of regressions.

In addition, the dependent variables and the main independent variables are defined such that we can better identify the treatment and selection effects. By using a flow rather than a stock measure of output (namely, focusing on annual patent output rather than aggregate stock of patents), we are able to

⁶ The probit model in the first stage can estimate the presence/absence of CVC, but not also different CVC types.

better identify the post-investment nurturing effect. Also, the main independent variable is 0 until the CVC enters, and 1 thereafter, hence estimating the change from pre- to post- investment.

Variable definitions

Dependent variables

$Patents_{i,t}$ is a count of patents⁷ for venture i and year t (flow variable). The flow of patents per year is a common measure of innovative outcomes (e.g., Ahuja & Katila, 2001; Cockburn *et al.*, 2002). With the help of several research assistants, we hand-collected patent information from the United States Patent and Trademark Office (U.S.P.T.O.), matching the biotechnology startup in the sample to the assignee of the patent. The matching took into consideration the location of the startup as established in the patent, checking whether the venture had research labs in other locations when necessary, and comparing the inventors across different patents to ensure the accuracy of the matching. We only included published patents, but used the date of application, as it is customary in the literature.

$Publications_{i,t}$ is a count of scientific publications for venture i and year t (flow variable), which is a typical measure of basic science on past research (e.g., Agrawal & Henderson, 2002; Azoulay *et al.*, 2009). We used the Web of Knowledge (formerly ISI) Database, from Thomson, hand-collecting those publications such that the focal venture is listed as the affiliation of one of the authors, and following the same matching criteria we used for patents. This database is widely used in prior work (Azoulay *et al.*, 2009; Cockburn & Henderson, 1998; Gittelman & Kogut, 2003; Goldfarb, 2008), and it has two features that suit our research question: it imposes quality filters to the journals included in their list, and unlike more specialized databases, it covers a wide array of disciplines. Less depth in the number of journals included allows us to have more comparable publications in terms of quality. Greater scope in the number

⁷ We chose to estimate the count of patents rather than the citations because our arguments are not related to the quality of the patent, but to the level of outcome in itself. The number of citations varies with the patent examiner additions, and with the traction of a particular field of research at a given point in time (e.g. monoclonal antibodies vs. stem cells). Since our theory does not speak to these choices we prefer to use a more conservative measure.

of journals included is an attractive feature for biotechnology research, which is a highly interdisciplinary area which draws from biology to computer science.

Independent variables and controls

$CVC_{i,t-1}$ is an indicator of whether venture i was CVC-backed in $t-1$. The variable is 0 until a CVC invests in the venture, and 1 thereafter. This is the main variable of interest in hypotheses 1 and 3.

$CVC\ Industry\ Overlap_{i,t-1}$ and $CVC\ No\ Overlap_{i,t-1}$ breaks the information from $CVC_{i,t-1}$ into two indicator variables. The former measure takes the value of 1 when there is a CVC investor, and that CVC parent firm operates in the same industry niche as the venture (as measured by a four-digit SIC code). The latter measure takes the value of 1 when there is a CVC investor, and the CVC–venture pair exhibit no industry-niche overlap. Industry overlap is defined following Dushnitsky and Shaver (2009); for ventures, we followed the Venture Economics Industry Classification (VEIC) and matched to the SIC classification using Dushnitsky’s VEIC_SIC concordance. We compare the industry that defines the primary operations of the investor with the industry of venture as defined by this concordance. These are the two main independent variables used to test hypotheses 2 and 4.

$VentureAge_{i,t-1}$ measures the number of years since the venture was founded. This variable proxies for the growth of the startup, that enables it to increase the patent and publication output.

First-step regressors

The first stage estimates the probability of CVC_i . In addition to $VentureAge_{i,t-1}$, we include the following additional variables:

$CVC\ Availability\ (Type)_i$ and $CVC\ Availability\ (Time)_i$ measure the percentage of biotechnology ventures that are CVC-backed, by type and by year, respectively. We use our sample as the market of reference. We measure the type of biotechnology using VentureXpert’s VEIC classification, at the two-digit level.

