# Strategic Patenting In Venture Capital Backed Firms

by

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*Abstract:*

This paper examines the relationship between patenting activities before exit and the type of exit that a start-up firm ultimately obtains. We consider the nature of this relationship for firms that will be acquired and firms that will secure an initial public offering, for both venture capital backed firms and a control group of other startups in the United States between 1980 and 2006. We also consider the nature of this relationship for venture capital backed firms that do not manage a successful exit. We draw a number of strategic predictions from the literature, based on theory regarding the appropriation of economic value from patents, theory regarding when patents would have signaling value, and the transaction cost economics implications of certain patent portfolios. We hypothesize and find that venture capital backed firms outperform their non-VC backed counterparts in matching their patenting strategies to their exit strategies as theory predicts they should. In the process of this analysis, we present a comprehensive review of patenting by venture capital backed firms, and provide some evidence of a treatment effect by venture capitalists with respect to patenting.

## Introduction

Venture capitalists typically exit[1] their investments in one of three ways: by securing a listing for their firms on a stock exchange through an initial public offering (IPO), by selling their firms outright to an acquirer, or by forcing their firms into liquidation. Economic theory predicts that certain patterns of patenting will be associated with the specific exit types. In this paper we examine the patterns of patenting by start-up firms and find that certain patterns of patenting are indeed associated with exit types as theory predicts. Furthermore, we find that venture capital backed firms exhibit patterns that more closely match what economic theory would predict than a control group of non-venture capital backed firms that experienced the same exit event.

Anecdotally, venture capital backed firms generally do not have a pre-determined exit path at the time of their first investment and venture capitalists are responsible for choosing the type of exit for their firms. Building upon these two assumptions, we present evident that is consistent with the notion that venture capitalists actively cause their portfolio firms to adopt strategic patenting behavior that is suited to their ultimate exit. There is some support for the first assumption in the literature, discussed later, and we make some attempt to address concerns regarding both assumptions.

We believe that this paper is a unique contribution to the literature in three regards. First, we use near-comprehensive data on venture capital investments over a 26 year period and compare these venture capital backed firms against the population of other firms that secured an initial public offering and a very large sample of other firms that secured an acquisition, which includes a subsample that approximately covers the population of material acquisitions by publicly traded firms. In total we consider the pre-exit patenting activities of over 80,000 firms that experienced an IPO or an acquisition. These start-up firms account for about one twentieth of all patenting activity in the United States from 1979 to 2006.

We found only a single paper in the literature that compared the patenting of VC backed firms with that of non-VC backed firms: Hsu (2000) used data on 118 firms divided almost evenly between VC backed firms and firms that received Small Business Investment Research (SBIR) grants. All other papers in the literature have examined only VC backed firms without a control group, and have been limited to certain sectors, certain years, and several hundred observations. Our descriptive analysis of pre-exit patenting covers a sample that probably closely resembles the entire (successful) entrepreneurial sector across the entire lifetime of the modern venture capital industry.

Second, we consider all three reasons for patenting that have appeared in the economic literature: to appropriate economic value, to signal value in the presence of information asymmetries, and for strategic purposes regarding potential holdup. To achieve this we use a breadth of patent measures that, to our knowledge, has never been attempted before in a single analysis. Third, we use the milestone based attributes of rounds of venture capital investment to consider the emergence of a pattern over time, and to make Granger causality inferences regarding a treatment effect. Again, to the best of our knowledge, prior work on the role of patenting in VC backed firms has not attempted to distinguish between a VC treatment effect and a VC selection before.

[1] Through-out this paper, we will refer to an exit event as a successful exit event, that is either an IPO or an acquisition, and not as an exit from production in an output market, unless otherwise indicated.

Overall, we present a "thirty thousand foot view" of the relationship between venture capital and patents. Mann and Sager (2007), for example, explore a part of this relationship within the context of software firms. Mann and Sager note that there are substantial differences between venture capital backed firms operating in the Internet software sector versus those operating in the (offline) software applications sector. They attribute these differences to differences in the appropriability regime. While we control for industry differences, we seek to report broad trends that hold across all sectors of interest to venture capitalists.

The broad trends that we expect to see are as follows. For VC backed firms that will ultimately fail we expect a burst of patenting before first investment as these firms attempt to attract venture capital. However, as these firms will not ultimately succeed, we expect patenting to fall off dramatically over the subsequent rounds of investment, as the firms fail to secure their niche within the ecosystem of potential competitors and as their venture capitalists prepare them for liquidation. For firms that will ultimately succeed, we expect to see an increase in patenting following the first round of venture capital.

However, the pattern of patenting should be markedly different for firms that will continue as standalone entities, raising money from public markets, and for firms that will be acquired. Firms that will have an initial public offering, and retain their independence, must be able to compete in output markets. We expect that these firms will have a claim to the dominant design that forms their technological base, or at least that they will be immune from holdup by incumbents. Furthermore, these firms must signal their value to uninformed public investors at IPO. Thus we expect that these firms will patent extensively, with patenting continuing, perhaps even accelerating, right through to exit. Their patent portfolios will receive a comparatively large number of citations, and these citations will come from a broad base of other firms, representing either the firm's superior technological position or immunity from holdup problems.

Firms that will be acquired, however, will not continue to patent right through to exit. Acquisitions are known in advance and take time to formalize. During the 'pre-acquisition' period, firms have no incentive to create new technologies that are not directly relevant to their future acquirer. Likewise, there is a comparatively smaller information asymmetry to overcome in an acquisition. Acquirers may well have knowledge of their target firms that public investors do not have. At the very least, if there are technological synergies between the acquirer and the target, one would expect the acquirer to have considerable familiarity with target's technology base.

Furthermore, a strategic player, such as a venture capitalist, might recognize that vertical integration will solve certain cospecialized asset problems. Specifically, a firm that holds comparatively few patents, so that it does not have a strong bargaining positions with respect to the underlying technology rights that it needs to succeed, and firms that have highly fragmented technologies, that is technologies where the underlying rights are widely held by a diverse group of incumbents, would benefit from being acquired by a firm that does have a strong bargaining position and can solve the potential holdup problem. Therefore we expect to find that firms with cospecialized asset problems will be acquired, and that firms with greater strategic expertise, which we associate with venture capital, will better recognize and solve their cospecialized asset problems through acquisitions.

## Literature Review

This section details the extant literature on the relationship between venture capital and patenting, which has seen some important recent developments. The literature began in 2000 with three papers: Kortum and Lerner (2000), Hellmann and Puri (2000) and Hsu (2000). Kortum and Lerner (2000) used aggregate industry data to estimate the degree to which venture capital causes innovation, as measured by patents. They found evidence consistent with venture capital dollars being about six times more effective in generating patents than other R&D dollars. Contemporaneously, Hellmann and Puri (2000) reported survey evidence that suggested that venture capitalists select firms with patents and then finance their commercialization. Hsu (2000) examined the commercialization strategy of venture capital backed firms. Specifically, Hsu looked at whether VC backed firms are associated with cooperative licensing strategies or with competitive intellectual property development strategies, with the later based upon filings for patent protection. Hsu found weak support for an association between venture capital and cooperation, suggesting that patents are less important for VC backed firms.

However, from 2000 to 2007 there was a period of presumption in the literature. Hall (2002) and Romain and Van Pottelsberghe (2004) implicitly assumed a positive causal relationship. That is that venture capitalists were actively causing their firms to patent. Whereas Dushnitsky and Lenox (2004), Mann (2005) and Hand (2007), among others, all implicitly assume that venture capitalists select firms with patents and then finance the commercialization of their new products.

Beginning in 2007 there were four new papers that hypothesized about the role that patents might play in venture capital backed firms. These papers are Mann and Sager (2007), Hsu and Ziedonis (2008), Cockburn and MacGarvie (2009), and Haeussler, Harhoff and Muller (2009). All of these papers consider only venture capital backed firms, without a non-VC backed control group, and do not directly attribute patenting to a VC treatment effect. Instead their dominant focus is on the use of patents as signals to secure venture capital.

Mann and Sager (2007) provide a descriptive analysis of 877 software firms that received their first round of venture capital in the boom years between 1997 and 1999. They find that around a quarter of their VC backed software first apply for one or more patents, and that patenting varies considerably by sub-industry. However, they are able to demonstrate a correlation between patenting and performance, in terms of the number of rounds a firm receives and the investment made into the firms. More importantly, they find that patents before the first round of investment do not influence the likelihood of receiving subsequent rounds beyond the first round. They state that their paper can not explicitly consider the role that patents play in venture capital backed firms, but that they feel that their results are consistent with "routine" patenting to extract economic value, rather than strategic patenting (i.e. patenting to solve transaction cost economics problems, discussed later).

Hsu and Ziedonis (2008) consider the financing and patenting histories of 370 venture capital backed semi-conductor firms. They report results that are consistent with firms patenting to appropriate economic value from their inventions and possibly consistent with a signaling hypothesis. The signaling

hypothesis is that high quality firms may use costly signals, in this case patents, to inform potential investors, in this case VCs, of their firm's quality. However, they fail to find evidence that the signaling effect is larger for novice entrepreneurs than it is for experienced entrepreneurs, which one would expect to be the case. Nevertheless, Hsu and Ziedonis (2008) ultimately provide compelling evidence of a venture capital selection effect, and document the importance of patents to venture capital backed firms.

Cockburn and MacGarvie (2009) consider 27 carefully defined software markets and the VC backed firms that enter into them. Using basic patent count and citation measures, they find that markets associated with patent thickets were less attractive to venture capitalists, and provide weak evidence that are less likely to achieve an initial public offering in thicket dense markets. Thus Cockburn and MacGarvie provide the first circumstantial evidence that VC backed firms use patents strategically, or at least are aware of the strategic implications of holding certain patent portfolios in certain industries.

Haeussler, Harhoff and Muller (2009) take a different approach and examine a self-selected sample of 162 German and 118 venture capital backed biotechnology firms. Using a hazard rate analysis, with their solely VC backed sample, they find that patents decrease the time to first investment and that VCs pay attention to the quality of patents. They attribute their results to a signaling hypothesis.

This paper begins where these four papers left off, considering the three different roles for patents in venture capital backed firms: the appropriation of economic value, signaling and for strategic purposes. However, in the process this paper attempts to answer a more fundamental question: Do venture capitalists play a role in the patenting behavior of their portfolio firms? The next section, which explains our conceptual framework, provides grounded theory and details the underlying literature.

## Conceptual Framework

### Selection and Treatment in Venture Capital

Venture capitalists[2] may select firms that are likely to succeed and finance them and/or may subject their firms to some treatment making them more successful. These selection and treatment effects are notoriously difficult to disentangle, and there is scant evidence in the literature of a direct VC treatment effect, with Hellmann and Puri (2002) standing as notable exception on the portfolio firm side, and Brander, Amit, and Antweiler (2002) providing some evidence that VCs may assemble their syndicates for value-added reasons rather than to improve investment selection[3]. There are two types of claims about treatment effects that researchers would like to be able to make: A strong claim would be that VCs actively enable a portfolio firm to take certain specific actions toward specific objectives, and a weak claim would be that VCs at least passively insist (for a given value of insist) that certain objectives are met. We pursue a strong claim and assume that one of these objectives relates to strategic patenting.

We make use of the discrete nature of venture capital financing rounds, and Granger causation, to attempt to discern our treatment effect. Although without good instruments, discussed later, we stress that

[2] See Sahlman (1990) and Gompers and Lerner (1996, 1998a, 1998b, and 1999) for the definitive summary of various aspects of venture capitalists and their investments.

[3] Hsu (2000 and 2006) found that start-up firms are willing to pay to be associated with "highly performing" venture capitalists. While this is consistent with purchasing a signal (the value of the reputation of the VC is costly and correlated with high-quality firms), it is more generally interpreted as the purchase of value-added management services.

we are only able to provide suggestive results whose interpretation hinges on some underlying assumptions. Our most important assumption is that venture capital rounds are tied to milestones in the firm's development. Venture capitalists select firms based on their performance and qualities before the first round of financing and then set milestones that the firm must achieve in order to secure each subsequent round. As the company progresses from round to round, the milestones become more onerous and focused more heavily on commercialization.

