Venture Capitalists in Mature Public Firms

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ABSTRACT

Using detailed hand-collected data on the backgrounds of board members of S&P companies we show that venture capitalists (VCs) play an important role in mature public firms long after their initial public offering (IPO). Almost one-third of mature public companies have at least one VC on their board. Their presence is not limited to mature companies that were VC-backed at the time of their IPO – over one-third of mature firms with VC directors were not VC-backed at the time of their IPO. Using an instrumental variables approach, we show that the presence of VCs has a substantial effect on the investment policies of mature firms. VCs have a significant positive effect on the research and development (R&D) intensity and on the innovation output of mature public firms. In addition, VC directors are positively related to the acquisition of VC-backed entrepreneurial firms, firm investment in corporate venture capital (CVC) and on the frequency of joint ventures and strategic alliances with other VC-backed firms. Thus, in addition to their function as providers of finance, monitoring and advice for small private firms, VCs play a significant role in mature public firms by promoting innovation activity and facilitating deals between these firms and other VC-backed entrepreneurial start-ups. Overall, our evidence illustrates a much broader role for VCs than has been established in the literature.

1. Introduction

Venture capitalists (VCs) have long been recognized as an important source of capital to meet the financing needs of entrepreneurs. A broad literature documents the importance of VCs in the financing and growth of small and private entrepreneurial firms. VCs provide advice and support to small entrepreneurial start-ups (Gompers (1995) and Lerner (1995)), help with the professionalization of the management team (Hellmann and Puri (2002)), exercise monitoring and corporate governance (Kaplan and Stromberg (2003) and (2004), Lerner (1994)), and foster innovation (Hellmann and Puri (2000) and Kortum and Lerner (2000)).

Our understanding of the role of VCs beyond the initial growth stage of firms, is however, very limited. Much of the evidence on the role of VCs in public firms comes from studies at the time of their initial public offering (IPO). For example, Barry, Muscarella, Peavy and Vetsuypens (1990) find that IPO firms with higher quality VCs are less underpriced than IPO firms with lower quality VCs and argue this is due to monitoring and certification roles of higher quality VCs. Similar results are shown by Megginson and Weiss (1991) who study VC-backing and IPO underpricing. Baker and Gompers (2003) analyze the effect of VCs on board size and composition at the time of the IPO and show that VC-backed companies have better performing boards of directors and these boards are related to better post IPO performance. Brav and Gompers (1997) study the stock returns of IPO firms and show that VC-backed firms do not suffer from post IPO underperformance. Hochberg (2008) studies the role of VC-backing on the corporate governance of the firm right after its IPO and finds that VC-backed firms have lower earnings management, adopt better takeover defenses, and have more independent boards, audit committees and compensation committees. Although these papers focus on different dimensions of VCs' involvement in public companies, they all have one feature in common: they analyze the effects of VC involvement for newly public firms around the IPO. We are unaware of research on what role, if any, VCs perform in mature public companies beyond their IPO years.

We examine the role of VCs in mature public companies and show that VCs serve on public company boards long after their IPO. Based on hand-collected dataset on board members of S&P 1500 companies, we show that 30.5% of firms have directors with a background as a VC prior to their appointment on the board. For these companies, VC directors are not a remnant of their pre-IPO board composition since the median firm in our sample has been public for 17 years. Strikingly, the presence of VCs on the boards of these mature companies is also not a direct outcome of VC backing at the time these firms went public - 34.8% of firms in our sample with VC directors were not VC-backed at the time of their IPO. In addition, of the companies that were VC backed at the IPO, almost half of them have VC directors from a VC firm that is different from the one that backed the firm at the IPO. These patterns suggest that VCs play a role in mature companies that is not a direct outcome of their pre-IPO involvement in these companies.

We postulate that VC directors bring specific expertise to the board that affects firms' abilities to pursue certain types of investment policies. We focus on investment decisions, because unlike young start-ups where VCs play an important financing role, the mature firms in our sample have access to a broad range of financing options including public equity and debt markets. Given the experience of VCs in evaluating new products, technologies, and other innovation intensive activities, we argue that VC directors are likely to be particularly valuable for pursuing investments in such information specific and intangible assets.

We find broad support for this view. Having a VC director on the board is strongly linked to higher R&D expenditures and also appears to have a meaningful effect on innovation activity, measured by the number of patents the firm obtains as well as how impactful these patents are. In addition, having a VC director on the board of a mature firm increases the likelihood of the mature firm acquiring a VC-backed firm, to establish strategic alliances with other VC-backed firms and to undertake corporate venture capital (CVC) investment in VC-backed entrepreneurial start-ups. We find that the proportion of VC directors on the board of a mature firm is positively related to both the number of CVC investments and the magnitude of CVC investment the mature firm undertakes in VC-backed entrepreneurial start-ups. Chesbrough (2002) and Dushnitsky and Lenox (2005, 2006) argue that CVC investments and strategic alliances are an important source of innovation for mature firms. Robinson (2008) shows that strategic alliances are valuable for established firms for undertaking projects with high risk and growth potential. Thus, our results imply that an important benefit of VC directors for established firms is to increase firm investment in innovative and entrepreneurial start-ups through CVC.

An important concern in our tests is that VC directors may self-select themselves onto boards of R&D intensive and innovative firms since they may obtain benefits arising from enhanced personal visibility in the business world, generating more attractive exit channels for their investments in start-up firms, or from creating synergies with mature firms and the start-ups in their own portfolio. Alternatively, self selection may arise if VC directors are invited to serve on boards of mature public firms that are embarking on extensive R&D and innovation activities. In other words, the positive relation between VC directors and innovation intensity could be due to endogenous selection.

To separate such selection effects from treatment effects of VC directors, we employ an instrumental variable (IV) approach throughout the paper. We use the density of VC firms near a mature firm's headquarters as an instrument for the presence of VC directors in firms. The predicted effect of VC density on the presence of VC directors in public firms is economically significant: a 10% increase in the VC density variable in a given state increases the probability of a public firm in that state having a VC director on its board by 8.3%. This result is interesting in the context of recent work showing geography impacts ownership structure of firms (Coval and Moskowitz (1999)), access to financing (Becker (2007)), market valuations (Hong, Kubik, and Stein (2008)), shareholder composition (Ivkovich and Weisbenner (2005)) and dividend policy (Becker, Ivkovich and Weisbenner (2010)). Our paper suggests that geography matters for board composition as well. Firms headquartered in areas with a high density of VC firms are more likely to have VC directors on their boards, consistent with the intuition that the local supply of directors matters for the board composition of local firms. In closely related work, Chen, Gompers, Kovner and Lerner (2009) study the geographical concentration of VC firms and VC-financed firms, and find that VC firms that are located in concentrated areas of VC activity tend to perform better.

The estimates from our instrumental variables approach show that the impact of VC directors on the investment policy of mature firms is economically important. A 10% increase in the proportion of VC directors leads to a 7.1% increase in the R&D intensity of the firm. The economic effect of VC directors on the productivity of R&D is also substantial. A 10% increase in the proportion of VC directors results in 10.4% increase in the number of patents obtained by the firm, and 10.6% increase in the number of future citations received by the patents. Since innovation is one of the most significant engines of firm growth, these results suggest that having VC directors on a firm's board is an important mechanism for generating growth in mature companies. In recent work, Aghion, Van Reenen and Zingales (2009) document that institutional ownership in publicly traded companies is positively related to innovation output measured by cite-weighted patents. Our paper illustrates another channel through which corporate governance structure affects the nature of innovation in public companies.