Geographical Distance_i measures the geographical distance between the investor and the venture. The variable takes lower values when the investor is closer to the venture (i.e., same economic area, same state, or same country). We follow the agglomeration literature (Alcácer & Zhao, 2011) and use the Bureau of Economic Analysis definition of economic areas (2004 classification), which is based on commuting distances. Hence, we define the closest distance as the same economic area. Note that when there is more than one investor, we utilize the maximum distance; results are robust to using the average or the median.

InvestorBiotechExperience_i measures the extent to which independent and corporate VCs are specialized in biotechnology, and proxies the degree of industry-niche overlap with the past portfolio of investments. For each investor we calculate the number of biotechnology investments in the past 15 years over the total number of investments. Because investors syndicate to build on each other's strengths (Brander *et al.*, 2002), we take the maximum of these ratios when there is more than one investor in the syndicate.

CVCSize_i measures the size (defined as total sales) of the CVC investor relative to the median size of their respective industry niches along the period of analysis. When more than one CVC investor was present, we averaged the relative size, but results were robust when considering the maximum.

VentureQuality_i measures whether the venture went public during the window of observation, building on previous literature that shows that an IPO is a testimony of the underlying quality of the venture (Gompers & Lerner, 1998).

RESULTS

Descriptive Statistics and Univariate Analyses

We present the descriptive statistics both for the cross section at the time of the last observation (table 2) and for the panel data (table 3). There are 574 ventures, and 4,091 venture-years, respectively. On average, ventures in the sample patent about 2.60 patents and 3.4 publications per year (table 3). In

general, those ventures that patent more, also publish more (the correlation is positive and significant, close to 45%). Note that because the sample was defined as VC-backed ventures, the percentage of CVC-backing is higher than in the population of startups. Roughly one third of the startups in the sample are funded by a CVC (table 2), corresponding to 21% of the venture-years (table 3). Consistent with previous findings (Dushnitsky & Shaver, 2009), most CVCs do not share industry niche with the ventures in the portfolio; indeed, roughly 4 out of 5 CVCs in the sample are in a different industry niche.

[Tables 2 and 3 about here]

Before moving to a multivariate framework, we conduct a univariate analysis of patents and publications for VC and CVC-backed ventures. On table 4 we divide the ventures into low/high patents per year, and into low/high publications per year. Note that the median patent and publication level is calculated for the cohort of ventures; that is, even though CVC firms tend to enter later in the life of the venture, the median is calculated for the corresponding age cohort, and so the table factors in the potential increase.

Panel A calculates the percentage of VC- and CVC-backed ventures in each of the four categories at the time of investment by the VC or the CVC (on average at year 1 and 3 respectively). Univariate analyses show that more than half the times, VCs choose ventures that are in the low/low category. According to the expectations, CVCs seem to select ventures that are, on average, more innovative: about a third are in the low/low category, but 30% are in the high/high/category, and 25% are high in publications.

Panel B calculates the same percentages but four years after the investment by the VC and the CVC. Interestingly, again about half of the VC investments continue to be on the low/low category. That is, VCs seem to maintain the status quo to a certain extent. CVC-backed ventures exhibit a change from investment: the percentage of ventures on the low/low category is slightly reduced (from one third to one quarter), but more importantly the percentage in the high/high category rises from 30% to 46%. In

essence, even though CVC firms did select the most innovative ventures, they seem to nurture them to become even more innovative.

To further explore this issue, on panel C we present the change in patents and publications per year, comparing the flow measures at the time of investment and the flow measures four years after investment. By comparing the flow measures at two points in time, rather than the average rate of change, we are able to assess the change in the trend. Consistent with the previous panel, more than half of VC-backed ventures are in the low/low category, and only 14% increased both their patenting and publication outcomes. In contrast, 31% of CVC-backed ventures experienced an increase in patents and publications.