Venture capitalists must exit their investments in order to realize gains. While some firms are passed from one generation of fund to another, typically a firm must be financed and exited within the lifespan of a single fund. That puts an upper limit of 10 years[4] from first financing to exit for most firms. Of course, particularly promising firms may take longer, perhaps as VCs await better market opportunities for an exit. The popular social networking site Facebook is one such example. Nevertheless, for the most part we assume that the exit decisions are made by the venture capitalists and forced[5] upon their firms. Furthermore, for most firms, we suppose that the type of exit is not predetermined at the time of first investment. That is a firm is not selected as a Cisco acquisition target, say, and financed accordingly. Rather, exceptions aside, all firms receive their first round of financing with the aspiration of an initial public offering. After the first round of investment firms are tailored to an endogenously emerging exit path through endogenously determined milestones.

With respect to patenting, this means that we should find evidence of a matching of patenting behavior suitable for the ultimately achieved exit type with said exit type. Of course, for non-VC backed firms we expect the market to match firm characteristics, such as patenting behavior, with exit type too. The degree of a VC treatment effect is therefore the degree to which VCs are better, whether because of their specialized expertise, networks, superior information, or other reasons, than the unassisted market at matching firm characteristics to the exit type. We do not explore the mechanism for this treatment, but we assume that it lies with the VCs and is not inherent in their firms anyway. This is the assumption that for us distinguishes the strong claim from the weak claim.

**Patenting and Exits**

Start-up firms might seek patents for three reasons: To appropriate economic value from their inventions; to signal the firm's quality to potential investors in the presence of information asymmetries; and for strategic purposes, particularly those relating to contractual bargaining with other intellectual property right holders. This paper develops hypotheses based on all three lines of reasoning.

Patents confer monopoly rights on inventions. Of course, not all patents are created equal, and it is possible that the benefit of the rights does not exceed the cost of the application in some instances, but nevertheless on average a firm with more patents should be more valuable. With respect to acquisitions and IPOs we believe that there are three primary value considerations. The first argument, based on Porter (1980), relies on the notion of core competencies. A firm should commercialize the fraction of its patent portfolio that is aligned with its core competencies. In an acquisition we expect that unless the target and the acquirer are a perfect fit for one another, which is unlikely, the core competencies of the acquirer will

[4] For standard VC partnerships; evergreen funds are potentially infinitely lived, though comparatively rare.
[5] In our experience, firms generally do not complain that they were forced to IPO, but do frequently complain that they were forced into an acquisition.

overlap with but not fully cover the core competencies of the target. Assuming that patents are generated with a focus on commercialization, this would imply that an acquirer could use a smaller fraction of a target's patents than a target would use as an independent firm. Presumably, in most cases, only certain key patents are of interest to the acquirer. Thus we would expect firms with a large number of patents to be worth more if they IPO, as an acquirer is only willing to pay for a (smaller) fraction of the patent portfolio.

The second argument relies on the notion of allocative efficiency due to Arrow (1962). Some entities may be better placed to extract value from certain innovations than others. Gans, Hsu and Stern (2002) showed that patents facilitate licensing, which would solve some but not all allocatively issues, particularly if there is "know-how" or "show-how" concerning the invention embodied in the firm. With our data it is generally not possible to determine who would value an innovation more, with the notable exception of patents that are cited by or that cite the acquirer. These citations indicate that the acquirer may have complementary innovations and may get returns to scale or scope from producing products based on these innovations. Unfortunately we do not have a measure of citations to or from a potential acquirer for initial public offerings, and so can only make prediction about the relative efficiency within acquisitions[6]. However, within the context of acquisitions, we can compare the technological "goodness of fit" of the target with the acquirer across VC backed and non-VC backed firms.

The third argument is drawn from the open innovation literature of Chesbrough (2003). Large incumbents may use acquisitions as a part of an open innovation strategy to source external ideas[7]. In this case the incumbent would like the idea developed to the point of commercialization. Venture capital is almost synonymous with the commercialization of invention. It therefore seems reasonable that if a firm were to be targeted towards an acquisition by their venture capitalists they would then be more likely to stop development of new ideas. The acquisition process takes time, with perhaps a year typical from the time that a "dance partner" is identified to the date of the formal announcement. The time from announcement to the actual date that an acquisition is effective (and in our data we use the date the acquisition is effective as the exit date) is approximately 60 days. Filing new patents during this period is only worthwhile if they will have value to the acquirer. Thus we hypothesize that in later stages of venture capital financing, the rate of patent filings will drop for firms that are acquired.

Backwards citations, that is citations made, may be an indicator of patent scope. Firms that make more citations are more likely to cite across patent classes. Lerner (1994) used a measure of patent scope that considered the number of subclasses into which the USPTO assigned a patent. Lerner found that broader scope was associated with greater economic value. Likewise forward citations, that is citations

[6] We experimented with using the largest fraction of citations accruing to or from a single entity as a proxy for the fraction of citations accruing to or from an acquirer, as we could use this measure with IPOs. We abandoned this proxy because we found that the correlation between this measure and a measure of the fraction of citations accruing to an acquirer was weakly negatively correlated. However, when the largest fraction of citations to or from a single entity is high, we might expect the allocative efficiency argument to hold. We comment on this again later.

[7] Arora and Merges (2004) suggested that patents may facilitate entry by smaller firms that contribute technology to larger firms. Thus patents may facilitate vertical specialization as detailed in Mowery (2009). In such a case, the entrant must be able to compete as a standalone firm, and would have to both broaden its technology base and continue to innovate. Thus we do not feel that this undermines our argument, rather that it reinforces it.

received, are generally taken as an indicator of the importance of the innovations. Greater importance implies greater economic value[8] and we expect that this will be associated with IPOs.

Patents may act as signals in the sense of Spence (1970). That is when firm quality is uncertain and information about quality is private to the firm, the firm can signal its quality to a market of outside investors by taking a costly action that is correlated with high quality, such as filing for a patent. We stress that both uncertainty and information asymmetry are necessary conditions for signaling. If there is no information asymmetry the investors are as informed about the firm's prospects as the firm itself, and, likewise, if there is no uncertainty over the prospects of a venture, there is no information to be revealed. Both the uncertainty inherent in start-ups and the degree of information asymmetry between start-ups and outside investors may vary considerably with both observable and unobservable factors. For instance, one might expect that firms that are attempting to achieve commercialization very quickly, or in markets with high rates of technological change, would face more uncertainty than those that attempt to do so slowly, or in markets that are technologically stable. Similarly, information asymmetries may be higher for certain sectors, or for certain firms, than for others, for example a firm operating in the software industry may know more about its product and prospects than outside investors, but the same may not be true for a retail establishment.

Amit, Brander and Zott (1998) consider venture capitalists to be financial intermediaries who specialize in information asymmetry mitigation. There is evidence in the literature, including Hsu and Ziedonis (2007) and Haeussler, Harhoff and Muller (2009), that venture capitalists use patents as signals of firm quality when making investment decisions. Mann and Sager (2007) also find results consistent with this hypothesis. Furthermore, venture capitalists may encourage their portfolio companies to secure (further) patents to signal their value to either outside investors at an initial public offering or to potential acquirers. Baker (1991) proposed and validated a model where patents were used (by non-VC backed firms) to signal value at IPO.

Hsu (2000, 2006) documents the value of venture capitalists reputations, and shows that start-ups are willing to pay to be financed by a more reputable VC. Kreps and Wilson (1982) provide the economic foundations for how reputations can be used for signaling and certification. Following Megginson and Weiss (1990), who showed that underwriters use their reputations to certify firms at IPO, Gompers and Lerner (1997) showed that venture capitalists can use their reputations to certify their firms to public market investors at exit. In the case of acquisitions Brander and Egan (2008) showed that venture capitalists are able to successfully certify their firms to their future acquirers. However, neither Gompers (1997) nor Brander and Egan (2008) controlled for patenting behavior, so it remains possible that the total certification effect can be decomposed into a patent signaling effect and a reputation signaling effect. We therefore develop hypotheses on the basis a patent signaling effect.

While Mann (2005) and Hsu (2004) both report survey evidence that suggests that investors, including VCs, place little weight on patenting when deciding to first invest, for a variety of reasons we do expect to see occurrences of patenting before the first round of venture capital investment. Shane (2002) suggested that firms may seek patents before investment in order to mitigate moral hazard by their future investors. Cockburn and Wagner (2007) noted that patents may allow venture capitalists to increase the salvage value that they can recover from a failed investment. And Haeussler, Harhoff and Muller

[8] For evidence of this claim, see Hall, Jaffe, and Trajtenberg (2005).

(2009) provide evidence that patents may help firms certify their value to venture capitalists in the presence of information asymmetries. However, we do not have a control group of non-VC backed firms that did not exit, and consider it infeasible to estimate when our control group of non-VC backed firms that did exit would have received venture capital. Therefore we cannot test this hypothesis directly except within VC backed firms, where we suppose that firms that will be successful are of higher quality than firms that will ultimately fail. However, we suppose that, for the vast majority of VC backed firms, an exit strategy is not formed before or at the time of first investment. This allows us to test whether there is a difference in patenting at exit between VC and non-VC backed firms.

Patent signals are only meaningful if they can create a separating equilibrium. Furthermore, we can differentiate between the existence of a signal, through the incidence of patenting, and the strength of a signal, through a patenting rate conditional on patenting. The existence of a signal is clearly the first order consideration. Therefore our first signaling hypothesis are that firms that are ultimately successful will signal their higher quality to VC investors by having a higher incidence of patenting than firms that will ultimately fail. Likewise, our second signaling hypothesis is that firms that are acquired will have not have a different incidence of patenting before the first round of venture capital from firms that achieve an initial public offering. We note that this second hypothesis could be taken to be a test of the assumption that an exit strategy is not formed before or at the time of first investment.

A potential acquirer faces less information asymmetry but the same uncertainty with respect to the target than public investors face with respect to a newly listed firm. The reasoning is straight forward – an acquirer has industry and technology specific knowledge that public investors do not have. Therefore we expect that if patents have signaling value at exit, they will have greater value in IPOs than in acquisition, and so the incidence of patenting at IPO should be higher than that at acquisition. We then make the argument that VCs may add value to their firms by tailoring their patenting strategy to overcome information asymmetries at exit. We propose testing this hypothesis by comparing whether VCs increase the incidence of patenting when they intend to publicly list the firm more than when they intend to sell it to an acquirer.

Certain patents will provide extremely useful information to the acquirer; patents that cite the acquirer's patents, or are cited by the acquirer's patents, will involve technologies will which the acquirer is intimately familiar. Therefore we expect that these patents will be particularly important in acquisitions. Again, unfortunately we cannot construct a set of similar patents for initial public offerings, as here there is no (potential) acquirer identity to determine citation counts with. However, within acquisitions we hypothesize that VCs will add value to their firms by recognizing this and tailoring their patenting accordingly. Therefore we anticipate that VC backed firms will have patents that cite or are cited by their acquirer more than their non-VC backed counterparts. Of course, information issues are not the only reason to make this prediction and there are other reasons that yield the same hypothesize. For example, citations to and from the future acquirer might represent the technological "goodness of fit" for the acquisition, and/or might indicate economies of scale or scope.

Patents are exclusionary rights. A patent holder does not have the right to commercialize their technology if there are underlying rights held by other parties; they instead have the right to exclude other users. As argued by Ziedonis (2004), a patent with highly fragmented underlying rights, as measured by the distribution of citations that the patent makes to other patent holders, will pose greater negotiation and

transaction costs for the firm. The firm must negotiate with each right holder individually and must evaluate each of the underlying rights for their impact, rather than negotiating rights collectively with a single entity where focus can be given to a small number of important rights. Ziedonis provides evidence to support the theory that patent holders use a "proud stack" of their own patents to mitigate these negotiation problems. That is a firm with diffuse underlying rights does not suffer from the potential holdup problem if it has a large number of patents with which to negotiate, or perhaps with which to deter legal action through the threat of counter action.

Teece (1986) provides strategic prescriptions for how to profit from technological innovation. Teece's transaction cost economics based rational supposes that to commercialize an invention the firm needs outside assets. These assets might be generic, such as capital, or they might be cospecialized. A cospecialized asset is one that needs a relational specific investment, in the Williamson (1971) sense, from either the firm or an outside party, or both. Teece further argues that development occurs in two phases, a preparadigmatic phase and a paradigmatic phase. In the former a dominant design is yet to emerge and in the later a dominant design has emerged and innovation is then incremental and based on this design. In the preparadigmatic phase claims to intellectual property are less material, due to the variation in experimental designs and the high turn over of ideas. In the paradigmatic phase any firm that has, even partial, claim to the dominant design is likely to succeed, otherwise success hinges on the terms under which a firm can access cospecialized assets.