The economic importance of VC directors on the acquisition strategy of the firm is also meaningful. A 10% increase in the proportion of VC directors translates into a 7.6% increase in the probability of the mature firm acquiring a VC-backed firm. Given that the unconditional probability of a mature firm acquiring a VC-backed firm is 14.9% in our sample, this effect is economically sizeable. Similarly, a 10% increase in the proportion of VC directors leads to 12.8% and 5.7% increase in the likelihood of the mature firm establishing a joint venture or a strategic alliance with a VC-backed firm, and undertaking a CVC investment in a VC-backed start-up respectively.

Overall, our paper provides new evidence that VCs' role in financing and promoting innovation and entrepreneurial activity is not limited to small private firms only. VCs also serve on the boards of mature public firms long time after their IPO and affect their R&D and innovation activity as well as their external growth through acquiring and forming strategic relationships with VC-backed entrepreneurial start-ups. Given that promoting innovation and identifying new growth opportunities is one of the most important challenges faced by mature firms, our results emphasize that mature firms benefit from the expertise, human capital and networks of VCs in order to become more innovative. Thus, VCs appear to have a much broader economic impact on the growth of companies than just their effect on younger and start-up ventures.

Finally, our paper is related to the literature on the optimal composition of corporate boards. We illustrate a specific channel through which board expertise affects a firm's investment policy. Though providing expertise has long been identified as important role of corporate boards (Fama and Jensen (1983)), much of the literature has focused on the monitoring role of directors. Prior work has focused how the financial expertise of bankers on the board affects financing arrangements (Guner, Malmendier and Tate (2008)) but our evidence suggests a wider role for board expertise.

The rest of the paper is organized as follows. Section 2 describes our sample and presents descriptive statistics of our sample. In Section 3, we analyze the patenting activity of our sample of firms, and in Section 4, we analyze the acquisition strategy of firms with VC directors. Section 5 investigates the R&D intensity and patenting output of our sample of firms, and their strategic investments in VC-backed firms in a multivariate setting. Section 6 concludes.

2. Data

Our director data come from Investor Responsibility Research Center (IRRC) which provides annual information on directors of S&P 1,500 firms from 1996 onwards. The IRRC database reports individual information for each director, such as their primary employment, committees they serve on, their board affiliation, shares held and total voting power. Since IRRC has detailed data on the primary employment of board members from 1998 on, our sample covers public U.S. companies from 1998 to 2006.

There are a total of 2,325 unique firms and 21,888 unique directors covered in IRRC database from 1998 to 2006. We exclude utility companies and financial companies from our sample since they operate in highly regulated industries. This restriction leaves us with a final sample of 1,839 firms and 16,911 directors, forming a panel dataset over nine years.[1]

We classify firms in the sample into two groups based on whether or not they have directors who have worked as venture capitalists in venture capital (VC) firms (denoted by *VC directors*). In order to identify the VC directors, we employ a two-step search as follows: In the first step, we search for keywords that might define a VC firm in four different data items provided by IRRC for each individual director.[2] The employment related data items that we search for are the primary company name, primary employment category, other employment title, and type of services for each director. If at least one of the keywords we search for is available in any of these data items, we record that director as a possible candidate for being a VC director. In the second step, we hand-collect biographical information from proxy statements on those board members identified as possible VC directors in the first step. Specifically, we obtain information about their professional backgrounds and check whether they work for VC firms. Using this second step, we identify 634 unique VC directors working in 516 different VC firms. We denote these as *VC directors* and the remaining directors as *non-VC directors*. Firms with at least one VC director on board are classified as *firms with VC directors* and firms with no VC director on board are classified as *firms without VC directors*.

Figure 1 shows the firms in our sample over the years, split into four groups based on the number of VC directors they have on their board. In each year from 1998 to 2006, 30.5% of the firms have at least one VC director on board, on average.

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[1] Our final dataset of directors includes 10,118 firm-years and 91,092 director-years.
[2] The keywords that we search for are: Venture, capital, partner, fund, investor, angel, finance, financial, and management.

In Panel A of Table 1, we report descriptive statistics for our sample firms. Firms with VC directors are on average younger, and they have been public for a shorter time period than firms with no VC directors.[3] However, even though they are comparatively younger, firms with VC directors are on average, 25.4 years old and have been public for almost 20 years. The median firm with VC directors has been public for 13 years.

We examine whether firms with VC directors were VC-backed at the time of their IPO. We define an indicator variable that takes the value of one for firms that were VC-backed at the time of their IPO, and zero otherwise.[4] This indicator variable has an average value of 0.65 for firms with VC directors and 0.32 for firms with no VC directors, implying that firms with VC directors are roughly twice as likely to have been VC-backed at the time of their IPO, compared to firms without VC directors. We find that 63.1% of our sample firms which were VC-backed at the time of their IPO have VC directors as mature public firms. Further evidence that the presence of a VC director does not arise automatically from VC backing at the IPO comes from firms which were not VC-backed at the IPO stage - 26.9% of these non-VC backed firms have VC directors as mature firms. In addition, being a VC backed firm during an IPO does not imply that these firms always retain VC directors when they become mature companies. Of the 63.1% of firms which were VC-backed at the IPO, only 33% of them have their original VCs as directors. In the remaining 30.1% of the firms, the VC directors are from different VC firms than the original VCs at the IPO stage. In other words, about half of the firms which were VC-backed at their IPO acquire VC directors from VC firms that are different from the original VCs backing the firm at the pre-IPO stage. These patterns are relevant for a number of reasons. First, they suggest that original VCs from the IPO stage can still be present in firms after a long period of time. Second, VCs' involvement in mature public firms is not necessarily an outcome of these firms being VC-backed at the IPO. Our data shows that it is

[3] The company founding dates are obtained from Jay R. Ritter's website, and are available for 43% of our sample firms. Data on IPO dates come from Securities Data Company (SDC)'s New Issues database starting from 1970 on. For firms that went public before 1970, we take the first listing date in CRSP as the IPO date.

[4] The data on VC backing at the time of the IPO come from SDC's New Issues database and are reported in SDC starting from year 1970 on. These data are available for 48% of our sample firms.

possible for a non-VC backed IPO firm to have VC directors later as a mature firm. It is also possible for a mature firm to gain VC directors who are different from the original VCs.

The average market value of firms with VC directors is $13.4 billion compared with $10.5 billion million for firms without VC directors, with the difference being statistically significant.[5] Although they are younger, firms with VC directors are larger than firms with no VC directors. Firms with VC directors also have a higher Tobin's Q of 2.47, on average, compared to firms with no VC directors which have a Tobin's Q of 2.0.

Panel B of Table 1 reports descriptive statistics for board characteristics for our sample firms. Of the 10,118 firm-year observations, 3,084 (30.48%) involve firms with VC directors on board and the remaining 7,034 (69.52%) involve firms with no VC directors on board. Both types of firms have similar board size with a mean and median board size of nine. For firms with VC directors, the average number of VC directors on board is 1.35, corresponding to 16.1% of the board size. Firms with VC directors have a greater proportion of independent directors on their board. We also find that 82% of VC directors are independent directors. VC directors serve on a greater number of boards than other type of directors, consistent with the intuition that their supply is scarce in the economy and/or their expertise is highly sought after by mature companies. Finally, VC directors have lower equity ownership in the firm and are younger than non-VC directors.

3. VC directors and innovation activity

Existing research shows that VCs help foster innovation activities in private and VC-backed firms. Hellmann and Puri (2000) present evidence that venture capital involvement helps speed the time to bring an innovation to market for start-up companies. Kortum and Lerner (2000) find that VC-backed firms are more likely to innovate and to obtain patents than non VC-backed firms. To understand whether

[5] The market value of firm is defined as total assets minus total equity plus market capitalization given by the number of shares outstanding times the share price.

VCs also play a similar role for mature firms, we analyze the R&D expenditures and the patenting activity of our sample firms and investigate whether the presence of VC directors on the board of mature firms is related to the R&D intensity and the patenting output of the firm.