[Table 4 about here]

Overall, the univariate analyses on table 4 support the thesis that CVCs not just select more innovative ventures, but they nurture their innovative activities to help them increase their outcomes. In contrast, VCs seem to select startups that are less innovative, consistent with the predictions of Amit et al. (1990), and they don't seem to have such a marked effect on nurturing them. In what follows, we seek to identify the selection and treatment effects using structural models.

Structural Models and Panel Data

The main econometric challenge of the paper is to assess if there is a treatment effect of CVC beyond the selection effect. First, we analyze the results of two-step structural models that seek to identify the treatment and selection effects (tables 5 and 6). Then, after assessing that there is a treatment effect, we proceed to a more fine-grained analysis of it (table 7).

On table 5 we show the results of structural-models of the flow of publications in the cross-section composed by the last observation for each venture. The first stage for all four models is a probit that estimates the presence of CVC. The second stage is an OLS estimated by maximum likelihood (models 5.1 and 5.2), or a Poisson which includes the residuals of the first stage and is estimated by bootstrap (models 5.3 and 5.4). The estimates for the first stage are robust throughout the four

specifications. Interestingly, the availability of CVC both by type of biotech and by time reduces the likelihood of a CVC, despite the positive correlation, which may be suggesting a crowding-out effect. The results for other variables are broadly consistent with those in Dushnitsky and Shaver's (2009). It is more likely that a CVC will join if the *Investor Biotech Experience* is high, and if the CVC is big relative to its competitors. Contrary to the expectations, distance increases the likelihood of the CVC joining. Since the distance is defined for both CVC and VC, this would be consistent with the VC being already geographically close to the startup, diminishing the need for more investors in the area. As expected, venture characteristics also affect the selection process, such that older ventures and those with greater quality have a greater chance of attracting a CVC.

The results for the second stage are robust throughout models and suggest that there is a positive effect of CVC on both publications and patents above and beyond selection. As expected, though, there is a selection effect. On models 5.1 and 5.2, the test of independent of equations is rejected, and on models 5.3 and 5.4 the residuals of the first stage are significant. However, after selection is accounted for, there is still a remaining effect of CVC on both patents and publications. This treatment effect is also economically significance: the presence of a CVC increases publications by 107% (model 5.3), and patents by 139% (model 5.4). Overall, these results yield support for hypothesis 1 and for hypothesis 3.a: there is a positive, and not a negative, effect of CVC on patents, above and beyond the effect of VC-backing.

[Table 6 about here]

On table 6 we present structural-models for the change in the flow of patents and of publications, calculated as the difference between the patents (publications) in the year of investment and the patents (publications) three years after. This difference is a continuous variable, which is positive when venture is patenting (publishing) at a higher per-year rate than when the venture was selected, zero when there is no change, and negative when the yearly outcomes are lower. The year of investment is defined as the year

the CVC invested, or if the venture is not CVC-backed, the year the VC invested. The results are broadly consistent with those of table 5: even after controlling for selection, CVC firms lead to a higher rate of publications per year. The same effect is true for patents, though it is only marginally significant.

Overall, the results from tables 5 and 6 show there is a treatment effect of CVC on publications and patents above and beyond the selection effect, in support of hypotheses 1 and 3.a. We turn now to present a more fine-grained analysis of this treatment effect, in a panel data regression framework, and controlling for selection as much as the technique allows.

Table 7 presents the fixed-effects Poisson regressions, estimated by quasi-maximum-likelihood.⁸ All these models include venture and year fixed-effects, and control for *Venture_Age*. Model 7.1 tests the effect of CVC_{t-1} investment on *Publications*, measuring the differential effect between CVC-backed and only VC-backed (hypothesis 1). The effect is positive, statistically significant, and economically relevant. In the years after the CVC joins the syndicate, the yearly publication output increases by 59%. In other words, ventures that are backed by a CVC produce nearly 60% more publications than those that don't.