We provide two strategic predictions that we adapt from Ziedonis and reinterpret through the lens of Teece. First, firms with a small patent portfolio that makes highly fragmented citations face a hold up problem that they can mitigate through vertical integration with a holder of a large number of patents. The integration partner has a cospecialized asset that the firm needs to succeed. We name a measure of the fragmentation of citations that are made by the firm's patents when patents holdings are small as "cospecialized asset problem" and hypothesize that it will be an important predictor of acquisitions for nascent firms.

Likewise, firms whose patents receive a large number of citations and that have a large number of patents would be in a strong bargaining position according to Ziedonis. This argument was elaborated in detail with respect to software startups by Cockburn and MacGarvie (2009). We name a measure "holdup immunity" accordingly. Through a Teecean lens we might view this measure as measuring a stronger claim to the dominant design. Under either interpretation we hypothesize that this measure will be an import predictor of IPOs for nascent firms. Finally we note that firms with patent portfolios that receive large amounts of citations might have stronger claims to the dominant design, so we expect that they will be more associated with IPOs than acquisitions.

**Hypotheses**

In the previous section we described the underlying economic theory that would give rise to specific patterns of patenting with respect to venture capital backed firms and exit events. In this section we place the predictions that the theories make in the context of statistic tests. However, first we briefly discuss the nature of these tests and the essence of this paper.

This paper is essentially descriptive in nature. In the discussion section we explore how we could strengthen the tests that we undertake in order to make causal inferences. However, we make two

attempts at moving beyond correlations and towards causality in the main body of the text that would benefit from further discussion now. The first is the use of Granger causality, and the division of patenting activity for venture capital backed firms into windows. It is entirely possible, perhaps probable, that firms approach venture capitalists without patents but with patentable inventions. A patent filing arising after the first round of venture capital does not, therefore, necessarily indicate an invention arising after the first round of venture capital. We claim that this is less problematic after the second round as venture capitalists should insist that prior inventions are patented as a part of the milestone requirements needed to secure a second round. Nevertheless, we acknowledge that such problems do still exist and can undermine our interpretation.

The second attempt at moving beyond correlation towards causation applies to our strategic patenting variables. In the case of a cospecialized asset problem, for example, the economically efficient outcome of vertical integration may not be achieved if the target, or their venture capitalists, have no bargaining power. In a buyer's market for firms, acquirers may and should use their bargaining power to purchase firms that could hold them up, not firms that will be held up by them anyway. We use the bust period of 2001-2003 as an indicator variable for when all bargaining power was held by the acquirers. This (weak) instrument is justified later, but is ultimately unsuccessful. We take little solace in the observation that most empirical analyses of transaction cost economics suffer from similar problems.

We also acknowledge that in many cases we will not be able to distinguish between economic value, signaling or strategic reasons for an outcome. This weakness is also explored later in the discussion section. However, the purpose of this paper is to provide, for the first time, some evidence that venture capitalists actively tailor the patenting behavior of their firms to match their exit trajectories. That there are many reasons why they should do so does not undermine the primary finding that they succeed in doing it at all.

We now turn to the patterns that we expect to emerge in the data. Whether for economic value reasons, signaling reasons, or strategic reasons, we predict that firms with more patents will be associated with IPOs. For signaling reasons and strategic reasons (n.b. we will control for differences in economic value at exit in tests that compare VC and non-VC backed firms), we predict VC backed firms will have more patents than non-VC backed firms. Likewise we predict that more forward citations will be associated with IPOs and VC backed firms. Distinguishing between patent incidence and patenting rates conditional on patents, we believe that incidence will be more important for signaling purposes than economic value or strategic purposes, and patenting rates will be more important for economic value and strategic purposes.

Within VC backed firms we predict that VC backed firms will hold patents before first investment but are ambivalent about whether they will hold them for economic value reasons, signaling, or other purposes. Haeussler, Harhoff and Muller (2009) suggest that signaling is important here. However, for either signaling or economic value reasons, we do expect that firms that will later be successful will have more patents than firms that will later fail, and we do anticipate that firms that will later fail will show reductions in the incidents and rates of patenting post investment as they neither achieve value nor need to signal that value at exit. Between VC backed firms that IPO and VC backed firms that are acquired we expect a materially different patenting pattern. Firms that are acquired should

show a reduction in patenting before exit, whereas firms that IPO should show a continued increase in patenting.

Total citations made may indicate patent scope and so economic value, or a hold-up problem. We do not ascribe a signaling interpretation to them. While we do predict that citations to and from the acquirer have signaling value, we cannot test this across exit types. Citations to acquirers may be of some importance for economic value reasons, specifically because they are indicative of potential returns to scope and scale, but we consider this to be of second order as compared with the potential hold-up problem. On the other hand, citations from acquirers may be important for potential hold-up reasons, but we consider this to be of second order (as it would entail a small start-up holding up a large incumbent that most likely has defensive capabilities), as compared with the economic value interpretation.

For the strategic measures, we predict for both VC backed and non-VC backed firms that a cospecialized asset problem will be correlated with acquisitions and that firms that have immunity from holdup will be correlated with initial public offerings. We further predict that VC backed firms will be particularly associated with solving the cospecialized asset problem. Furthermore, as we believe that our holdup immunity measure captures both a strong strategic position and a potential claim to the dominant design we predict that this measure will be correlated with IPOs, and that VC backed firms will out perform non-venture backed firms in this regard.

We take this opportunity to belabor a point. We feel that the "hold-up immunity" prediction above could at best support a weak claim of a treatment effect. It is possible that it could support only a VC selection hypothesis. Suppose that a firm invented a crucial component of the dominant design and then used the money from its venture backers to secure more surrounding rights that gain high levels of citations. The firm would be suited to an IPO, and would perhaps IPO. Then the holdup immunity measure would be correlated with an IPO based solely on the (good) selection of an investment by a venture capitalist. The cospecialized asset measure, however, would support a weak treatment claim, perhaps even a strong treatment claim. Suppose a firm came up with a new innovation but after receiving their first investment their evolution led them to create technology that was dependent on others. Their VC, realizing this, finds them a potential acquirer. From this point on the VC stipulates that the firm must stop searching for new technologies and focus on its exit path. The firm's patent count would remain low, and its citation pattern would remain unchanged. Our assumption that firms are not financed in order to be acquired, but instead that this decision is arrived at by the VC, is obviously key[9].

## Data, Measures and Descriptive Statistics

### Data

The data was drawn from four sources and joined using name based matching. The sources were the Thompson Global New Issues (GNI) database for data on initial public offerings; the Securities Data Corporation (SDC) Mergers and Acquisitions database for data on acquisitions; the Thompson VentureXpert dabase on venture capital backed firms; and the NBER patent data for data on patent

[9] Once again, we point out the significant negative correlation between the fraction of citations to or from the future acquirer and the largest fraction of citations to or from any entity, for firms that are acquired. The acquirer is not the largest citer and cited entity, and in fact is often one of the smallest. This would make it very difficult for the venture capitalist to identify the future acquirer from citation patterns.

applications and grants. The name based matching was performed using exact matching on firm names that were normalized with Bronwyn Hall's normalization technique. Matches were confirmed with other data, such as the state of incorporation, the year of founding of the firm, or the primary industry of operation of the firm, where possible. In other work (Egan 2005) we have explored the efficacy of these matches and found that using Hall normalization and confirming matching using other data yields almost no false positive and less than 5% false negatives. Furthermore, false negatives do not appear to introduce any systematic bias.

The IPO data covers the period from 1980 to 2006, with requirements that the firm be private prior to the issue, that the issue be the first issue, that the firm be headquartered in the US, and that the listing be on a major exchange (i.e. the AMEX, NASDAQ or New York Stock Exchange). The requirement that the listing be the first listing is not made redundant by the requirement that the firm be privately held; rather it is specifically used to prevent the inclusion of leveraged buyouts (LBOs). The Acquisitions data covers the period from 1986-2006, as 1986 was the start of the available data. We required that the target be privately held prior to the acquisition, that the acquisition be completed, that the acquirer own 100% of the target post-purchase, and that both the target and the acquirer be headquartered in the US. For a small number of firms, the firm was either taken private again post-IPO and then acquired or spun-off from the acquirer and then IPO'd. In either case, we include only the first exit event. The GNI data is known to be near comprehensive, and so our 10,134 observations are approximately the population of initial public offering by US firms on major US exchanges. The SDC data, however, does not contain the population of acquisitions. Acquisitions are recorded in the data if they are recorded in SEC filings, or if they are reported in survey responses by private firms. We therefore have predominantly large acquisitions, as these meet the 'material disclosure' requirement for SEC filings and are more easily observed even if the acquirer is privately held. We have data on some 71,915 acquisitions in the period of interest, and while they are almost certainly not representative of all acquisitions, we have no reason to believe that the non-VC backed acquisitions are not a suitable control group, after controlling for observable differences, for the VC backed treatment group.

The venture capital data was drawn from VentureXpert for the period 1980-2006. Any portfolio company that received any round of investment in this period was included provided that its investment was classified as venture capital by PWC Moneytree (again to prevent the inclusion of LBOs), that the firm was headquartered in the US, and that the firm received investment from a US venture capitalist. Data from VentureXpert has substantial known issues prior to 1980, and so could not be included. Data post 1980 is known to resemble the population. Explicit details on coverage and issues relating to the VentureXpert data are explored in Kaplan, Sensory and Stromberg (2002). We have data on 26,583 venture capital backed firms that meet our criteria. Data on portfolio company exit events was determined by matching to the SDC and GNI datasets, as although VentureXpert does contain indicators for IPOs and acquisitions, these are known to be very incomplete and occasionally incorrect. In total we have 4,088 venture capital backed acquisitions, representing approximately 6% of all acquisitions in our sample, and 1,374 venture capital backed IPOs, representing approximately 14% of all initial public offerings in our sample. The truncation of venture capital investment in our dataset means that we will have some firms that we classify as having failed, that in due course will actually succeed. We do not consider this to be problematic. This truncation will make our failed group of VC backed firms appear more successful than it actually is, and any comparison between the failed group and the successful group will be inherently conservative.

We used the entirety of the NBER patent data with valid assignee names[10], covering all patents applications filed with the USPTO by all entities in all nations from 1979-2006. This was data on some 2,414,214 patents (out of 3,209,376 patents), that have in total 20,063,230 forward citations (out of a total of 23,650,891 forward citations including those accruing to patents with invalid assignee names). Full details of the data are available in Hall, Jaffe, and Trajtenberg (2001). Our 82,049 firms that experienced an exit event in our period of interest collectively held 104,129 patents prior to exit, which received a total of 1,243,050 forward citations. Thus our firms, before they exit, account for about 4% of US patents, which receive about 6.2% of all forward citations. Of all of the 26,583 venture capital backed firms that we examine, 3,396 (13%) had one or more patents. However, of the 5,462 venture capital backed firms that secured a successful exit, 1424 (26%) had one or more patents. As a point of comparison, Mann and Sager (2007) reported that about a quarter of their (successful and unsuccessful) VC backed software firms did some patenting.

**Measures**

For all exited firms, we have data on the state of the headquarters, the year of the exit, the primary NAIC code, and details of all patent applications filed. For IPOs we have the total proceeds raised for all observations, but for acquisitions the transaction value is recorded in only 23,351 cases. We refer to the total proceeds raised and the transaction value as the exit value throughout. For IPOs we have the date of founding, and so can calculate the age at exit, in about a third of cases. For acquisitions, we do not have years of founding (unless the firm is also VC backed), but we do have other acquisition characteristics including whether the acquirer was a publicly traded firm, and whether the acquisition was horizontal, vertical or conglomerate. We define horizontal acquisitions as those where the target and the acquirer have identical 6 digit NAIC codes, vertical acquisitions as those where the target and the acquirer have the same 2 digit NAIC codes but not the same 6 digit NAIC codes, and conglomerate acquisitions as all other acquisition that are not horizontal or vertical.

The data on venture capital backed firms provides us with measures of the number of rounds of investment, the total amount of investment, and the date of founding as well as at each round of investment. We preprocess the venture capital data to merge together rounds that occur in the same calendar year, in part because VentureXpert often misclassifies tranches as rounds and in part because we want to use rounds as milestones and measure patenting rates between them.