Table 2 shows that firms with VC directors have greater R&D expenditures, both in dollar terms and relative to firm size than do firms without VC directors. For example, R&D expenditures to firm market value averages 2.4% for firms with VC directors and 1.4% for firms without VC directors, the difference being statistically significant at the 1% level.

Although R&D expenditure is a commonly used measure of how innovative a firm is, patents obtained by a firm have been shown to be a better measure for the research productivity of the firm (Trajtenberg (1990) and Griliches (1990)). Hence, we proceed with the analysis of the patents obtained by our sample firms. We use the patent database created by Hall, Jaffe and Trajtenberg (2001) and provided by the National Bureau of Economic Research (NBER). These data comprise detailed information on all U.S. patents granted between January 1963 and December 1999, all citations made to these patents between 1975 and 1999, and a broad match of these patents to Compustat firms.[6] Updates of the patents and citations data through 2006 and the match of all the patent assignees to Compustat firms are obtained from NBER Patent Data Project (PDP). The updated patent database makes it possible for us to analyze the innovation output of our sample of firms in terms of the patents they produce and citations they receive for the whole sample period from 1998 to 2006.

NBER records a patent only after it is granted, i.e. after it is approved by United States Patent and Trademark Office (USPTO), and this causes the patent data to suffer from a truncation problem. For example, the data on most of the patents filed in 2005 or 2006 are missing since the review process by the patent office takes on average two years (see Hall, Jaffe and Trajtenberg (2001)), and the patent data is available only until the end of 2006. This truncation problem is addressed in the PDP, and the patent and

[6] The original work by Hall, Jaffe and Trajtenberg (2001) covers patent data until the end of year 1999, which is then extended by Bronwyn H. Hall until the end of 2006.

citation numbers provided by PDP are corrected for truncation using the methodology as described by Hall, Jaffe and Trajtenberg (2001).

We analyze the number of patents produced by our sample firms as a measure of their R&D productivity. However, the simple count of patents on its own is not a sufficient measure for the technological or economical significance of the patents. Trajtenberg (1990) and Hall, Jaffe and Trajtenberg (2005) document that patent citations are a better measure of the value of innovations since they show a patent's influence on further research activities and its economical significance. Therefore, in addition to the number of patents, we also investigate the total number of citations and the number of citations received per patent for our sample firms.

Table 2 shows the summary statistics for the number of patents and citations for our sample firms. Firms with VC directors produce more patents compared to firms with no VC directors. More specifically, when we pool all available patent data for our sample period, we find that firms with VC directors produce on average 31 patents per year compared with 21 patents per year for firms with no VC directors, the difference being statistically significant at the 1% level. We also find that for the patents produced from 1998 to 2006, firms with VC directors receive 309 citations until the end of 2006 whereas firms without VC directors receive only 218 citations, the difference being statistically significant at the 1% level. Finally, we find that firms with VC directors receive on average nine citations per patent, whereas firms with no VC directors receive seven citations per patent, the difference being statistically significant at the 1% level. Overall, these results suggest that firms with VC directors appear not only more innovative in terms of their patenting ability, but they also have more influential and economically significant innovations as measured by the number of citations they receive on these patents.

4. VC directors and deals with VC-backed start-ups

Having a VC director on the board may expand the investment opportunity set of a mature firm by increasing its access to and information about VC-backed start-ups through the connections and the network of the VC director. Hochberg, Ljunqvist and Yu (2007) show that connections and networks are particularly important in the venture capital industry and VCs exploit their networks to help their portfolio companies succeed. In addition, they find that VC firms with more influential network positions generate significantly better performance. In this section, we examine whether having a VC director is related to the firm's transactions with other VC-backed entrepreneurial start-ups such as the acquisition of VC-backed firms, equity investment in external VC-backed start-ups (also known as CVC investment), and formation of business relationships with VC-backed firms through joint ventures (JV) and strategic alliances.

Our data on acquisition activity, JVs and strategic alliances come from Securities Data Company (SDC)'s Mergers and Acquisitions database and data on corporate venture backed (CVC) investment come from the VentureXpert database. Our sample of firms participated in 9,436 M&A transactions, 3,306 CVC investment rounds, 1,395 joint ventures and 6,637 strategic alliances from 1998 to 2006.

Panel A of Table 3 shows that firms with VC directors appear to exhibit a slightly lower level of M&A activity. On average, mature firms with VC directors engage in acquisitions amounting to 6.9% of firm value, compared to 7.6% for mature firms without VC directors. However, there is a sharp difference in the type of M&A targets that these two sets of firms pursue. Firms with VC directors are more likely to acquire other VC-backed firms. We find that 31.06% of the acquisition volume of firms with VC directors involves a VC-backed target whereas this percentage is only 16.57% for firms with no VC directors. In addition, target firms acquired by firms with VC directors exhibit greater R&D intensity. The R&D to firm value ratio averages 5.4% for targets acquired by firms with VC directors compared to 3.6% for targets of firms without VC directors.

There is a growing literature on the importance of CVC to promote the innovation output of mature and established firms (Dushnitsky and Lenox (2005, 2006) and Robinson (2008)). Hence, another channel by which VC directors might improve firm ability to invest in VC-backed start-ups through their networks and contacts. Consistent with this view, Panel B of Table 3 shows that firms with VC directors engage in much more CVC activity. They invest in 0.45 portfolio companies on average, compared to 0.27 companies for firms without VC directors and the size of the investment as a percentage of the firm's fund is also greater. In addition, the total amount of CVC investment managed by firms with VC directors averages 3% of their firm market value compared to 1% for firms without VC directors. These differences are significant at the 1% level. Thus, firms with VC directors invest in a greater number of VC-backed firms, make a greater amount of investment in each start-up, and exhibit a larger amount of total CVC investment than firms with no VC directors. Similarly, Panel C of Table 3 shows that firms with VC directors form a higher number of strategic alliances and JVs, and partner firms in these deals are more likely to be VC-backed companies.

One explanation for these results is that VC directors use their board membership at a mature firm to channel funding to the companies in their own portfolio. If this is the case, the higher investment in other VC backed firms might be reflective of an agency cost of having VC directors on the board rather than the pursuit of an efficient investment strategy by mature firms. To evaluate this, we collect data on all the partner companies in strategic alliances, JVs, and CVC deals as well as target companies in acquisitions, and examine the identity of the VC firms involved in these target companies. Strikingly, in only 3 .8% of the strategic alliance, JV and CVC deals does the VC director at the mature firm originate from the same VC firm that is also backing the target entity. Similarly, in only 3.3% of the acquisitions of VC-backed firms, the VC director at the mature firm comes from the VC firm backing the target firm in the acquisition. This suggests that the link between VCs presence in mature firms and their investment decisions is not driven by the motive of VC directors to generate exit opportunities for the start-up companies in their own portfolio.

5. Multivariate analysis

Our univariate findings show that mature firms with VC directors have greater R&D intensity and higher innovation output as measured by the number of patents produced. They also appear to participate in a greater number of deals involving other VC-backed firms. One potential explanation for these results is that VCs endogenously choose to serve on the boards of R&D intensive and innovative companies, because their association with such mature firms enhances their personal visibility and reputation that may be valuable in pursuing their own pipeline of start-up investments. Under this interpretation, the link between VC directors and mature firms' investment policies arises due to a selection effect rather than a treatment effect of VC directors. To separate selection from treatment effects of VC directors, we use an instrumental variable (IV) approach.

5.1. Instrumental variable approach

Our primary variable of interest is the *proportion of VC directors*, which measures the extent of VC presence on the board and is defined as the ratio of the number of VC directors on a board to the total number of board members. Identifying the effect of this primary variable on a firm's R&D intensity and innovation output is challenging due to the potential endogeneity of VC directorships in firms. To address this endogeneity issue, we employ an instrumental variables approach and develop a geographic instrument for the presence of VC directors on board in order to estimate the effect of VC directors in mature firms.