[Table 7 about here]

Model 7.2 tests separately the differential effects of *CVC_Industry_Overlap* and *CVC_No_Overlap* versus being only VC-backed, to analyze whether the two effects are positive and significant or not. In support of hypothesis 2, both coefficients are positive and statistically significant. The estimated effect of having a CVC in the same industry niche is a 90% increase in publications, while the effect of a CVC in a different industry niche is of 55%. While big in magnitude, this difference is only marginally significant: a one-sided test of CVCs in the same industry niche having a greater effect on

⁸ Fixed-effects models estimate the within-venture variation, and as a result all ventures with only one observation or with no change in the dependent variable drop. Hence, the number of observations is lower than in tables 2 and 3. In unreported analyses we compared the sub-samples used in the patents and publications regressions finding that: a) the sub-samples used in the patents and publications regressions have significantly more patents and more publications on average, which is explained by the fact that ventures with zero patents and zero publications throughout the period of analysis dropped in these regressions; and b) there are no significant differences between sub-sample used in the patent models and the one used in the publication models.

publications than in different industry niche yields a 6% significance. However, this is a conservative test, because the fixed-effects and the partial likelihood estimation all increase the standard errors.

Model 7.3 tests the effect of CVC_{t-1} investment on *Patents* (hypotheses 3a and 3b). The effect of *CVC* on *Patents* is positive and significant, yielding support for hypothesis 3a. The effect is economically relevant, with a 50% increase in the yearly patent output after the *CVC* joins the investment syndicate. Model 7.4 separates this effect into *CVCs* in the same industry niche, and *CVCs* in a different industry niche. In support of hypothesis 4, both effects are positive and significant. Unlike in the case of publications, however, we find that the effect is very close: 62% increase in patents if the industry niche is the same, compared to 50% in different industry niche.

Jointly considered, the results in models 7.2 and 7.4 show that *CVCs* in different industry niche foster both publications and patents similarly. And while *CVCs* in the same industry niche as the venture foster both publications and patents, there seems to be a greater emphasis on publications than on patents. This may suggest that there is a “division of labor”, where same-industry ventures are pushed to do more publications than patents.

To further analyze this issue, we estimate how publications turn into patents, and whether *CVC* firms affect the rate at which this change happens. Departing from the model in Gallasso and Simcoe (2010), we first estimate the flow of publications, and the direct effect of *CVC* on publications. Then, we estimate the flow of patents, and the effect of *CVC*, publications, and the interaction of both, to capture how *CVCs* affect the extent to which publications increase the productivity of patents. In all these regressions we use two-year lags (Dushnitsky & Lenox, 2005b), rather than the standard one-year lag, to allow for sufficient time for the effects to develop.

The two first models on table 8 test the effect of *CVC* on publications and patents. We find that *CVC* parent firms foster the number of publications, and of patents, but we do not find evidence of an indirect effect of *CVC* on patents through publications (model 8.1). However, when we separate *CVC*

into those that share the industry niche with the venture and those that don't, the results are strikingly different (model 8.2). Those CVCs in the same industry niche foster publications more than CVCs in different industry niche, though both effects are positive (model 8.3). And while those CVCs in different industry niche foster patents, they don't necessarily foster how publications turn into patents (model 8.4). In contrast, CVCs in the same industry niche don't have a direct effect on patents, but they do have an indirect effect through publications (model 8.4).

These results seem to suggest that when the CVC is in the same industry as the venture, there is an increase in the productivity that is consistent with greater resource complementarity. Yet, there seems to be no direct effect on patenting, which may suggest indeed there is a division of labor between the venture and the CVC, with the venture more focused on the upper part of the research value chain.