With respect to the patent data, we are able to determine the number of patents that any firm has filed for pre-exit, and in the case of venture capital backed firms pre-VC and between the various rounds of investment received and exit. Likewise we calculate the total citations that accrue to these patents, as well as the total citations to or from any future acquirer. We also replicate the fragmentation measure of Ziedonis (2004) and create an analogous variable that measures the fragmentation of the citations received. Our measure "Cospecialized Asset Problem" is constructed as the interaction of the Ziedonis fragmentation measure with an indicator variable that takes the value one if the firm has less than the median number of patents conditional on patenting (i.e. 3 patents) and zero otherwise; and our measure "Holdup Immunity" is constructed as the interaction of the fragmentation of citations received with an

[10] Assignee names were not systematically recorded prior to 1979. The data without valid assignee names is predominantly from the period 1963-1979. We only use this data for determining citation (made) variables where the identity of the cited entity is unimportant.

indicator variable that takes the value one if the firm has more than the 95th percentile[11] of patents conditional on patenting (i.e. more than 28 patents) and zero otherwise. Both Ziedonis's fragmentation measure and our forward citation fragmentation measure are defined below. We are aware of the problems of censoring with citation data and of biases in Herfindahl-type measures on count data (see Hall 2005) but are unable to address them in this version of the paper due to technical limitations[12]. Year fixed effects should address any censoring issues or count inflation issues relating to the patents, and should address at least a part of the problem with the citations.

Ziedonis's fragmentation measure is defined as:

$$FRAG_i = 1 - \sum_{j=1}^{J} \left( \frac{NBCITES_{ij}}{NBCITES_i} \right)^2, \quad i \neq j$$

Our forward citation fragmentation measure is defined as:

$$RECFRAG_i = 1 - \sum_{j=1}^{J} \left( \frac{NFCITES_{ij}}{NFCITES_i} \right)^2, \quad i \neq j$$

Our "Cospecialized Asset Problem" measure is defined as:

$$FRAG_i \times \mathbb{I}(NoPatents \leq NoPatents_{50pc})$$

Our "HoldUp Immunity" measure is defined as:

$$RECFRAG_i \times \mathbb{I}(NoPatents \geq NoPatents_{95pc})$$

**Descriptive Statistics**

In table 1 we report some basic descriptive statistics for full sample, our sample conditional on a firm conducting some patenting, and our sample conditional on a firm receiving venture capital. We report counts, means and standard deviations for all exits, IPOs only and acquisitions only respectively, for the raw variables. We caution readers that many of these variables are significantly skewed. A Kolmogorov-Smirnov test rejects the null hypothesis that the exit value measure is normally distributed and that the measures of numbers of patents and citations follow a negative binomial distribution. We therefore take the log of one plus these variables to correct their distributions when we use them in the econometrics; however, we report the raw variables here as we find this most instructive.

[11] We experimented with using the 95th percentile for both fragmentations measures, as well as the median, the 75th percentile and the 99th percentile. The patent of results was similar throughout but the coefficients changed materially. We selected the median and 95th percentile respectively in part because their effects were clear, and in part because we found their values meaningful. 3 patents (the median) is a small number of patents to hold at exits, whereas 28 patents is a fairly 'proud stack'.

[12] The author requested an installation of PostgreSQL on the Bear high-performance computing cluster so that these issues could be addressed at the start of June 2010. The code to address these issues is complete and awaits the availability of a sufficiently powerful database server. At present the CTO of Haas estimates that a database server will be available for use at the start of August.

Table 1: Descriptive Statistics

The table provides descriptive statistics for all exits, IPOs only, and acquisitions only, and includes sections conditional on patenting and conditional on VC. The full sample of all exits has 82049 observations, of which 10134 are IPOs, and 71915 are acquisitions. The table reports the availability of variables, as well as their means and standard deviations.

| | All Exits | | IPO | | Acquisitions | |
|---|---|---|---|---|---|---|
| | N | μ(σ) | N | μ(σ) | N | μ(σ) |
| **Full Sample** | | | | | | |
| Exit Value ($m) | 33485 | 62.5 (218.5) | 10134 | 81.2 (252) | 23351 | 54.3 (201.7) |
| No. of Patents | 82049 | 1.3 (55.7) | 10134 | 2.4 (43.9) | 71915 | 1.1 (57.2) |
| Age At Exit | 7350 | 9.6 (13.4) | 3913 | 11.4 (16.4) | 3437 | 7.5 (8.3) |
| Acquirer Public Status | 71915 | 0.5 (0.5) | - | - | 71915 | 0.5 (0.5) |
| Horizontal Acquisition | 71915 | 0.3 (0.5) | - | - | 71915 | 0.3 (0.5) |
| Vertical Acquisition | 71915 | 0.2 (0.4) | - | - | 71915 | 0.2 (0.4) |
| Conglomerate Acquisition | 71915 | 0.4 (0.5) | - | - | 71915 | 0.4 (0.5) |
| **Conditional On Patenting** | | | | | | |
| Exit Value ($m) | 3405 | 75.2 (267.7) | 1538 | 67.7 (322.7) | 1867 | 81.5 (211.9) |
| No. of Patents | 6179 | 16.9 (202.5) | 1538 | 16.1 (111.7) | 4641 | 17.1 (224.6) |
| Citations Made | 6179 | 141.6 (1483.1) | 1538 | 151.5 (583) | 4641 | 138.4 (1678.1) |
| Citations Received | 6179 | 201.2 (2136.5) | 1538 | 234.2 (960.1) | 4641 | 190.2 (2402.5) |
| Cospecialized Asset Prob. | 6179 | 0.4 (0.4) | 1538 | 0.3 (0.4) | 4641 | 0.4 (0.4) |
| Holdup Immunity | 6179 | 0.05 (0.2) | 1538 | 0.07 (0.2) | 4641 | 0.04 (0.2) |
| Cites From Acquirer | 4641 | 0.3 (3.7) | - | - | 4641 | 0.3 (3.7) |
| Cites To Acquirer | 4641 | 0.6 (4.7) | - | - | 4641 | 0.6 (4.7) |
| **Conditional On VC (and Patenting)** | | | | | | |
| Exit Value ($m) | 3236 | 73.6 (196.8) | 1374 | 47.5 (73.1) | 3236 | 73.6 (196.8) |
| No. Patents | 1435 | 20.3 (279.3) | 510 | 10.3 (14.4) | 925 | 25.8 (347.7) |
| Citations Recieved | 1435 | 292.3 (3150.7) | 510 | 244.7 (491.6) | 925 | 318.6 (3907.8) |
| No. of Rounds | 5462 | 3.7 (2.8) | 1374 | 4.3 (3) | 4088 | 3.5 (2.7) |
| Investment ($m) | 5259 | 30.3 (61.2) | 1327 | 38.4 (75.3) | 3932 | 27.6 (55.3) |
| Age at First Investment | 3255 | 5.1 (8.3) | 899 | 5.3 (7.9) | 2356 | 5 (8.5) |
| Time To Exit | 4727 | 4.6 (3.6) | 1232 | 4.2 (3) | 3495 | 4.7 (3.8) |

In the full sample IPOs are larger, in terms of exit value, than acquisitions, and the average number of patents, whilst low, follows this trend. Firms are, on average, about 10 years old when they exit, confirming that this is a valid sample of start-up firms. Acquisitions are spread evenly between publicly held and privately held acquirers, and there is a reasonable mix of horizontal, vertical and conglomerate acquisitions. Conditional on patenting, the exit value of firms is comparable, perhaps slightly higher. On average firms have about 17 patents and make about 150 citations, no matter their exit path, when they patent at all. The average total number of citations received is on the order of 200, with perhaps firms that IPO receiving more. Our "cospecialized asset problem" and "holdup immunity" measures lie in the range of zero to one. Conditional on patenting we find that the acquisitions are associated with slightly higher values of "cospecialized asset problem", and that IPOs are associated with notably higher values of "holdup immunity". Citations to and from acquirers are rare, with firms that

patent and get acquirer having on average less than a single citation to or from their acquirer, though the large standard deviation indicates that for a small number of firms this is not the case.

VC backed firms do not appear too different from the full sample with respect to exit value and the total number of patents. However, it seems probable, despite the high standard deviation, that they receive more citations. On average a VC backed firm received about 4 rounds of investment, totaling an average of $30m to $40m of disclosed investment. VC backed firms were, on average, five years old when the received their first investment, and then took an average of about 4.5 years to exit.

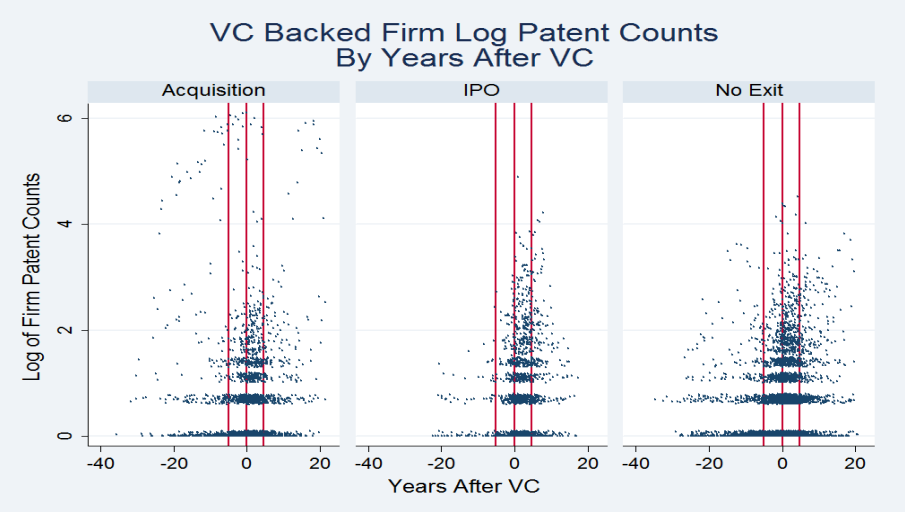
## Results and Analysis

### Patenting by VC Backed Firms

We begin our analysis with an examination of patenting behavior by VC backed firms. As we do not have a control group of non-VC backed firms for firms that do not exit, and as it is unclear how to determine when our control group of exited non-VC backed firms would have obtained venture capital, we adopt a Granger causality approach, dividing the time from founding to exit into windows and then t-testing the difference between windows.

Before we create our windows, it is instructive to get a feel for the data. Figure 1 shows scatter plots of the log of patent counts a firm receives before exit against the number of years after first investment. For guidance we include three vertical lines: the first shows the mean time of founding, the second is at zero (the first round of investment), and the third shows the mean time of exit. In the case of the firms that did not exit, we arbitrarily imposed a limit of five years after the last round of investment on the sample of patents. In unreported tests we experimented with using all patent applications ever filed (within the limits of the patent data), and found that the imposition of a five year limit post last round of investment did not materially affect the results, and that the number of patents post-VC was not significantly different using either window. We refer to this five year cut-off as the exit year for firms that did not exit.

Figure 1: Scatter Plot of Patents Counts by VC Exit Type



A casual examination of the plots would seem to reveal three findings: First, for all three groups there are a material quantities of patents filed before the first round of venture capital. Second, the weight of patent filings occur post-VC for the set of firms that will later IPO, and perhaps for the other two sets of firms. Third, firms that will later IPO appear to have higher patent counts more frequently than firms that are acquired, and given than there are far fewer firms that IPO, these firms probably have higher patent counts more frequently on a per firm basis than firms that do not exit.

In table 2 we conduct t-tests using the windowing approach. The windows are defined as: the period from founding to the first round investment inclusive of the year of first investment, the period from one year following the first investment to exit; the period from one year following the second distinct round of investment (note that to be distinct a round must occur in a different and later year than the previous round) conditional on receiving a second round of investment and exiting more than one year later; and the period from one year following the third distinct round of investment to exit conditional on receiving a third round of investment and exiting more than one year later. The single year separations are used to aid in causal interpretation. That is a filing that occurred in the same year as the first round of investment say, may have occurred before or after the first round, but a filing that occurred at least one year following the round must have occurred after the round. As this may classify patents that occur after venture capital as occurring before, but not vice versa, our results are inherently conservative.

The results are presented for four samples: VC backed firms with successful exits, with no exit, with an IPO, and with an acquisition. Two types of results are presented for each sample: results using an indicator variable that takes the value one if the firm patented in the window and zero otherwise; and results using the log of the annual patenting rate within the window conditional on a firm having at least one patent at some point pre-exit or within five years of the date of last investment for the firms that did not successfully exit.

The first thing to notice from table 2 is that whether the firm patented and the log patenting rate for every window and every sample is highly statistically significantly different from zero. VC backed firms do patent, irrespective of their ultimate exit. They patent before receiving venture capital and they patent after receiving venture capital. We do not focus on the set of VC backed firms that did not exit in this paper, as we have no control group to compare them against. However, panel 2A columns 3 through 6 provide some basic results on patenting behavior for this set. The results indicate that firms reduce their incidence and rate of patenting following the first round of venture capital. The rate drops by about a quarter after the first round of investment and is at half the pre-venture capital rate for firm after the second round of investment for firms that have a second round of investment.