The construction of our instrument is based on the argument that venture capitalists working at VC firms located in a given geographical region are natural candidates for directors of local public firms in that region. Alam, Chen, Ciccotello and Ryan (2010) argue that having locally based directors is advantageous when a firm's assets tend to be intangible and when evaluating 'soft' information is important. To evaluate the validity of this argument, we collect data on the location of the headquarters

(HQs) of the public firms in our sample and the location of the HQs of their directors' primary firms.[7] We find that 40% of the VC directors in our sample hold board seats in public firms that are located in the same state as their primary firm where they work as VCs. This percentage is 30% for other types of directors on the board. In other words, compared to other types of directors, VC directors tend to hold board seats in firms located geographically closer to the VC firm they work for. Motivated by this observation, we define our instrument for the presence of VC directors in a firm as the density of VC firms near the firm's HQs. More specifically, *VC density* is defined as the ratio of the number of VC firms in a given state to the number of public firms headquartered in that state. We expect this variable to serve as an instrument for the supply of VC directors for a given mature firm.

In addition to our primary variable of interest, we include several firm-level control variables in all of our IV models. The main control variables are *firm size* defined as the natural logarithm of total assets, *Tobin's Q* defined as the ratio of the market value of the firm to the book value of the firm, *leverage* defined as interest bearing debt divided by operating assets, and *firm public age* defined as the natural logarithm of the number of years since the firm's IPO. In addition, we control for whether the firm was VC backed at the time of its IPO.

5.2. The validity of our instrument

An important concern with the instrumental variables estimation is that the estimators can be biased if the instrument exhibits only weak correlation with the endogenous regressor. Staiger and Stock (1997) formalize the definition of a weak instrument in the IV estimation and provide guidance to test whether or not a particular instrument is sufficiently correlated with the endogenous regressor. We follow their approach and run first stage regressions to test whether our VC density instrument is correlated with our endogenous variable given by the proportion of VC directors, after controlling for other exogenous variables.

[7] The location data come from Compustat for public firms and from VentureXpert for directors' primary firms if these firms are VC firms.

Another potential concern regarding our instrument is that an omitted variable may be driving the decision of both VC firms and innovative public firms to locate in same geographical areas. We address this concern in the multivariate models by controlling for state-level factors, such as the wealth and educational level in a state, which might affect the location choice of both public firms and VC firms. The wealth level in a state is proxied by *state per capita income*, and the educational level in a state is proxied by *state educational attainment*, defined as the percentage of the population aged 25 and over with a high school degree. These data are obtained from U.S. Census Bureau for each year in the sample period and for each U.S. state, and included as control variables in the first-stage regressions as well.

Table 4 shows the results of the first-stage regressions where we regress the proportion of VC directors on the VC density variable and other exogenous variables. We include year and industry fixed effects in all the models, and cluster standard errors at the firm level to correct for heteroskedasticity and correlation of errors within firms. Our main interest in these models is the t-statistics reported for our instrument. Models (1)-(5) show the ordinary least squares estimates, where the dependent variable is the proportion of VC directors on board. In all the models we employ, the estimated coefficient of the VC density variable turns out to be statistically significant at the 1% level, showing that the VC density in a state significantly predicts the proportion of VC directors in a public firm located in the same state. The effect of the VC density variable on the proportion of VC directors in a public firm is economically significant as well: Based on model (4) of Table 4, a 10% increase in the VC density in a given state increases the percentage of VC directors on boards of public firms in that state by 1.45%. Given that the mean percentage of VC directors in public firms is 4.91% in our sample, this effect is economically large.

In model (5) of Table 4, we include an additional indicator variable called *VC-backed at the time of IPO* that takes the value of one if the public firm was VC-backed at the time of its IPO and zero otherwise.[8] We include this variable to address the concern that the public firms in our sample that were

[8] The sample size in model (V) of Table IV drops considerably compared to other models since the VC backing data from SDC's New Issues database are limited to firms that go public from year 1970 onwards.

VC-backed at their IPO might still have their original VCs on board. As expected, the coefficient of this variable is positive and statistically significant at the 5% level. However, being VC-backed does not eliminate the significant effect of the VC density variable in explaining the proportion of VC directors on board. Model (5) of Table 4 also shows that larger firms, younger firms and firms with a higher Tobin's Q are more likely to have VC directors on board.

Staiger and Stock (1997) suggest that if the F-statistic on the instrument in the first stage regression is greater than ten, one can reject the null hypothesis that the instrument is weak. In all the models we employ in Table 4, the estimated coefficient of the VC density variable is statistically significant at the 1% level with a t-statistic is greater than 3.30, corresponding to an F-statistic greater than 10.9. This implies that our instrument is significantly correlated with the endogenous regressor, and suggests that we do not face a weak instrument problem in our IV models.[9]

Overall, the first-stage regressions show that VC density significantly predicts the proportion of VC directors on board even after controlling for firm- and state-level factors, suggesting its validity as an instrument in the IV models to investigate the effect of VC directors on mature firms.

5.3. VC directors and R&D expenditures and patenting activity of a mature firm

Our first set of regressions involves panel data estimates relating the R&D expenditures normalized by firm size to VC directors on the board and other firm characteristics. Table 5 presents the results. Models (1) and (2) show that the coefficient for the proportion of VC directors is positive and statistically significant at the 1% level, indicating that the greater the proportion of VC directors on board, the greater is the firm's R&D spending, after controlling for industry and year fixed effects. The positive relation between the proportion of VC directors and R&D intensity remains robust after controlling for

[9] We run other under-identification and weak-identification tests to check whether our instrument is significantly correlated with the endogenous regressor. Specifically, we find the Kleibergen and Paap (2006) Chi-squared statistic to test for under-identification and the Kleibergen and Paap (2006) F-statistic to test for weak-identification of the first stage regression model. The comparison of these statistics to critical values given in Stock and Yogo (2005) confirms that our model does not suffer from under- or weak-identification problems.

state-level factors in model (3). We get similar results in model (4) as well, which additionally includes the VC-backed indicator variable, which turns out to be insignificant in explaining the R&D intensity of our sample firms. The positive effect of VC directors on the R&D intensity of mature firms is economically significant. Based on model (4), a 10% increase in the proportion of VC directors leads to 7.6% increase in the R&D intensity of the firm.

To see whether our univariate result that firms with VC directors are more innovative as measured by their patenting output hold in our multivariate setting as well, we estimate Poisson maximum likelihood models to investigate the determinants of the number of patents produced and the number of citations obtained from these patents.

The patent related variables are adjusted for technology class and year effects before estimating the regressions as suggested by Hall, Jaffe and Trajtenberg (2001). Specifically, the number of patents is adjusted by dividing the number of patents obtained by a firm by the mean number of patents in the same cohort to which the patent belongs, where the cohorts are constructed for each year and technology class defined by USPTO.[10] Similar adjustments are made for the number of citations and the number of citations per patent as well. The adjusted numbers are then rounded to the nearest integer to be used as the dependent variables in the Poisson models.

Table 6 presents the estimates for the Poisson maximum likelihood models of the patenting activity for our sample firms, where proportion of VC directors is instrumented by the local VC density variable. As expected, the coefficient of the R&D intensity is positive and statistically significant at the 1% level in determining the number of patents, citations and citations excluding self-cites. The proportion of VC directors also turns out to be important in determining patenting activity. Its coefficient is positive and significant in all the models we employ. In terms of economic magnitude of this effect, 10% increase in the proportion of VC directors results in a 10.4% increase in the number of patents, and a 10.6%

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[10] The technology classes defined by USPTO are: computers and communications, drugs and medical, electrical and electronics, chemical, mechanical and others.

increase in the number of citations received by these patents. These results are related to the finding in Kortum and Lerner (2000) who show that increases in venture capital activity in an industry are associated with significantly higher patenting rates. While Kortum and Lerner (2000) look at VC funding in *private* firms in an industry, our results point to a complementary finding on the positive effect of VC directors on the innovation output of *mature public* firms.