DISCUSSION AND CONCLUSION

This paper analyzes the effect of CVC investment, compared to VC investment, on two types of innovative outcomes of startups: scientific publications, as the outcome of basic research, and patents, as the outcome of applied research. We found that CVC-backing greatly increases the publication outcomes of the venture. We argue that with greater incentives to foster basic research, as a ticket of admission to applied research (Rosenberg, 1990), and with a greater pool of resources and knowledge (Acs *et al.*, 1997), CVC parent firms help the startups greatly increase their scientific discoveries. These effects are even stronger when the parent of the CVC and the venture operate in the same industry niche, because there are greater complementarities in the knowledge-base of the two firms.

The dynamics are very different when we analyze the effect of CVC on patents. While they foster patents above and beyond VCs, this is the outcome of two opposite effects. On one hand, CVC parent firms have resources and knowhow above and beyond those of VCs, and are therefore capable of nurturing the venture's applied research. And yet, these same resources and infrastructure provide an alternative avenue to the venture to profit from the innovation, avoiding the costly patenting process.

Notwithstanding, the corporation may also have incentives to expropriate the technology to commercialize it on its own. By distinguishing between CVCs in the same industry niche as the venture – where there are more incentives to internalize the innovation – and CVCs in a different industry niche, we conclude that both processes are operating simultaneously. Indeed, there seems to be a “division of labor” such that CVCs in the same-industry niche foster more basic research than applied research, then pushing the ventures they fund up in the research value chain.

Empirical studies in the entrepreneurship financing literature face the challenge of separating selection and nurturing effects. Specifically, the empirical challenge lies in the fact that both VCs and CVCs choose where to invest. Indeed, our results seem to support the idea that the latter select more innovative ventures than the former. However, the results consistently show that there is an effect beyond selection that indicates that CVCs in effect nurture the startups in their portfolio and allow them to innovate more. This increases our confidence that the results are not driven by selection only and, indeed, there is a nurturing effect once the ventures are selected.

The paper seeks to contribute to the CVC literature by showing that CVCs are not just an alternative source of financing. They provide entrepreneurial ventures with valuable resources that add to those provided by VCs, and allow them to increase the rate of innovation by an economically significant amount. Our results further suggest that when the venture and CVC pair operate in the same industry niche, the resources of the latter provide the venture with an alternative way to profit from their innovation. Yet, the corporation is also in a position to expropriate the technology developed by the venture. The effects of CVC on the innovation processes are, therefore, not neutral to the competition between the two, showing that this is a case where the knowledge sharing dynamics pointed out by the strategic alliance literature are aggravated.

We have also sought to contribute to the literature on basic vs. applied research, by analyzing the drivers of these two different types of innovation. Our results are consistent with previous findings, which

show that basic research leads to applied research, but not necessarily (Stern, 2004). Importantly, we find that not only do ventures have an incentive to do both applied and basic science (Rosenberg, 1990), but corporations also have an incentive to foster the basic research of the startups they fund. This suggests that they benefit in some way from this knowledge spillovers, and is consistent with the idea of corporate investing as a window into other technologies (Dushnitsky & Lenox, 2005b).

More research is needed to clarify some of these issues. Our data did not allow us to identify the different mechanisms by which startups with CVC investors from the same industry niche patent less. Future research could delve into this important issue, to further understand the influence of established corporations on startups' innovative processes. Our research is also limited by the analysis of just one industry: biotechnology. Even though focusing on this industry allowed us to net out alternative explanations, it raises the question of generalizability. Specifically, this is a field prone to the division of labor in research, where basic and applied research are highly intertwined, but this may not be the case in all high technology industries.

Our research has implications for ventures, CVCs and their parents, and for public policy. When seeking additional funding, entrepreneurial ventures should better understand the implications of being financed by an established corporation. In particular, they should evaluate the resources that the corporation may share with them, and the extent to which these resources are valuable for their innovation processes. Moreover, whether the venture is a competitor or whether they have a focus on basic vs. applied science are also important issues to consider.