For successful firms the incidence and rate of patenting increases after receiving venture capital and then drops slowly. However, this overall effect masks two dramatically different underlying effects. Firms that will later IPO see strong rises in the incidence and rate of patenting that persist past the first round of venture capital.

## Table 2: Patenting Rates Before and After Venture Capital

The panels below present the results of t-tests. In both panels the first set of variables are indicators for whether a firm had any patents during a certain period, and the second set of variables is the patenting rate per year contingent on a firm having at least one patent pre-exit. The rate is calculated only for firms with patents that have disclosed founding years. In the case of firms without exits, a date of five years post the final round of investment was used as cut-off. In unreported tests, total volumes of patents without the cutoff are no significantly different from those occurring within the cutoff. The column "difference to before VC" reports a t-test against the incidence or count before VC, rather than against zero, and is null for patents before VC.

Panel 2A: Successfully Exited Firms and Firms without Exits

| | Successful Exit | | | No Exit | | |
|---|---|---|---|---|---|---|
| | N | Coefficient (Std Error) | Difference To Before VC | N | Coefficient (Std Error) | Difference To Before VC |
| Patent Before VC | 5462 | 0.15 (0.005***) | - | 21155 | 0.062 (0.002***) | - |
| Patent After VC | 5462 | 0.194 (0.005***) | 0.044 (0.007***) | 21155 | 0.056 (0.002***) | -0.006 (0.002***) |
| Patent After Second Round | 5462 | 0.128 (0.005***) | -0.022 (0.007***) | 21155 | 0.03 (0.001***) | -0.032 (0.002***) |
| Patent After Third Round | 5462 | 0.078 (0.004***) | -0.072 (0.006***) | 21155 | 0.018 (0.001***) | -0.044 (0.002***) |
| Log Rate Before VC | 1186 | 0.358 (0.016***) | - | 1557 | 0.383 (0.013***) | - |
| Log Rate After VC | 1431 | 0.546 (0.017***) | 0.188 (0.023***) | 1972 | 0.258 (0.009***) | -0.125 (0.016***) |
| Log Rate After Second Round | 1432 | 0.401 (0.016***) | 0.043 (0.023*) | 1972 | 0.154 (0.008***) | -0.229 (0.015***) |
| Log Rate After Third Round | 1433 | 0.259 (0.014***) | -0.099 (0.022***) | 1972 | 0.093 (0.006***) | -0.29 (0.015***) |

Panel 2B: VC Backed Firms that had an IPO or Acquisition

| | IPO | | | Acquisition | | |
|---|---|---|---|---|---|---|
| | N | Coefficient (Std Error) | Difference To Before VC | N | Coefficient (Std Error) | Difference To Before VC |
| Patent Before VC | 1374 | 0.172 (0.01***) | - | 4088 | 0.142 (0.005***) | - |
| Patent After VC | 1374 | 0.328 (0.013***) | 0.156 (0.016***) | 4088 | 0.148 (0.006***) | 0.006 (0.008) |
| Patent After Second Round | 1374 | 0.241 (0.012***) | 0.069 (0.015***) | 4088 | 0.09 (0.004***) | -0.052 (0.007***) |
| Patent After Third Round | 1374 | 0.154 (0.01***) | -0.017 (0.014) | 4088 | 0.052 (0.003***) | -0.09 (0.006***) |
| Log Rate Before VC | 446 | 0.304 (0.026***) | - | 740 | 0.391 (0.021***) | - |
| Log Rate After VC | 507 | 0.811 (0.03***) | 0.507 (0.039***) | 923 | 0.401 (0.018***) | 0.01 (0.028) |
| Log Rate After Second Round | 508 | 0.659 (0.033***) | 0.355 (0.042***) | 923 | 0.259 (0.016***) | -0.132 (0.026***) |
| Log Rate After Third Round | 510 | 0.448 (0.031***) | 0.144 (0.04***) | 923 | 0.155 (0.013***) | -0.236 (0.025***) |

***, **, * indicate significance at the 0.01, 0.05 and 0.1 level, respectively

For these firms that will IPO, the incidence of patenting almost doubles post investment and does not drop back to below the pre-VC incidence until after the third round. But more importantly, for firms that have a patent at some point, the patenting rate almost triples post investment, remains at double the rate post the second round of investment and is still 30% higher than the pre-investment rate after the third round of investment. On the other hand, firms that will later be acquired see no significant rise in the incidence or rate of patenting post investment, and see a dramatic fall in both the incidence and the rate after the second round of investment. We will return to explanations of these effects later.

We conducted this analysis for two reasons. The first is that we need evidence that VC backed firms do actually patent. While this may seem trivial, without evidence of patenting, there is no point in any further discussion of patenting strategy. Clearly we have succeeded in this regard. The second reason is that we want to take a first look at the patterns that emerge between patenting behavior and exit. As there are noticeable patterns and we now discuss them with respect to our hypotheses.

The difference between the incidence of patenting for successful and non-successful (i.e. no exit) before first investment is 0.088 (0.005***)[13]. Using incidence as the first order consideration for signaling it appears we have evidence consistent (on average and for large samples) with a separating equilibrium signaling equilibrium on quality of firms financed by VCs. It is also consistent with an economic value interpretation – patents confer value and higher value firms are more likely to succeed. The difference between the incidence of patenting VC backed IPO and acquisitions before first investment is 0.030 (0.012), which is not statistically significant. This would be consistent with the assumption that VCs are unable to distinguish between firms that will later IPO and firms that will later be acquired at the time of first investment.

Using the log rate of patenting conditional on patenting we find that the pre-investment difference between successful and non-successful firms, 0.025 (0.13), is not statistically significant. If having a patent is first order for signaling, and the volume of patents is first order for economic value, this would be consistent with a signaling hypothesis and not an economic value hypothesis. On the other hand, for the difference between patenting rates pre-investment for VC backed IPOs and acquisitions is 0.086 (0.033***). Again with signaling first order on incidence and economic value first order on rates, this would suggest that successful firms send a pooled signal to the VCs, but that firms that will ultimately be acquired have more patents conditional on patenting before the first round of investment. This second finding is slightly puzzling – our economic theory arguments would have predicted the opposite. However, comparing the rates after VC investment, we find the predicted pattern. The difference in incidence, 0.288 (0.019***), and the difference in rate, 0.41 (0.035***), are both large, positive and highly statistically significant. VC backed firms that patent heavily after the first round of investment are very firmly associated with initial public offerings.

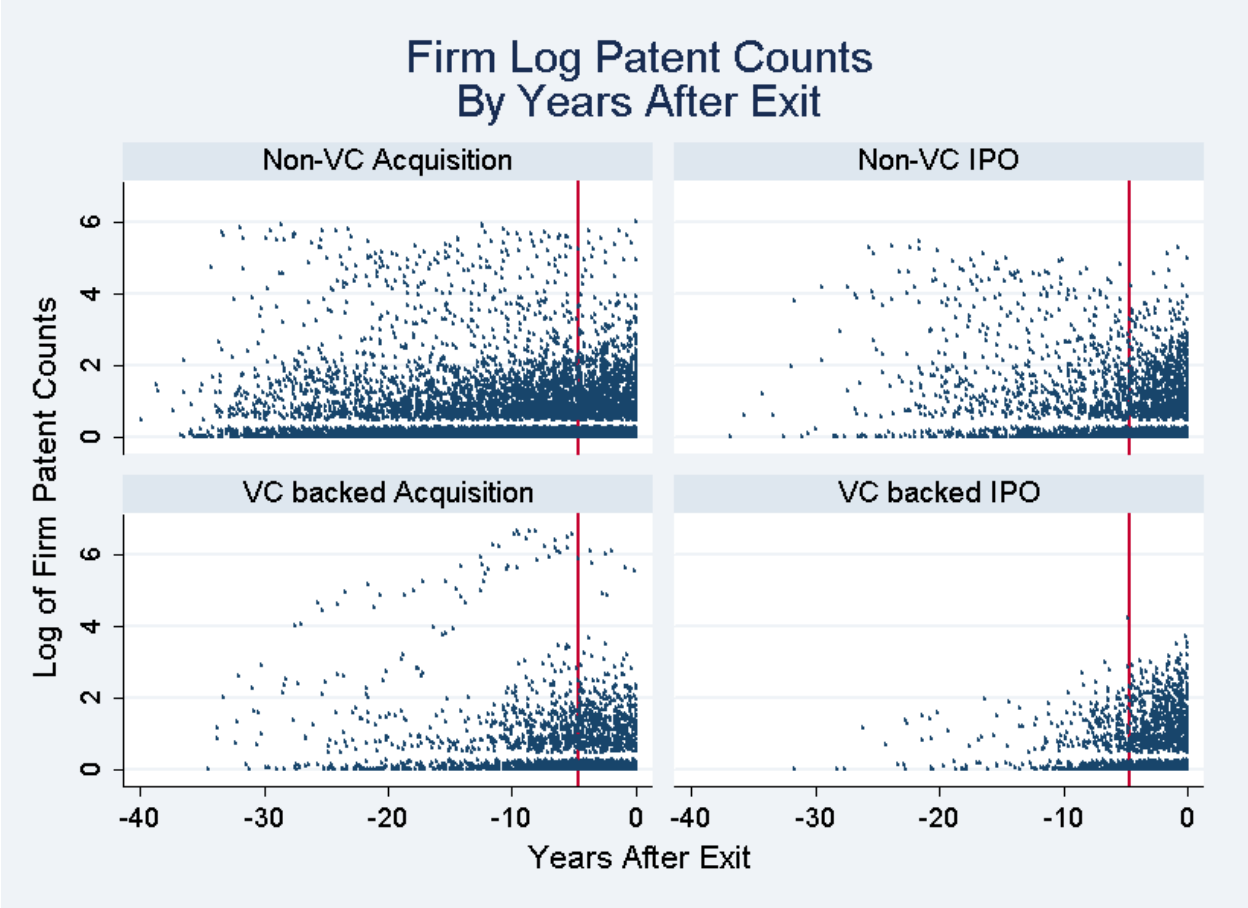
Overall the pattern that emerges over the rounds of investment is consistent with our economic value arguments and our signaling arguments: For firms that will fail, patent incidence and rates drop continuously relative to before VC; for firms that will be acquired, the incidence and rate increases and then falls back below the pre-VC level as the exit approaches; and for firms that will IPO the rate increases dramatically and stays well above the pre-investment all the way to exit.

[13] Whenever we report statistics in the body of the text we report coefficients with standard errors in parentheses with asterisks to denote significance at the 0.1, 0.05 and 0.01 levels, for *,**, and ***, respectively.

**Comparing VC-backed firms to non-VC backed firms**

We now turn to estimating the effect of venture capital, whether through selection of firms by venture capitalists or through their treatment of firms. We use the non-VC backed IPOs and acquisitions as a control group, claiming that, after controlling for observable differences, this is a group of start-up firms that are at risk of receiving venture capital but did not. However, before the estimations we present scatter plots of the log of patent counts by years after exit (i.e. the years are numbered from -40 to 0, where -40 is 40 years before exit). The plots include a vertical line at -4.6 to indicate the mean time when a venture capital backed firm receives its first investment relative to exit.

Figure 2: Scatter Plot of Patenting – VC exit type against Control Groups




Two main observations should be noted with regard to figure 2. First, the non-VC acquisitions and IPOs have much longer tails in their distributions; that is they have many more patents occurring much further from the exit event. Patents confer rights for 20 years, so patents more than 20 years from exit have no economic or strategic value. Practically all VC backed patents occur within 20 years of exit, whereas many patents accruing to non-VC backed firms, particularly for firms that will be acquired, occur earlier. This, in part, may be an age effect. Despite the mean age at exit being comparable for VC and non-VC backed firms, there are many non-VC backed firms with patents that have extensive operating histories, whereas this is comparatively rare for VC backed firms. An age effect would be particularly problematic for the firms that get acquired, as for these firms we have no date of founding for non-VC

backed start-ups and so are unable to correct for their comparative maturity. The second important observation is the difference between firms that will IPO and firms that will be acquired in terms of their patenting activity pre-exit. There is a clear upward trend over the ten years before exit of patenting for firms that will secure an initial public offering, but firms that will be acquired appear roughly flat in their patenting activity over the period.