5.4. VC directors and acquisitions of VC-backed firms

In this section, we investigate in a multivariate setting whether VC director presence on the board increases the probability of a mature firm of acquiring a VC-backed firm.

We employ IV models as before where we instrument the proportion of VC directors by the local VC density variable. First, we investigate the likelihood of the public firms in our sample acquire VC-backed firms. We estimate probit models where the dependent variable takes the value of one if the target firm is VC-backed and zero otherwise. Model (1) in Table 7 presents the results. The coefficient of the proportion of VC directors is positive and statistically significant at 5% level, implying that having VC directors on board increases a firm's likelihood of acquiring VC-backed target firms. The predicted effect of VC directors on the acquisition of VC-backed firms is economically important as well. A 10% increase in the proportion of VC directors translates into a 7.6% increase in the likelihood of acquiring a VC-backed firm.

In model (2) of Table 7, we estimate an IV regression where the dependent variable is the proportion of the total acquisition volume spent on the acquisition of VC-backed firms. We find that the higher the proportion of VC directors on the board, the higher is the proportion of the total acquisition volume involving VC-backed target firms. Economically, a 10% increase in the proportion of VC directors corresponds to a 12.2% increase in the volume of acquisition spending involving VC-backed target firms.

To understand whether VC directors have an impact on the acquisition of R&D intensive firms, we also estimate an IV regression model using the target firm's R&D intensity as our dependent variable.[11] As shown in Model (3) of Table 7 we find that the proportion of VC directors is positively related to the acquisition of firms with a greater R&D intensity.

5.5. VC directors and strategic investment in VC-backed firms

In addition to facilitating the acquisition of VC-backed firms, VC directors on the board of a mature firm might also play a role in establishing strategic relations with VC-backed firms or in undertaking equity investments in VC-backed firms. Consistent with this view, Lindsey (2008) shows firms sharing a common VC investor are more likely to form strategic alliances.

First, we investigate whether having VC directors on the board is positively related to the firms' joint venture and strategic alliance activity involving VC-backed start-ups. Models (1) and (2) in Table 8 present the estimates from the Poisson maximum likelihood models with the IV approach. The dependent variable in these models is the total number of JVs and strategic alliances for each firm and each year. The models include the usual control variables along with industry and year fixed effects. The coefficient of the proportion of VC directors is positive and statistically significant at the 1% level. This result suggests that firms with a higher proportion of VC directors engage in a greater number of JVs and strategic alliances, providing support for the VC directors' role as a facilitator for strategic relationships with other firms. We also examine whether having a VC director is related to the likelihood that the mature firm establishes a strategic business relation with a VC-backed firm. In model (3) of Table 8, we estimate a probit model for the probability of a public firm to form JVs and strategic alliances with VC-backed companies. The dependent variable takes the value of one if the partner firm is VC-backed and zero otherwise. The coefficient of the proportion of VC directors turns out to be positive and significant at the 5% level, implying that the higher the proportion of VC directors on board, the higher is the

[11] The sample size in model (IV) of Table VII drops considerably compared to other models since we are able to find the target firm's R&D only if the firm is public and also has a match in the Compustat database.

likelihood that the firm will form a JV or strategic alliance with another VC-backed firm. Economically, a 10% increase in the proportion of VC directors leads to a 12.8% increase in the likelihood of the mature firm establishing JVs or strategic alliances with VC-backed firms.

Finally, we examine the effect of VC directors on both the number and the amount of CVC investments in VC-backed start-ups in a multivariate IV setting. Model (4) in Table 8 shows probit estimates for the likelihood of the public firm undertaking a CVC investment, where the dependent variable takes the value of one if the public firm invests in a VC-backed start-up and zero otherwise. The coefficient on the proportion of VC directors is positive and statistically significant at the 1% level, indicating that VC directors have a significant positive effect on the mature firm undertaking CVC investments in start-ups. This effect is economically significant as well: a 10% increase in the proportion of VC directors leads to a 5.7% increase in the likelihood of a mature firm undertaking an equity investment in a start-up company. Models (5) and (6) present the estimates from the Poisson maximum likelihood models with the IV approach for the number of CVC investments in a VC-backed firm. The coefficient on the proportion of VC directors is positive and statistically significant at the 1% level, showing that VC directors lead the mature firm to undertake a greater the number of CVC investments in VC-backed firms. In addition, in model (7), we find that the presence of VC directors on board has a positive effect on the total amount of CVC investment in VC-backed firms as well.

Overall, our results on JVs, strategic alliances, and CVCs suggest that the VC directors play a significant role in expanding the investment opportunity set of the mature firms by facilitating strategic relationships of between these firms and entrepreneurial VC-backed firms. Business relations with such VC-backed firms could be one explanation for why VC directors appear to have a positive effect on the innovation output of mature firms. To the extent that VC directors have specialized expertise in evaluating investments in new technologies, their presence on the board serves as a channel to lower informational asymmetries faced by mature firms in investing in start-up firms, thereby allowing them to pursue innovation and growth oriented investment strategies.

6. Conclusions

This paper provides the first piece of evidence that VCs play an important role in mature public firms a long time after their IPO. This result is novel since current literature to date has focused primarily on the different roles VCs play in small and private companies. Our paper complements the findings on the importance of VCs for small and private start-ups by documenting that VCs provide expertise to mature public companies past their IPO stage. More specifically, our paper shows that VCs serve on the boards of mature public firms, and have an effect on the investment policies of such firms. Firms with VC directors exhibit a greater amount of R&D and innovation output in terms of their patenting activity, are more likely to acquire VC-backed firms, and more likely to establish business relationships with other VC-backed firms in the form of strategic alliances and joint ventures. In addition, they exhibit a greater amount of corporate venture capital investment in VC-backed entrepreneurial start-ups. These results illustrate a specific channel through which board composition affects corporate policies through the expertise of directors and imply that boards play a larger role than their monitoring function.

Overall, our paper suggests that, in addition to their role as providers of finance and advice for small and private firms, VCs play a significant role for mature public firms, even long time after the IPO stage, especially in promoting R&D and innovation activity in such firms. Thus, the effect of VCs appears to be much broader than is commonly thought.

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Figure 1

This figure shows the number of public firms available in the IRRC database from 1998 to 2006 excluding utility companies and financial companies. The firms are split into four groups according to the number of VC directors on board. Directors who are partners or executives of a venture capital firm are denoted as VC directors.