Finally, given the innovation contribution of CVC-backing, policy makers should reward CVC investment in a similar manner to their support of venture capital funds. At this time of crises, when reactivating the innovation and the damaged entrepreneurial net is needed the most, and when individual investors are more risk averse than ever before, strengthening the investment of corporations may be one important step for the future of the economy.

Table 1. Sample distribution by year of founding

Year of founding	No. of Ventures: Total	No. of Ventures: CVC-backed
1990	19	5
1991	23	6
1992	45	17
1993	33	13
1994	38	13
1995	40	18
1996	42	12
1997	59	21
1998	51	16
1999	42	16
2000	62	19
2001	53	17
2002	35	15
2003	32	10
<i>All ventures</i>	<i>574</i>	<i>198</i>

Table 2. Descriptive statistics, cross-section (at the time of the last observation).

	Mean	s.e.	Min	Max	1	2	3	4	5	6	7	8	9
1. Patents	1.68	3.91	0	41									
2. Publications	3.83	8.91	0	141	.47								
3. CVC	0.35	0.48	0	1	.17	.18							
4. CVC Availability (Type)	0.37	0.06	0.17	0.63	-.01	.07	.14						
5. CVC Availability (Time)	0.33	0.06	0.02	0.36	.01	-.01	.05	-.01					
6. Geographical Distance	1.46	0.63	0	2	.19	.17	.38	.12	.08				
7. CVC_Size	1.87	4.20	0	15.5	.21	.18	.56	.04	.05	.26			
8. Investor_Biotech_Experience	0.45	0.30	0	1	.09	.11	.41	.19	.01	.41	.22		
9. Venture_Quality	0.20	0.40	0	1	.34	.41	.15	.09	.10	.18	.18	.13	
10. Venture_Age	6.13	3.43	0	14	.11	.24	.03	.06	.21	.12	-.01	-.03	.40

No. ventures = 574. Correlations 0.09 or greater are significant at 5%.

Table 3. Descriptive statistics, panel data.

	Mean	s.e.	Min	Max	1	2	3	4	5	6	7
1. Patents _t	2.59	8.08	0	245							
2. Publications _t	3.43	9.26	0	209	.44						
3. CVC _{t-1}	0.20	0.40	0	1	.11	.20					
4. CVC_Industry_Overlap _{t-1}	0.04	0.19	0	1	.01	.05	.39				
5. CVC_No_Overlap _{t-1}	0.16	0.37	0	1	.13	.20	.88	-.09			
6. Publications _{t-1}	2.92	8.71	0	209	.40	.90	.20	.05	.20		
7. Patents _{t-1}	2.42	7.99	0	245	.80	.49	.12	.01	.14	.46	
8. Venture_Age _{t-1}	3.89	3.18	0	14	.10	.26	.23	.08	.20	.30	.15

No. venture-years = 4,091 (no. ventures 574). Correlations 0.04 or greater are significant at 5%.

Table 4. Distribution of VC- and CVC-backed ventures.

Panel A. At time of investment by VC/CVC
(VC-backed only; CVC-backed)

	Publication Flow \leq median value	Publication Flow $>$ median value
Patent Flow \leq median value	(53%, 33%)	(11%, 25%)
Patent Flow $>$ median value	(24%, 12%)	(12%, 30%)

No. of Ventures: 377 VC-backed, 198 CVC-backed.

At time of investment by VC: Age median=1, Patent Flow median=0, Publication Flow Median=0.

At time of investment by CVC: Age median=3, Patent Flow median=1, Publication Flow Median=0.

Panel B. Four years post investment by VC/CVC.
(VC-backed only; CVC-backed)

	Publication Flow \leq median value	Publication Flow $>$ median value
Patent Flow \leq median value	(48%, 24%)	(19%, 19%)
Patent Flow $>$ median value	(13%, 10%)	(20%, 46%)

No. of Ventures: 230 VC-backed, 103 CVC-backed.

4 years post-VC investment: Age median=5, Patent Flow median=1, Publication Flow Median=1.