Tables 3 and 4 present the empirical tests of the difference in patenting between VC and non-VC backed firms. Table 3 provides the results of Logit estimations using a binary indicator of patenting incidence as the dependent variable. Table 4 provides the results of OLS estimations using log patenting and forward citation rates conditional on patenting at some point. As the header to table 4 notes, we would have preferred to present the estimation of negative binomial models, but had convergence issues. The results we do present are very similar, despite the differences in the estimation techniques.

Table 3: Pre-Exit Patenting – VC versus a Control Group

The dependent variable is a patenting indicator, taking the value of one if a firm filed for at least one patent pre-exit and zero otherwise. The estimation uses a Logit model with heteroskedastic correction to standard errors. The three specifications are all exits, acquisitions only, and IPOs only, with respective controls. The sample size is dramatically reduced by the inclusion of the exit value measure, which weakens the significance of the other measures slightly; though the coefficients on the other measures are slightly reduced, the inclusion or exclusion of an exit value control does not materially affect the results.

| | All Exits | Acquisitions | IPOs |
|---|---|---|---|
| VC Backed | 0.896<br>(17.47***) | 0.987<br>(14.16***) | 0.739<br>(7.71***) |
| Log of Exit Value ($m) | 0.000<br>(4.51***) | 0.000<br>(5.05***) | 0.000<br>(1.90*) |
| Bust Period Indicator | -0.139<br>(-0.54) | 0.850<br>(3.44***) | -0.73<br>(-0.92) |
| Acquisition Indicator | -0.693<br>(-14.23***) | - | - |
| Acquirer Publicly Traded | - | -0.091<br>(-1.46) | - |
| Horizontal Acquisition | - | -0.24<br>(-3.57***) | - |
| Vertical Acquisition | - | 0.183<br>(2.92***) | - |
| Age at IPO | - | - | 0.00<br>(0.94) |
| State Fixed Effects | yes | yes | yes |
| Year Fixed Effects | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes |
| Constant | -1.516<br>(-1.76*) | -3.964<br>(-3.15***) | 2.357<br>(0.79) |
| R-Squared | 0.2227529 | 0.1930302 | 0.2117171 |
| No. Observations | 33480 | 23324 | 3733 |

Results are reported as coefficients with z-scores in parentheses.
***, **, * indicate significance at the 0.01, 0.05 and 0.1 level, respectively

In both tables 3 and 4 we present the results for all exits, which include a binary 'acquisition indicator' variable, as well the result with the sub-samples of acquisitions and IPOs. In the sub-sample we use all of the exit event specific controls that are available to us, and in all specifications we include state,

year and industry fixed effects. Industry fixed effects are created using the primary two-digit NAIC code of the firms. The inclusion of these fixed effects is crucial and we do not report results without them. The fixed effects have considerable explanatory power, and fully explain the outcome for many observations.

The findings in table three indicate that being venture capital backed is highly correlated with having patents, no matter the exit type. Taking a relative likelihood interpretation, VC backed firms are almost 90% more likely to have some patents. The results also show that larger exits are more likely to have patents, though the coefficient is negligible, and overall acquisitions are associated with a 70% lower likelihood of having any patents. For acquisitions VC backed firms are very highly correlated with patenting prior to exit; VC backed firms are 99% more likely to have some patents at acquisition. Perhaps surprisingly, horizontal acquisitions are associated with less patenting, and vertical acquisitions are associated with more patenting, with conglomerate acquisition as the omitted reference category.

Table 4: Pre-Exit Patent Counts and Citations Received

The dependent variables are the log of one plus the number of patents or one plus the number of forward citations respectively. Observations must have at least one patent (pre-exit) to be included. The estimation uses OLS with heteroskedastic correction to standard errors. Very similar results were achieved using count data and a negative binomial model, but there were frequent convergence issues. For each dependent variable the three specifications are all exits, acquisitions only, and IPOs only, with respective controls. Again, the sample size is dramatically reduced by the inclusion of the exit value measure, though this does not materially affect the results.

| | Log of No. Patents | | | Log of Forward Citations | | |
|---|---|---|---|---|---|---|
| | All Exits | Acquisition | IPOs | All Exits | Acquisition | IPOs |
| VC Backed | 0.104<br>(2.96***) | 0.020<br>(0.42) | 0.248<br>(3.43***) | 0.375<br>(6.33***) | 0.200<br>(2.37**) | 0.550<br>(4.69***) |
| Log of Exit Value ($m) | 0.001<br>(4.65***) | 0.001<br>(2.80***) | 0.000<br>(0.13) | 0.001<br>(4.29***) | 0.001<br>(2.45**) | 0.000<br>(0.45) |
| Bust Period Indicator | 0.395<br>(2.69***) | -0.051<br>(-0.20) | 0.361<br>(0.60) | -0.595<br>(-2.15**) | -0.916<br>(-2.89***) | -1.261<br>(-1.48) |
| Acquisition Indicator | -0.363<br>(-8.75***) | - | - | -0.435<br>(-6.67***) | - | - |
| Acquirer Publicly Traded | - | -0.019<br>(-0.37) | - | - | 0.080<br>(0.89) | - |
| Horizontal Acquisition | - | -0.134<br>(-2.30**) | - | - | -0.259<br>(-2.62***) | - |
| Vertical Acquisition | - | -0.098<br>(-1.87*) | - | - | -0.114<br>(-1.25) | - |
| Age at IPO | - | - | 0.021<br>(4.80***) | - | - | 0.021<br>(3.57***) |
| State Fixed Effects | yes | yes | yes | yes | yes | yes |
| Year Fixed Effects | yes | yes | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes | yes | yes |
| Constant | 1.506<br>(4.67***) | 1.326<br>(3.50***) | 2.446<br>(4.64***) | 4.783<br>(10.41***) | 4.250<br>(7.70***) | 6.626<br>(7.53***) |
| R-Squared | 0.1421577 | 0.1021286 | 0.2466433 | 0.1894638 | 0.1499375 | 0.2918729 |
| No. Observations | 3405 | 1867 | 890 | 3405 | 1867 | 890 |

Results are reported as coefficients with t-statistics in parentheses.
***, **, * indicate significance at the 0.01, 0.05 and 0.1 level, respectively

It also appears that acquirers may have taken advantage of the bust period of 2001 to 2003 (described in detail later) to purchase targets with patents. Whether or not the acquirer was publicly traded

at the time of the acquisition is not significantly correlated with the presence of patents in the target. For IPOs we find that the exit value effect is less significant, and that the age of firms at IPO is irrelevant. Both of these results are somewhat reassuring, as they suggest that if VC backed firms are relatively homogenous with respect to these variables then the IPO control group, at least, is valid.

Table 4 tells a similar story with the log of the total number of patents conditional on some patenting, with a few notable exceptions. First, in the bust period firms that patented at all are associated with having more patents. Second, although VC backed firms were positively correlated with having patents in firms that are acquired, they are not significantly correlated with having higher numbers of patents, though from the forward citation measure we infer that the patents that they did have were more important. Third, the bust period indicator is not correlated with having more patents for firms that were acquired, and it seems that these acquirers were buying firms with dramatically fewer forward citations in this period

This section seeks to answer the question "Are venture capital backed firms associated with more patenting that non-venture capital backed firms?" While there may be issues with our control group of non-venture capital backed firms that are not addressed by our fixed effects and other controls, we believe that this is the first direct test of this very important question in the literature. The findings are consistent with venture capital backed firms having a higher incidence and conditional rate of patenting. Furthermore, consistent with our predictions, acquisitions are associated with less patenting than IPOs, at least once one has controlled for the presence of venture capital. This section does not address whether this is due to a selection or treatment effect.

**Patenting Strategy for Acquisition Targets**

We now turn to an examination of the determinants of exit type using the pre-exit patenting behavior of firms. In table 5 the dependent variable is an indicator that takes the value one if the exit is an acquisition and zero if it is an IPO. We remind readers that we only have exit value for a fraction of acquisitions, so including this control dramatically reduces our sample size. However, specification 2 shows that the results are largely robust to the exclusion of this variable, with the notable exception of our "immunity from holdup measure". Specification 1 shows that on average larger exit values are associated with IPOs. We posit and find that firms that are immune from hold-up are also associated with IPOs. In fact these measures are highly statistically significantly positively correlated. The immunity from hold up measure is positive when the firm patents at or above the $95^{th}$ percentile (conditional on patenting) level, and is increasing in fragmentation of citations received, which itself is increasing in the citations received, which is a measure of the importance of the patents. Thus the measure captures not only a high level of highly valuable patenting but also the hold-up. While we control for the patenting and citations received separately, it seems likely that these controls are not sufficient.

In table 5 specifications 1 and 2, we find that acquisitions are associated with more patenting, but with lower patent scope. Patent importance is not a significant predictor of exit type, but the having the cospecialized asset problem is – firms with higher cospecialized assets problems are significantly more likely to be acquired. However, specification 3 tells a more elaborate story. For VC backed firms we find that acquisitions are associated with less patenting and that patenting scope and importance is increased relative to non-VC backed firms in acquisitions. For VC backed firm a cospecialized asset problem is highly statistically significantly associated with acquisitions, and once we control for whether the

cospecialized asset problem relates to a VC backed or non-VC backed firm, we find that for non-VC backed having a cospecialized asset problem is immaterial.

Table 5: Determinants of Acquisitions

The dependent variable is a binary indicator for whether the exit is an acquisition. The estimation uses a Logit model with heteroskedastic correction to standard errors. Specifications 1 and 2 differ in the inclusion of the log of exit value. Coefficients for other explanatory variables are generally robust to this inclusion, but the loss of power from the loss of sample size affects the fine-grained results in specifications 3 and 4, and so exit value is omitted in these specifications. The effect of exit value on immunity from holdup is discussed in the text.

| | Specification 1 | Specification 2 | Specification 3 | Specification 4 |
|---|---|---|---|---|
| Log of Exit Value ($m) | -0.538<br>(-47.41***) | - | - | - |
| Log of No. Patents | 0.394<br>(3.61***) | 0.365<br>(4.27***) | 0.412<br>(3.97***) | 0.412<br>(3.96***) |
| Log of Citations Made | -0.370<br>(-7.99***) | -0.455<br>(-12.60***) | -0.443<br>(-10.25***) | -0.446<br>(-10.30***) |
| Log of Citations Rec'd | -0.029<br>(-0.76) | -0.039<br>(-1.20) | -0.056<br>(-1.39) | -0.054<br>(-1.33) |
| Cospecialized Asset Problem | 0.336<br>(3.17***) | 0.209<br>(2.37**) | 0.060<br>(0.60) | 0.061<br>(0.60) |
| Immunity From Holdup | -0.167<br>(-0.70) | -0.433<br>(-2.29**) | -0.443<br>(-1.94*) | -0.443<br>(-1.94*) |
| VC Backed | - | - | -1.156<br>(-22.27***) | -1.111<br>(-20.02***) |
| VC * Log of No. Patents | - | - | -0.348<br>(-1.70*) | -0.346<br>(-1.69*) |
| VC * Log of Citations Made | - | - | 0.144<br>(1.74*) | 0.160<br>(1.93*) |
| VC * Log of Citations Rec'd | - | - | 0.115<br>(1.68*) | 0.099<br>(1.45) |
| VC * Cospecialized Asset Problem | - | - | 0.612<br>(2.92***) | 0.624<br>(2.83***) |
| VC * Immunity From Holdup | - | - | -0.366<br>(-0.87) | -0.35<br>(-0.85) |
| Bust Period Indicator | - | - | - | 22.370<br>(13.47***) |
| VC * Bust | - | - | - | -0.307<br>(-2.61***) |
| VC * Bust * Cospecialized Asset Problem | - | - | - | -0.056<br>(-0.14) |
| State Fixed Effects | yes | yes | yes | yes |
| Year Fixed Effects | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes |
| Constant | -17.978<br>(0.00***) | -19.290<br>(0.00***) | -19.293<br>(-4.99***) | -18.107<br>(-9.87***) |
| R-Squared | 0.2571283 | 0.1960595 | 0.206224 | 0.2063626 |
| No. Observations | 31685 | 80240 | 80240 | 80240 |

Results are reported as coefficients with z-scores in parentheses.
***, **, * indicate significance at the 0.01, 0.05 and 0.1 level, respectively

In specification 4 we include a bust period indicator and interaction effects for the bust period with VC measures. In the figures 4 and 5, below, we provide visual evidence that the bust period was

associated with a precipitous drop in IPO volumes and values, but that the M&A market was only slightly affected. We argue that this shifted all bargaining power to the acquirers. Firms were now dramatically less able to secure an IPO and could only exit through acquisition. This would particularly affect VC backed firms, as VCs generally must exit their investment on a constrained timetable. Thus we argue that VCs were forced to exit firms through acquisition that they would have liked to have exited through IPO in this period. To the degree that the crash came as a shock (the negative IRRs for VCs during this period provide some evidence that this did come as a shock), we expect that the patenting strategies could not be adapted.