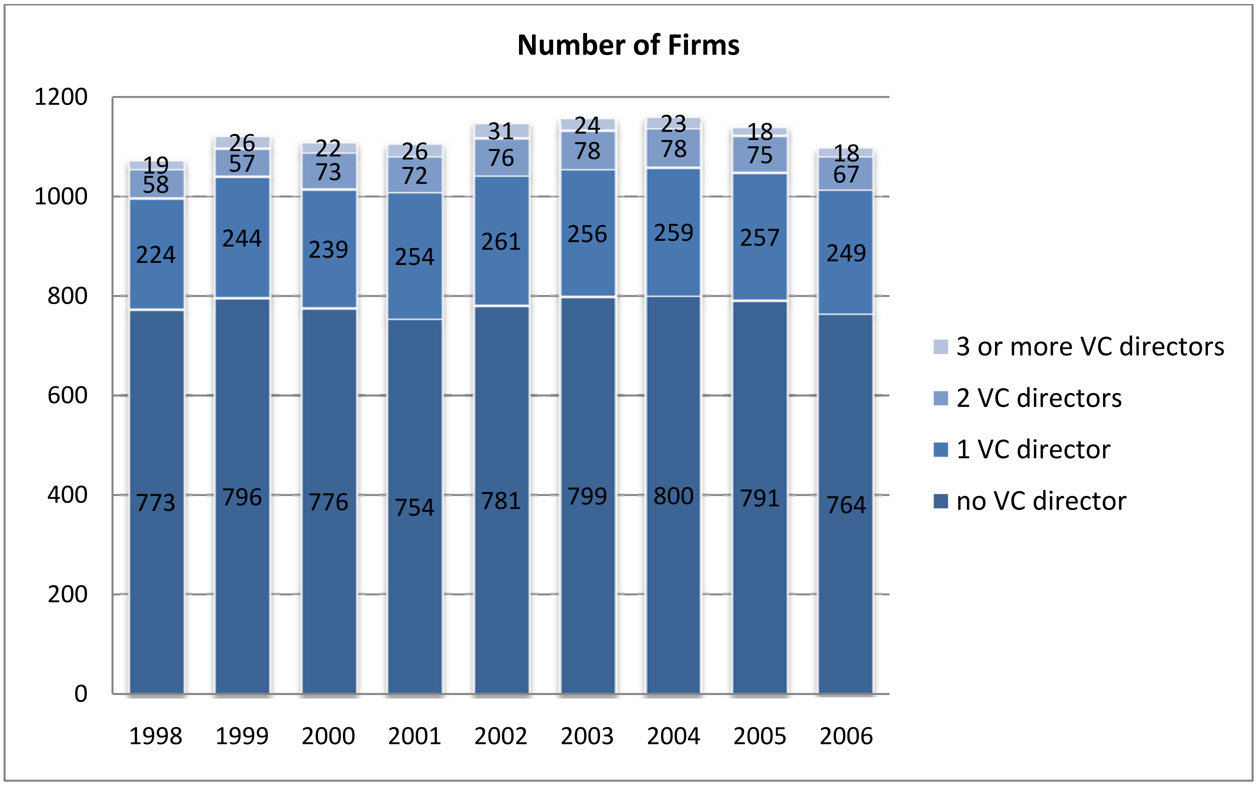

Table 1
Summary Statistics

This table presents the descriptive statistics of firm, board, and director characteristics for IRRC firms between 1998 and 2006. Panel A presents the descriptive firm statistics of our sample of IRRC firms. Firm age is defined as the number of years since the firm's foundation. "VC-backed at the time of IPO" is a dummy variable which takes the value of 1 if the firm is VC-backed at the time of the IPO and 0 otherwise. The market value of assets (MVA) is defined as total assets minus total equity plus market capitalization given by the number of shares outstanding times the share price. Total assets give the book value of assets. Tobin's Q is the ratio of market value of assets to book value of assets. Leverage is the ratio of interest bearing debt to operating assets. Panel B presents the descriptive board and director statistics of our sample. VC directors are directors serving on public firms' boards who are actually executives or partners of venture capital firms. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

Panel A: Descriptive Firm Statistics

	Overall Sample			Firms with at least one VC director on board			Firms with no VC director on board			Comparison between VC- and nonVC-board firms	
	N	Mean	Median	N	Mean	Median	N	Mean	Median	t-statistics	z-statistics
Firm age	3971	31.33	23	1566	25.38	19	2405	35.21	26	-13.62***	-16.28***
Number of years since the firm went public	9250	22.81	17	2841	19.40	13	6409	24.32	19	-12.29***	-15.30***
VC-backed at the time of the IPO (indicator)	4608	0.45	0	1768	0.65	1	2840	0.32	0	23.26***	22.01***
Market value of assets (MVA) ($ millions)	8519	11417.1	2202.5	2593	13439.6	2816.6	5926	10532.1	1984.0	3.10***	9.21***
Total assets ($ millions)	8537	5776.75	1230.42	2597	5613.47	1429.59	5940	5848.13	1152.64	-0.48	4.47***
Tobin's Q	8519	2.14	1.66	2593	2.47	1.88	5926	2.00	1.58	11.13***	13.67***
Leverage	8515	0.30	0.30	2590	0.29	0.26	5925	0.31	0.32	-1.30	-7.07***

Table 1 (continued)

Panel B: Descriptive Board and Director Statistics											
	Overall sample			Firms with at least one VC director on board			Firms with no VC director on board			Comparison between VC- and nonVC-board firms	
	N	Mean	Median	N	Mean	Median	N	Mean	Median	t-statistics	z-statistics
Board size	10118	9.00	9	3084	9.03	9	7034	8.99	9	0.85	0.01
Number of VC directors	10118	0.41	0	3084	1.35	1	7034	0.00	0		
Percentage of VC directors	10118	4.91	0	3084	16.09	12.5	7034	0.00	0		
Percentage of independent directors	10118	66.01	66.67	3084	68.19	71.43	7034	65.05	66.67	8.75***	8.34***
Percentage of shares held by all directors	10104	9.89	3.97	3078	8.16	3.35	7026	10.65	4.32	-6.77***	-6.96***
Average percentage of shares held by each director	10104	1.20	0.48	3078	0.97	0.41	7026	1.30	0.51	-8.30***	-6.62***
Number of other boards served	91046	0.91	0	4163	1.28	1	86883	0.90	0	17.29***	20.95***
Percentage of shares held	90994	1.10	0.06	4155	0.61	0.07	86839	1.12	0.05	-10.07***	1.76*
Director age	91071	59.14	59	4166	57.02	57	86905	59.24	59	-16.05***	-15.28***

Table 2
Innovation Activity

This table presents the descriptive statistics for the innovative activity of the firms in our sample. We report the statistics for the R&D intensity, the number of patents produced and eventually granted, the number of citations received by those patents, the number of citations excluding self-cites and the number of citations per patent. These numbers are corrected for truncation and pooled for all firm-years during the sample period from 1998 to 2006. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

	Overall sample			Firms with at least one VC director on board			Firms with no VC director on board			Comparison between VC- and nonVC-board firms	
	N	Mean	Median	N	Mean	Median	N	Mean	Median	t-statistics	z-statistics
R&D expense ($ millions)	8526	143.17	5.50	2596	191.13	23.81	5930	122.18	0.47	4.65***	16.57***
R&D expense (as a percentage of MVA)	8512	1.68	0.32	2593	2.41	1.15	5919	1.36	0.03	13.09***	16.00***
Number of patents	8802	23.79	0	2679	31.21	0	6123	20.54	0	2.75***	8.99***
Number of citations	8802	270.24	0	2679	389.99	0	6123	217.85	0	2.77***	8.40***
Number of citations excluding self-cites	8802	201.96	0	2679	313.22	0	6123	153.27	0	3.19***	8.30***
Number of citations per patent	3422	7.87	5.09	1194	8.64	5.47	2228	7.46	5.00	3.24***	2.82***
Number of citations per patent excluding self-cites	3422	6.58	3.81	1194	7.17	4.20	2228	6.26	3.79	2.77***	2.51***

Table 3
Acquisitions, Corporate Venture Capital Investments and Strategic Partnerships

This table presents the summary statistics for the acquisition transactions, corporate venture capital (CVC) investments, joint ventures (JVs) and strategic alliances conducted by our sample of firms between 1998 and 2006. Panel A reports the statistics for acquisition volume for firm-years when the firm conducts an acquisition. Target's R&D is reported for public target firms which have a match in Compustat. Panel B shows the number and volume of the CVC investments of the sample firms. Panel C presents the statistics for the number of JVs and strategic alliances formed by the sample firms. VC-backed partner firm is an indicator variable that takes the value of one if the partner firm in the JV or strategic alliance is VC-backed and zero otherwise. The market value of assets (MVA) is defined as total assets minus total equity plus market capitalization given by the number of shares outstanding times the share price. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