4 years post-CVC investment: Age median=6, Patent Flow median=1, Publication Flow Median=1.

Panel C. Change in patent and publication flows 4 years after investment by VC/CVC
(VC-backed only; CVC-backed)

	Δ Publication Flow \leq median value	Δ Publication Flow $>$ median value
Δ Patent Flow \leq median value	(54%, 20%)	(20%, 33%)
Δ Patent Flow $>$ median value	(12%, 16%)	(14%, 31%)

No. of Ventures: 230 VC-backed, 103 CVC-backed.

4 years post-VC investment: Age median=5, Δ Patent Flow median=1, Δ Publication Flow Median=1.

4 years post-CVC investment: Age median=6, Δ Patent Flow median=0, Δ Publication Flow Median=0.5.

For all ventures that are VC-backed only, we calculate the median number of patents and publications at the time of VC investment (generally at year 1). Likewise, we calculate the median for CVC-backed ventures, which are typically funded around year 3. Then, we calculate the proportion of VC-backed ventures that fall into each of the four cells, and the corresponding proportions for the CVC-backed ventures.

The number of observations on panels B and C drops because of right-censoring.

Table 5. Two-Stage Structural Models on Patents Flow and Publications Flow, at time of last observation of the data

	5.1	5.2	5.3	5.4
Model (estimation technique)	Treatment- Effects (Maximum Likelihood)	Treatment- Effects (Maximum Likelihood)	Two-step structural model (bootstrap)	Two-step structural model (bootstrap)
First Stage, DV	CVC	CVC	CVC	CVC
CVC Availability (Type)	-2.63** (0.86)	-2.80*** (0.80)	-2.78*** (0.82)	-2.78*** (0.82)
CVC Availability (Time)	-3.81*** (0.91)	-3.61*** (0.85)	-3.72*** (0.88)	-3.72*** (0.88)
Geographical Distance	0.53*** (0.11)	0.57*** (0.11)	0.53*** (0.15)	0.53*** (0.15)
CVC_Size ^a	0.23*** (0.05)	0.23*** (0.05)	0.23*** (0.03)	0.23*** (0.03)
Investor_Biotech_Experience	1.49*** (0.24)	1.39*** (0.25)	1.52*** (0.25)	1.52*** (0.25)
Venture_Quality	0.12 (0.21)	0.14 (0.20)	0.03 (0.19)	0.03 (0.19)
Age ^b	-0.00 (0.02)	-0.01 (0.02)	-0.00 (0.02)	-0.00 (0.02)
Second Stage, DV	Publications	Patents	Publications	Patents
CVC [H1, H3]	3.14** (0.99)	1.70** (0.59)	1.07*** (0.27)	1.39*** (0.34)
Patents ^a	9.60* (4.00)		0.69*** (0.19)	
Publications ^a		1.92*** (0.21)		0.22 (0.15)
Age ^b	0.50*** (0.10)	0.01 (0.04)	0.15*** (0.02)	0.04 (0.03)
Constant	-2.46** (0.92)	0.30 (0.32)	-0.51* (0.23)	-0.54* (0.26)
Residuals First Stage			-0.31** (0.11)	-0.54*** (0.15)
No. Venture-Years	572	572	572	572
Wald test (H ₀ : independence)	2.93†	8.37**		

a Linearly transformed for ease of interpretation. Unit: 10 patents, 10 publications; CVC_Size was divided by 100.

b Winsorized (for convergence). Venture_Aget ≥13 is assigned a value of 13.

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Table 6. Treatment-effects models on the change in patent and publication flows: from t, at the time of the investment by the VC or CVC, to t+3.