Figure 4: Log Counts of Exit Events by Year and Type

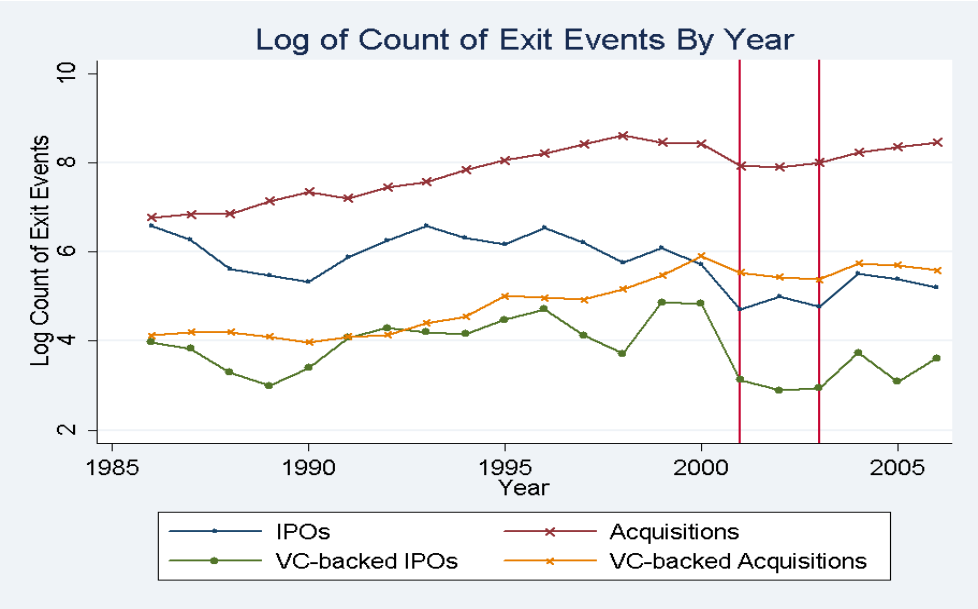
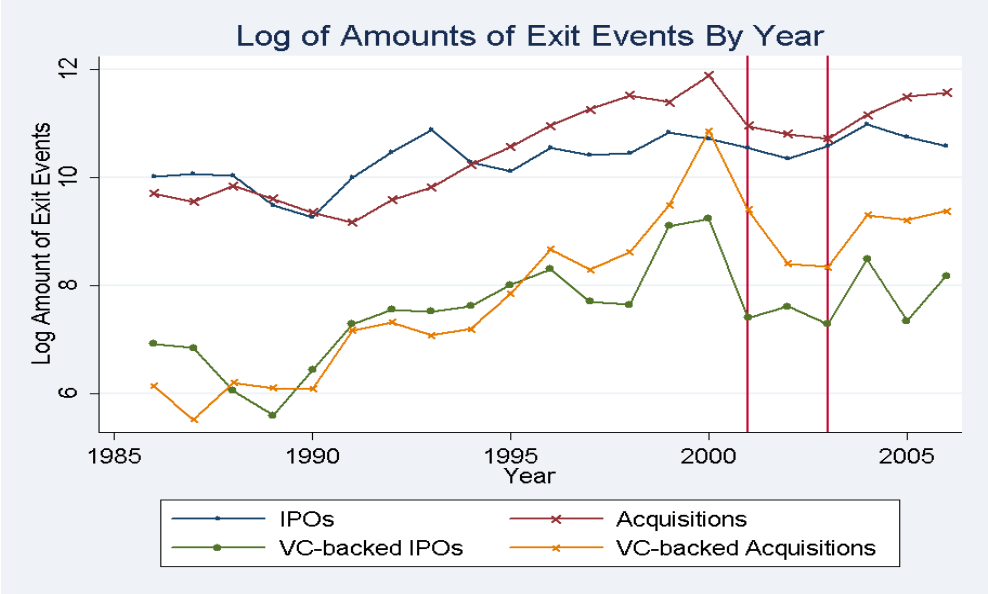



Figure 5: Log of (recorded) Amounts of Exit Events by Year and Type



Unfortunately this instrument does not have the predicted consequences. The coefficients from specification 3 are robust to the inclusion of these new variables in specification 4. And while the bust period clearly was associated with a massive relative increase in acquisitions (the coefficient is approximately 22 on the bust variable, and highly statistically significant), VC backed firms appear to have achieved relatively more IPOs. The sign on the VC-Bust-Cospecialized Asset Problem interaction is negative, but the coefficient is statistically insignificant.

In table 5 we took our first look at the nature of the patenting (conditional on firms having at least one patent) and its relationship with the exit type, rather than just the volume. However, we first discuss a puzzling volume finding. Across all specifications it appears that having more patents is associated with acquisitions not IPOs. This is in direct contradiction to our hypotheses regarding signaling and economic value. A careful inspection of the results, though, reveals that this puzzling finding is limited to non-VC backed firms. VC backed firms behave consistent with our predictions in this regard. The negative coefficients on the VC indicator and on the interaction term between the VC indicator and the number of patents support this result. The signs on the VC interaction with the log of citations made and received are also negative, in stark contrast to the signs on these measures for non-VC backed firms. These findings alone suggest that VC backed firms have different patenting strategies with respect to their ultimate exit types than non-VC backed firms. It seems difficult to attribute this to a selection effect alone, assuming that the control group is valid and genuinely at risk of receiving venture capital prior to exit.

Perhaps the most interesting finding from table 5 regards the "cospecialized asset problem" measure. The results support the notion that non-VC backed firms do not solve their cospecialized asset problem by seeking acquisitions, whereas VC-backed firms do. To the extent that VCs choose their exit strategy for their firms, this would be reasonable compelling evidence of a cogent patent and/or exit strategy imposed on portfolio companies by venture capitalists.

In figures 6 and 7 we provide scatter plots of the (log) count of patents with citations from and to the future acquirer by year, that where filed before exit, for both VC and non-VC backed acquisitions. Again, a vertical line indicates on average where the first round of VC investment occurs relative to exit. There are two noticeable trends: The non-VC backed acquisitions begin citing their future acquirers much earlier in their lives; and for VC-backed acquisitions the weight of the patents that cite or are cited by the acquirer occur after the first round of venture capital. This is particularly apparent for patents that make citations to their acquirer, where there are very few firms with such patents before venture capital investment. In fact, for this group, the earliest patent with a citation to their acquirer is filed on average 1.5 years after the first round of venture capital.

In table 6 we replicate the analysis of the acquisition specification of table 4 using the count of patents that received citations from, or made citations to, their acquirer. We also extend the analysis to consider the effect of receiving more rounds of venture capital and the effect of the bust period. The count of patents that cited or are cited by the acquirer is significantly associated with venture capital, and is significantly increasing in the number of rounds that the firm received. The results control for the number of patents and the number of citations received or made (respectively for citations from and to the acquirer), as increases in these would increase the statistical likelihood of getting cited by or citing to the acquirer by chance.

Figure 6: Scatter Plot of Patents with Citations From Acquirers

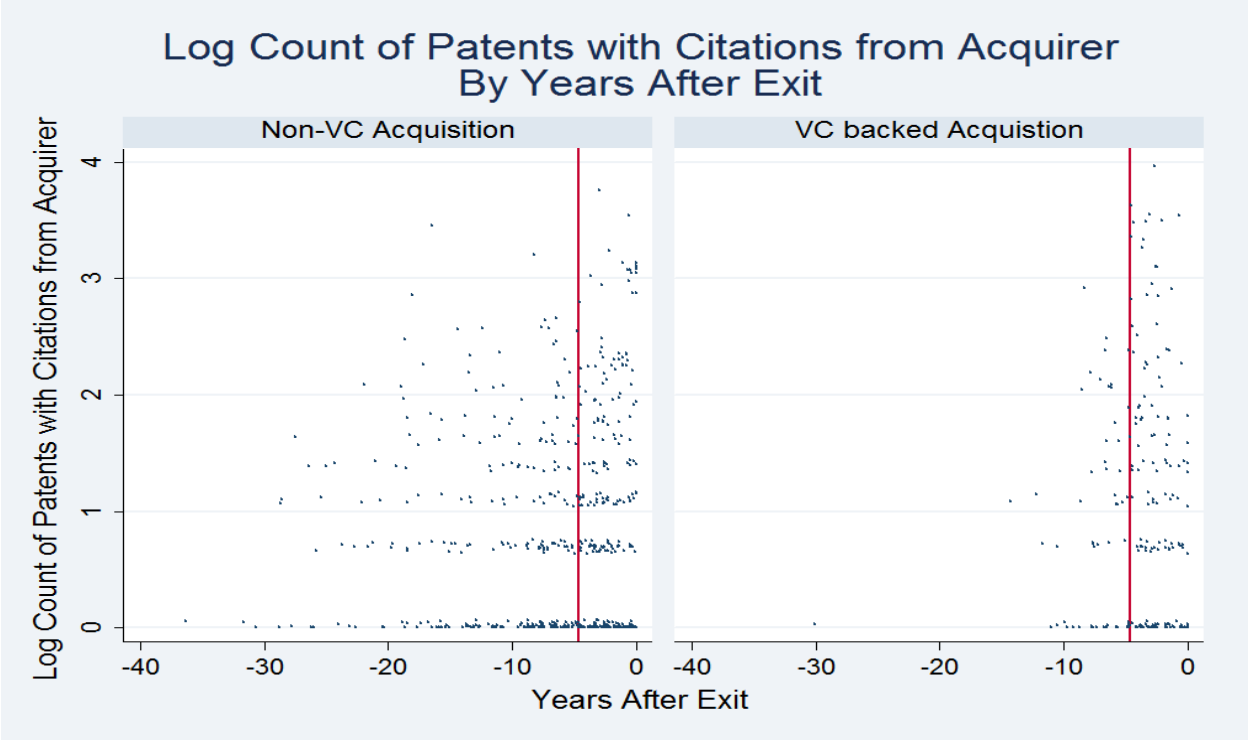
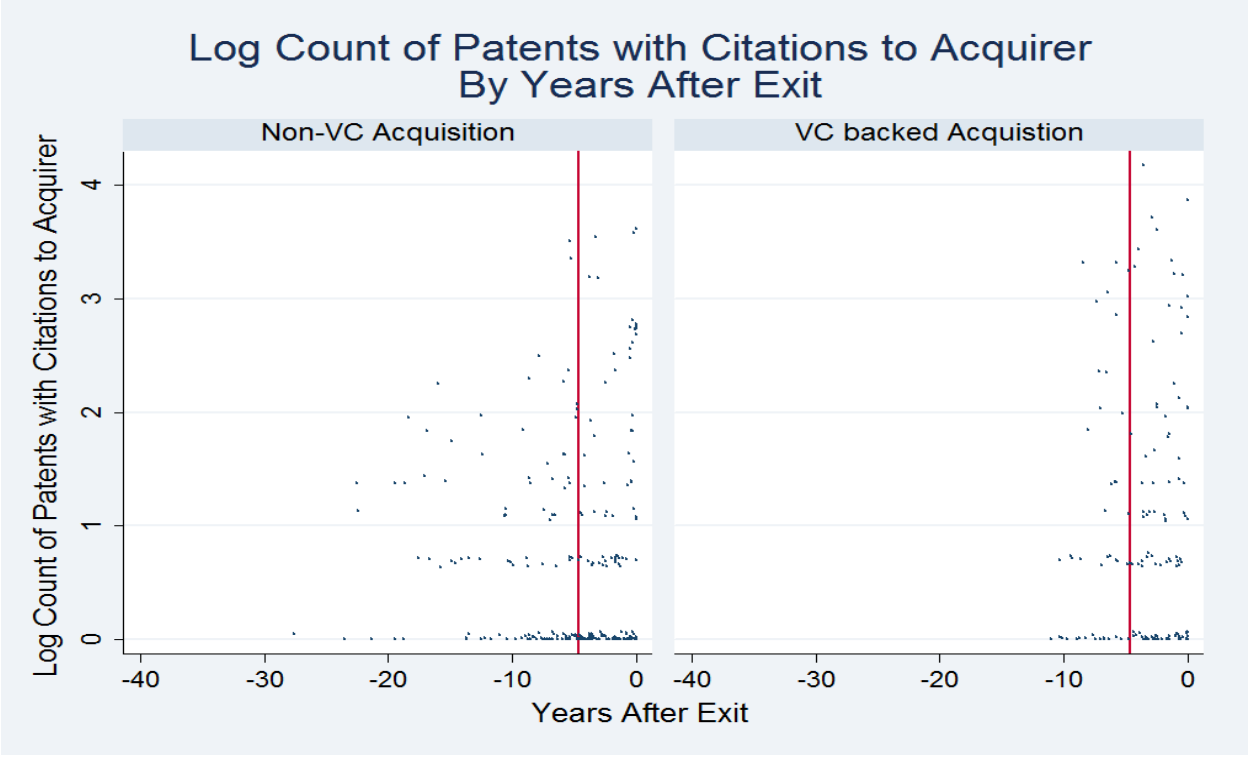



Figure 7: Scatter Plot of Patents with Citations To Acquirers



The results indicate that horizontal and vertical acquisition, where the target has an industry relationship with the acquirer anyway also significantly increase patents with citations, as does the acquirer being public. This is consistent with these citations measuring a technological "goodness of fit" between the target and the acquirer. The bust period is not associated with an increase or decrease of patents with citations from the acquirer, but is significantly negatively correlated with citations to the acquirer. There is no significant interaction between the bust period and venture capital.