	Overall Sample			Firms with at least one VC director on board			Firms with no VC director on board			Comparison between VC- and nonVC-board firms	
	N	Mean	Median	N	Mean	Median	N	Mean	Median	t-statistics	z-statistics
Panel A: Acquisition Activity											
Acquisition volume as a percentage of acquirer's MVA	3005	7.35	2.73	1112	6.91	2.50	1893	7.62	2.88	-1.47	-1.89*
VC-backed target acquisition volume as a percentage of total acquisition volume	3005	21.93	0	1112	31.06	0	1893	16.57	0	9.43***	10.50***
Target's R&D (as a percentage of its MVA)	266	4.47	1.09	129	5.43	1.41	137	3.56	0.77	2.15**	2.37**
Panel B: Corporate Venture Capital (CVC) Investments											
Number of portfolio companies for which the firm provided CVC	10118	0.33	0	3084	0.45	0	7034	0.27	0	2.42**	11.72***
Total CVC invested by the firm's fund in the portfolio companies (as a percentage of its MVA)	8507	0.01	0	2592	0.01	0	5915	0.00	0	5.86***	10.96***
Total CVC under the firm's management (as a percentage of its MVA)	8207	0.02	0	2415	0.03	0	5792	0.01	0	3.14***	3.75***
Panel C: Joint Ventures and Strategic Alliances											
Total number of JVs and strategic alliances	10118	0.79	0	3084	1.33	0	7034	0.56	0	8.25***	15.21***
Total number of JVs and strategic alliances with VC-backed firms	10118	0.18	0	3084	0.35	0	7034	0.11	0	9.24***	15.49***

Table 4
First-Stage Regressions for the Presence of VC Directors

This table presents the first-stage regression results for the instrumental variables (IV) model. Models (1)-(5) show the estimates for ordinary least squares model, where the dependent variable is the proportion of VC directors on board, which is defined as the ratio of the number of VC directors on a board to the total number of board members. *VC density* is the ratio of the number of VC firms in a given state to the number of public firms headquartered in that state. *Firm size* is the natural logarithm of total assets, *Tobin's Q* is the ratio of market value of assets to book value of assets, *Leverage* is defined as interest bearing debt divided by operating assets, *Firm public age* is the natural logarithm of the number of years since the firm's IPO, *Sales growth* is the annual percentage change in sales, *Operating cash flow* is defined as the cash flow from assets-in-place, *State per capita* income is the per capita income in the state of the firm, and *State educational attainment* is defined as the percentage of the population age 25 and over with a high school degree. *VC-backed at the time of IPO* is an indicator variable taking the value of one if the firm is VC-backed and zero otherwise. The regressions also include a constant term and year dummies which are not reported. Industry dummies are assigned according to the Fama-French 48 industry groups. For each independent variable, the first row reports its estimated coefficient and the second row the corresponding t-statistic. All standard errors are heteroskedasticity-robust and are clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

	Proportion of VC Directors				
	(1)	(2)	(3)	(4)	(5)
VC density	0.177	0.164	0.164	0.145	0.131
	5.51***	5.16***	5.19***	3.72***	3.30***
Firm size		0.005	0.005	0.005	0.006
		3.00***	2.99***	3.00***	1.88*
Tobin's Q		0.004	0.003	0.003	0.002
		3.78***	3.06***	3.04***	1.99**
Leverage		0.002	0.002	0.002	0.012
		2.49***	2.54***	2.54***	1.12
Firm public age		-0.020	-0.019	-0.020	-0.029
		-7.19***	-7.10***	-7.26***	-4.67***
Sales growth			0.005	0.006	0.005
			1.21	1.30	0.78
Operating cash flow			0.031	0.031	0.048
			1.34	1.34	1.45
State per capita income				0.001	0.002
				1.52	1.30
State educational attainment				0.020	0.017
				0.32	0.16
VC-backed at the time of IPO (indicator)					0.055
					2.12**
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.12	0.15	0.15	0.15	0.22
Sample size	8736	8351	8247	8247	3889

Table 5
VC Directors and R&D Intensity

This table shows the results of the instrumental variables (IV) models for the R&D outlays of our sample of firms. The dependent variable is the R&D outlay of the firms as a percentage of their total assets. *Proportion of VC directors* is defined as the ratio of the number of VC directors on a board to the total number of board members, *Firm size* is the natural logarithm of total assets, *Tobin's Q* is the ratio of market value of assets to book value of assets, *Leverage* is defined as interest bearing debt divided by operating assets, *Firm public age* is the natural logarithm of the number of years since the firm's IPO, *Sales growth* is the annual percentage change in sales, *Operating cash flow* is defined as the cash flow from assets-in-place, *State per capita* income is the per capita income in the state of the firm, and *State educational attainment* is defined as the percentage of the population age 25 and over with a high school degree. *VC-backed at the time of IPO* is an indicator variable taking the value of one if the firm is VC-backed and zero otherwise. The regressions also include a constant term and year dummies which are not reported. Industry dummies are assigned according to the Fama-French 48 industry groups. For each independent variable, the first row reports its estimated coefficient and the second row the corresponding t-statistic. All standard errors are heteroskedasticity-robust and are clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

	R&D as a Percentage of Firm Size			
	(1)	(2)	(3)	(4)
Proportion of VC directors	0.623	0.595	0.712	0.762
	4.60***	4.60***	3.55***	2.16**
Firm size	-0.007	-0.007	-0.008	-0.013
	-4.84***	-4.65***	-4.38***	-3.59***
Tobin's Q	0.001	0.001	0.001	0.001
	0.82	0.20	0.42	0.76
Leverage	0.001	0.001	0.001	0.008
	0.54	0.79	0.64	0.50
Firm public age	0.009	0.009	0.011	0.023
	3.06***	2.93***	2.64***	2.07**
Sales growth		-0.005	-0.006	-0.010
		-1.01	-1.14	-1.21
Operating cash flow		0.081	0.078	0.090
		3.02***	2.74***	2.49***
State per capita income			-0.001	-0.001
			-1.53	-0.89
State educational attainment			-0.020	-0.027
			-0.41	-0.31
VC-backed at the time of IPO (indicator)				-0.025
				-1.14
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Sample size	8342	8239	8239	3884

Table 6
VC Directors and Innovation Activity

This table presents estimates from Poisson maximum likelihood models with an instrumental variable approach. The dependent variables are the adjusted number of patents, the adjusted number of citations, and the adjusted number of citations excluding self-cites. The adjusted number of patents is obtained by dividing the number of patents for each firm by the mean of the number of patents in the same cohort to which the patent belongs, where the cohorts are constructed for each year and technology class defined by United States Patent and Trademark Office (USPTO). Similar adjustments are made for the number of citations and the number of citations excluding self-cites. The adjusted numbers are then rounded to the nearest integer for the Poisson model. *Proportion of VC directors* is defined as the ratio of the number of VC directors on a board to the total number of board members, *Normalized R&D* is the R&D outlay of the firm as a percentage of its total assets, *Firm size* is the natural logarithm of total assets, *Tobin's Q* is the ratio of market value of assets to book value of assets, *Leverage* is defined as interest bearing debt divided by operating assets, *Firm public age* is the natural logarithm of the number of years since the firm's IPO, *Intangible Assets* is defined as assets minus net property, plant and equipment divided by assets. The regressions also include a constant term and year dummies which are not reported. Industry dummies are assigned according to the Fama-French 48 industry groups. For each independent variable, the first row reports its estimated coefficient and the second row the corresponding t-statistic. All standard errors are heteroskedasticity-robust and are clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