Model (estimation technique)	6.1 Treatment-Effects (Maximum Likelihood)	6.2 Treatment- Effects (Maximum Likelihood)
First Stage, DV	CVC	CVC
CVC Availability (Type)	-4.71*** (0.97)	-3.68* (1.44)
CVC Availability (Time)	-2.75** (1.04)	-2.44** (0.83)
Geographical Distance	0.27* (0.12)	0.32** (0.12)
CVC_Size ^a	0.30*** (0.08)	0.28** (0.10)
Investor_Biotech_Experience	1.64*** (0.27)	0.92† (0.51)
Venture_Quality	-0.16 (0.22)	-0.01 (0.16)
Age ^b	0.10** (0.04)	0.08† (0.04)
Second Stage, DV	ΔPublications	ΔPatents
CVC [H1, H3]	2.26* (0.89)	5.16† (3.01)
ΔPatents ^a	0.18 (0.15)	
ΔPublications ^a		0.35† (0.19)
Age ^b	-0.32** (0.11)	-0.17 (0.11)
Constant	2.67*** (0.57)	-0.52 (1.03)
No. Venture-Years ^c	420	420
Wald test (H ₀ : independence)	2.01	23.03***

^a Linearly transformed for ease of interpretation. Unit: 10 patents, 10 publications; CVC_Size was divided by 100.

^b Winsorized (for convergence). Venture_Aget ≥13 is assigned a value of 13.

^c If the venture is CVC-backed, the investment reference is CVC; if not, then the reference is VC.

Attrition is due to right censoring.

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, †p<0.10

Table 7. Poisson Panel Fixed-Effects regression on Patents and on Publications, estimated by quasi-maximum-likelihood

Model	7.1	7.2	7.3	7.4
Dependent Variable	Publications	Publications	Patents	Patents
CVC _{t-1} [H1, H3]	0.59*** (0.10)		0.49*** (0.12)	
CVC_Industry_Overlap _{t-1} [H2a,H4a]		0.90*** (0.23)		0.62* (0.27)
CVC_No_Overlap _{t-1} [H2b,H4b]		0.55*** (0.11)		0.50*** (0.13)
Patents _{t-1} ^a	0.05 (0.04)	0.05 (0.04)		
Publications _{t-1} ^a			0.02 (0.01)	0.02 (0.01)
Venture_Age _{t-1} ^b	0.34* (0.15)	0.33* (0.15)	0.44 (0.33)	0.44 (0.33)
Venture fixed-effects	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
No.venture-years	3,391	3,295	3,471	3,380
No.ventures	445	431	448	436

Attrition in the fixed-effects models is due to: a) ventures with only one venture-year, or b) ventures with no change in Publications (Patents) drop from Publications (Patents) regressions. There are missing data in the CVC_SIC_Overlap and CVC_No_Overlap variables.

a Linearly transformed for ease of interpretation. Unit: 10 publications or 10 patents, respectively.

b Winsorized (for convergence). Venture_Age_t ≥ 13 is assigned a value of 13.

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Table 8. Poisson Panel Fixed-Effects regression on Patents and on Publications, estimated by quasi-maximum-likelihood

Model	8.1	8.2	8.3	8.4
Dependent Variable	Publications	Patents	Publications	Patents
CVC _{t-2}	0.41*** (0.11)	0.50*** (0.11)		
CVC _{t-2} * Publications _{t-2}		-0.00 (0.01)		
CVC_Industry_Overlap _{t-2}			0.80*** (0.18)	0.39 (0.29)
CVC_No_Overlap _{t-2}			0.37** (0.12)	0.51*** (0.12)
<i>Test (Chi²₁)</i>			4.67*	0.17
CVC_Industry_Overlap _{t-2} * Publications _{t-2}				0.04* (0.02)
CVC_No_Overlap _{t-2} * Publications _{t-2}				-0.00 (0.01)
<i>Test (Chi²₁)</i>				6.87**
Publications _{t-2}		0.01 (0.01)		0.01 (0.01)
Venture_Age _{t-2}	0.27† (0.15)	0.32 (0.30)	0.27† (0.15)	0.31 (0.30)
Venture fixed-effects	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
No.venture-years	2,908	2,955	2,827	2,876
No.ventures	426	424	413	412

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

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