	Technology Class- and Year-Adjusted Number of Patents		Technology Class- and Year-Adjusted Number of Citations		Technology Class- and Year-Adjusted Number of Citations Excluding Self-Cites	
	(1)	(2)	(3)	(4)	(5)	(6)
Proportion of VC directors	29.640	24.255	33.027	27.945	33.431	27.916
	2.57***	2.06**	2.67***	2.20**	2.62***	2.14**
Normalized R&D	1.056	0.910	1.148	0.988	1.096	0.959
	3.94***	2.86***	4.01***	2.97***	4.07***	2.99***
Firm size	1.339	1.372	1.458	1.491	1.401	1.433
	5.07***	5.27***	5.01***	5.18***	4.83***	5.03***
Tobin's Q	0.142	0.233	0.199	0.296	0.186	0.276
	1.35	1.90*	1.46	1.88*	1.4	1.83*
Leverage	-0.033	-0.059	-0.061	-0.091	-0.053	-0.075
	-0.52	-0.77	-0.67	-0.83	-0.65	-0.81
Firm public age	0.994	0.871	0.929	0.809	0.934	0.808
	2.47***	2.14**	2.11**	1.81*	2.08**	1.78*
Return on assets		-2.392		-2.550		-2.269
		-1.82*		-1.62		-1.58
Intangible assets		-0.235		-0.441		-0.135
		-0.32		-0.45		-0.18
Sample Size	8341	8309	8341	8309	8341	8309

Table 7
VC Directors and Acquisition Strategy

This table presents estimates of the instrumental variable (IV) models for the acquisition activity of our sample of public firms. Model (1) presents probit estimates for the probability of a firm in our sample to acquire a VC-backed target, where the dependent variable takes the value of one if the target firm acquired is VC-backed and zero otherwise. Model (2) shows the estimates for the IV regression of the proportion of the acquisition volume invested in VC-backed targets. Model (3) shows IV regression estimates for the target firm's R&D outlays, where the dependent variable is the target firm's R&D normalized by its assets. *Proportion of VC directors* is defined as the ratio of the number of VC directors on a board to the total number of board members, *Normalized R&D* is the R&D outlay of the firm as a percentage of its total assets, *Firm size* is the natural logarithm of total assets, *Tobin's Q* is the ratio of market value of assets to book value of assets, *Leverage* is defined as interest bearing debt divided by operating assets, *Firm public age* is the natural logarithm of the number of years since the firm's IPO, *Intangible Assets* is defined as assets minus net property, plant and equipment divided by assets, *Diversifying acq* is an indicator variable that takes the value of one if the acquirer and the target are not in the same Fama-French 48 industry group and zero otherwise, and *Private target* is an indicator variable that takes the value of one if the firm acquires a private target and zero otherwise. The regressions also include a constant term and year dummies which are not reported. Industry dummies are assigned according to the Fama-French 48 industry groups. For each independent variable, the first row reports its estimated coefficient and the second row the corresponding t-statistic. All standard errors are heteroskedasticity-robust and are clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

	Probit Model for Acquiring VC-Backed Targets	Proportion of Acq Volume on VC-Backed Targets	Target's R&D
	(1)	(2)	(3)
Proportion of VC directors	2.847	1.223	0.325
	1.97**	1.68*	3.73***
Normalized R&D	3.015	1.022	1.022
	4.08***	3.47***	2.80***
Firm size	0.115	0.022	-0.004
	8.14***	3.48***	-0.86
Tobin's Q	-0.001	0.006	-0.003
	-0.16	1.47	-2.12**
Leverage	0.008	0.006	0.014
	0.33	0.22	0.35
Firm public age	0.035	0.005	-0.023
	0.88	0.30	-1.81*
Return on assets	-0.198	-0.091	0.140
	-0.78	-0.78	1.33
Intangible assets	-0.060	-0.053	0.042
	-0.36	-0.78	0.60
Diversifying acq (Indicator)	0.074		0.004
	1.96**		0.25
Private target (Indicator)	0.185		
	5.11***		
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Sample size	8263	2657	221

Table 8
VC Directors and Strategic Investment

This table presents estimates of the instrumental variables (IV) models for the strategic partnerships formed by our sample of public firms. Models (1) and (2) show Poisson maximum likelihood estimates for the determinants of the number of joint ventures (JVs) and strategic alliances. Model (3) shows probit estimates for the probability to collaborate with VC-backed partners in joint ventures (JVs) and strategic alliances where the dependent variable takes the value of one if the partner firm is VC-backed and zero otherwise. Model (4) shows probit estimates for the probability to undertake a corporate venture capital (CVC) investment where the dependent variable takes the value of one if the public firm invests in a VC-backed start-up and zero otherwise. Models (5) and (6) show Poisson maximum likelihood estimates for the determinants of the number of CVC investments undertaken by the firm, and model (7) presents the regression estimates for the total amount of CVC invested by the firm as a percentage of its size. *Proportion of VC directors* is defined as the ratio of the number of VC directors on a board to the total number of board members, *Normalized R&D* is the R&D outlay of the firm as a percentage of its total assets, *Firm size* is the natural logarithm of total assets, *Tobin's Q* is the ratio of market value of assets to book value of assets, *Leverage* is defined as interest bearing debt divided by operating assets, *Firm public age* is the natural logarithm of the number of years since the firm's IPO, *Intangible Assets* is defined as assets minus net property, plant and equipment divided by assets, *Diversifying JV/alliance* is an indicator variable that takes the value of one if the public firm and its partner are not in the same Fama-French 48 industry group and zero otherwise, and *Private partner* is an indicator variable that takes the value of one if the partner firm is private and zero otherwise. The regressions also include a constant term and year dummies which are not reported. Industry dummies are assigned according to the Fama-French 48 industry groups. For each independent variable, the first row reports its estimated coefficient and the second row the corresponding t-statistic. All standard errors are heteroskedasticity-robust and are clustered at the firm level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level, respectively.

	Poisson Model for Number of JVs and Strategic Alliances		Probit Model for VC-Backed Partners	Probit Model for CVC Investments	Poisson Model for Number of CVC Investments		Total CVC Invested by the Firm's Fund
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Proportion of VC directors	24.908 2.94***	24.762 2.78***	3.268 2.18**	15.31 5.11***	276.636 5.39***	286.536 5.33***	4.685 5.22***
Normalized R&D	14.411 4.86***	14.704 4.90***	-0.268 -0.35	2.04 2.08**	20.407 1.19	27.943 1.60	0.392 1.38
Firm size	2.459 27.64***	2.461 26.58***	0.020 1.14	0.51 14.63***	9.133 14.89***	8.878 14.13***	0.114 10.84***
Tobin's Q	0.119 2.22**	0.122 2.20**	-0.022 -2.92***	-0.03 -1.58	-0.448 -1.57	-0.579 -1.96**	-0.012 -2.46***
Leverage	-0.114 -1.23	-0.108 -1.16	-0.022 -0.29	-0.03 -1.11	-0.751 -1.66*	-0.561 -1.17	-0.012 -1.5
Firm public age	0.144 0.72	0.142 0.68	0.135 2.50***	0.31 3.51***	4.282 3.28***	4.440 3.30***	0.069 3.10***
Return on assets		0.565 0.55	0.531 1.85*	0.68 1.83*		22.420 3.33***	-0.012 -0.11
Intangible assets		0.705 0.89	-0.062 -0.28	0.36 1.14		-0.424 -0.08	0.002 0.02
Private partner (Indicator)			-0.133 -2.60***				
Diversifying JV/alliance (Indicator)			-0.127 -2.73***				
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	8342	8310	4068	6702	8342	8310	8289