Table 6: Citations To and From Acquirers

The dependent variables are the log of the number of patents held by a firm pre-exit that have citations to or from an acquirer, respectively. To be included in the analysis firms must have at least one patent pre-exit and be acquired. The estimation uses OLS with heteroskedastic correction to standard errors, though a negative binomial model on the raw count data provides very similar results (when it converges).

| | Citations From Acquirer | | | Citations To Acquirer | | |
|---|---|---|---|---|---|---|
| VC Backed | 0.082<br>(4.24***) | - | 0.077<br>(3.60***) | 0.080<br>(3.50***) | - | 0.015<br>(2.80***) |
| No Rounds of VC | - | 0.012<br>(3.43***) | - | - | 0.014<br>(2.84***) | - |
| Log of No. Patents | 0.058<br>(5.12***) | 0.057<br>(5.01***) | 0.059<br>(5.12***) | 0.054<br>(3.86***) | 0.053<br>(3.75***) | 0.053<br>(3.98***) |
| Log of Citations Rec'd/Made | 0.008<br>(1.65*) | 0.009<br>(1.84*) | 0.008<br>(1.64) | 0.031<br>(4.28***) | 0.032<br>(4.27***) | 0.016<br>(2.64***) |
| Acquirer Publicly Traded | 0.042<br>(3.87***) | 0.043<br>(3.97***) | 0.042<br>(3.88***) | 0.082<br>(5.89***) | 0.082<br>(5.96***) | 0.006<br>(6.88***) |
| Horizontal Acquisition | 0.065<br>(4.12***) | 0.065<br>(4.08***) | 0.065<br>(4.13***) | 0.070<br>(3.70***) | 0.069<br>(3.68***) | 0.006<br>(5.40***) |
| Vertical Acquisition | 0.043<br>(3.12***) | 0.042<br>(3.07***) | 0.043<br>(3.15***) | 0.043<br>(2.37**) | 0.043<br>(2.38**) | 0.006<br>(4.08***) |
| Bust Period Indicator | - | - | 0.020<br>(0.93) | - | - | -0.019<br>(-2.60***) |
| VC * Bust | - | - | 0.026<br>(0.53) | - | - | 0.008<br>(0.71) |
| State Fixed Effects | yes | yes | yes | yes | yes | yes |
| Year Fixed Effects | yes | yes | yes | yes | yes | yes |
| Industry Fixed Effects | yes | yes | yes | yes | yes | yes |
| Constant | -0.157<br>(-1.43) | -0.155<br>(-1.40) | -0.155<br>(-1.40) | 0.778<br>(1.38) | 0.782<br>(1.39) | 0.029<br>(1.52) |
| R-Squared | 0.0741383 | 0.0722683 | 0.074255 | 0.094616 | 0.0947276 | 0.0865556 |
| No. Observations | 4641 | 4641 | 4641 | 4641 | 4641 | 71915 |

Results are reported as coefficients with t-statistics in parentheses.
***, **, * indicate significance at the 0.01, 0.05 and 0.1 level, respectively

Table 7 presents the timing results for patents that cite or are cited by the acquirer for VC backed firms. The level of citations is always significantly greater than zero for all periods and both patent types. The reduced sample size and the small effect make it hard to find significance in differences between periods, however, for patents with citations to the acquirer there is a rise in incidence and rate after venture capital and the rise in rate persists past the second round. For patents with citations from the acquirer there is a much smaller rise in incidence and rate after venture capital, but neither of these rises is persistent.

Table 7: Timing of Patents with Citations To or From Acquirers

The first set of variables are indicators for whether a firm had any patents that cite or are cited by an acquirer during a certain period, and the second set of variables is the patenting rate per year contingent on a firm having at least one patent that cites or is cited by the acquirer pre-exit. The rate is calculated only for firms with patents that have disclosed founding years. The column "difference to before VC" reports a t-test against the incidence or count before VC, rather than against zero, and is null for patents before VC.

| | Patents with Citations To the Future Acquirer | | | Patents with Citations From the Future Acquirer | | |
|---|---|---|---|---|---|---|
| | N | Coefficient (Std Error) | Difference | N | Coefficient (Std Error) | Difference |
| Any Before VC | 925 | 0.039 (0.006***) | - | 925 | 0.058 (0.008***) | - |
| Any After VC | 925 | 0.057 (0.008***) | 0.018 (0.01*) | 925 | 0.079 (0.009***) | 0.021 (0.012*) |
| Any After Second Round | 925 | 0.04 (0.006***) | 0.001 (0.009) | 925 | 0.049 (0.007***) | -0.01 (0.01) |
| Any After Third Round | 925 | 0.024 (0.005***) | -0.015 (0.008*) | 925 | 0.03 (0.006***) | -0.028 (0.01***) |
| Count Before VC | 112 | 0.184 (0.054***) | - | 73 | 0.398 (0.105***) | - |
| Count After VC | 112 | 0.542 (0.101***) | 0.358 (0.115***) | 73 | 0.691 (0.133***) | 0.293 (0.169*) |
| Count After Second Round | 112 | 0.394 (0.089***) | 0.21 (0.104**) | 73 | 0.494 (0.12***) | 0.096 (0.159) |
| Count After Third Round | 112 | 0.218 (0.058***) | 0.034 (0.079) | 73 | 0.263 (0.095***) | -0.135 (0.141) |

***, **, * indicate significance at the 0.01, 0.05 and 0.1 level, respectively

The results in table 7 follow the pattern we predicted for acquisitions, that is the incident and conditional rate of patenting rise after venture capital investment and then fall back as the exit approaches. However, for these particular patents, the incidence and rate do not fall below the pre-VC patenting rates, consistent with the notion that further innovation on these technologies is still valuable to the acquirer. We cannot draw firm distinctions between economic value, signaling and strategic reasons for these patents. However, the persistently higher rate of patenting with citations to the acquirer, which would result in both a holdup problem for the target and would mitigate information asymmetries in the acquisition, relative to the rate of patenting with citations from the acquirer, which does not present a holdup problem for the target but still mitigates information asymmetries, is slightly suggestive that solving holdup problems is of strategic importance for VC backed firms.

## Discussion, Extensions and Conclusion

This analysis would benefit enormously from some good instruments to determine causation and from a strong method for discerning between economic value, signaling and strategic predictions. In this section we discuss these two main issues, as well as some smaller issues.

An ideal instrument for the comparison of VC and non-VC backed firms would exogenously reassign some firms from one category to the other. The Prudent Man Act that reformed restrictions on the amounts of investment institutional investors could make into venture capital occurred in 1979. Venture capital data pre-1980 is essentially unusable, rendering this otherwise excellent instrument obsolete. The SBIC program, which provides matched financing to on the order of 90% of the US

government sponsored venture capital industry, was suspended in 2003. Unfortunately this potential instrument suffers from two issues: First the suspension was not exogenous – it resulted from a period of prolonged poor performance, which indicated an excess supply of venture capital; and second, in other unpublished work we found that firms financed by US government sponsored venture capitalists do not behave in a comparable fashion to their privately financed counterparts with respect to patenting[14]. One other instrument that we entertained also likely fails the exclusion restriction. We considered attempting to use changes in the allocation of a major institutional investor, CALPERS, which single handedly accounts for a large share of investment into venture capital funds. However, absent some policy shock or other exogenous reason, we have to acknowledge that institutional investors are endogenous optimizers. We also considered using a shock to non-VC based financing. In 2008 the availability of debt capital for nascent firms suddenly became extremely constrained. Venture capital did not suffer in the same fashion, in part because of the discrete and long-lived nature of venture capital funds – monies committed to a fund started in 2007 cannot be withdrawn because of new circumstances in 2008, and remains available for placement into start-ups. We propose looking at this instrument in the future to see whether it can be used for our purposes. Finally we note that President Obama campaigned on the promise of $10b investment into venture capital for green energy. If this investment materializes, it would provide a shock to the propensity to secure venture capital in that sector.

To establish causation within venture capital backed firms is even more difficult, and we believe that our current approach represents the state of the art. However, the current approach could be considerably strengthened by survey evidence and contractual documentation on the milestones. Survey evidence could be used to confirm that, for the most part, firms are not pre-destined for their exit type at the time of first financing, and contract documentation could provide clear and compelling evidence that specific patenting behavior is required of VC backed firms. A test of the "no predetermined exit path" assumption might be to have VCs mark new firms that the finance according to their best bet of an exit type at the time of founding, and then wait to see their accuracy rate.

The shock to bargaining power was largely unsuccessful as an instrument for us with regard to the strategic predictions. An alternative would be a shock to the appropriability regime. Such a shock could affect the entire sample or a subsample such as one specific sector of the economy. The famous Diamond v Chakrabarty (1980) case that confirmed the patentability of artificially engineered genetic organisms comes too early for us, as does the Diamond v Diehr (1981) case regarding the patentability of software. However the Hatch-Waxman Act (1984) that increased the importance of patents for drug firms may be useable, as may the Texas Instruments (1985/6) cases or the Kodak-Polaroid decision (1986), both of which increased the overall strength of the appropriability regime. The 1994 TRIPS agreement may also be able to provide an exogenous shift in the appropriability regime, though in this instance it would be instructive to include non-US data in our dataset. Cockburn and MacGarvie (2009) took advantage of a policy shift that affected software patents in the mid 1990's, which we could also use. Finally, the State Street and AT&T vs. Excel decisions (1998) are well placed within out sample time frame, and did increase the appropriability regime with respect to patents on business methods. If certain sectors of the economy could be determined to be at risk of business method patenting, this could be used to test whether cospecialized asset problems suddenly mattered more. Likewise, Levin et al. (1987)

[14] Evidence that firms financed by Canadian government sponsored venture capitalists do not behave like firms financed by traditional private venture capitalists is presented in Brander, Egan and Hellmann (2010).

suggested that patent strength materially varies across industries, again indicating that an inter-industry comparison may be fruitful.

Brander and Egan (2008) provide a detailed analysis of five information asymmetry measures from the literature. Some of these measures can only be applied to IPOs, such as the volatility of stock returns, and others, such as the ratio of intangible assets are too intricately related to patenting to be used in our context. Nevertheless Brander and Egan show that some sectors are associated with much higher levels of information asymmetries (notably information technology and biotechnology) than other sectors in which venture capitalists do invest (such as energy and certain new materials). These measures, or differences between these sectors, could be used to disentangle signaling effects. Once again, signaling is only important in the presence of information asymmetries and signals should increase when information asymmetries are higher. This might allow us to discern between signaling and economic value, or in conjunction with a shock to the appropriability regime between signaling and strategic considerations.

Through-out this version of this paper there are footnotes discussing a "largest fraction of citations to or from a single entity" measure. This measure was discarded because of it unclear interpretation. We found that this measure was significantly correlated with IPO exits rather than acquisitions, and it was unclear how to interpret this in an economic value, signaling or transactions cost economics framework. However, the negative correlation between this measure and the fraction of citations to or from an acquirer suggest that acquisition partners are hard to identify from patent patterns. We will therefore consider reintroducing this measure, and exploring it further, in subsequent version of this paper. Likewise we would consider introducing the Lerner (1994) measure of patent scope so that backward citations could have only a holdup interpretation. On a different note, we also point out that our cospecialized asset problem should only be solved by an acquisition when the acquirer has a large patent portfolio. We propose exploring this further too.

Finally we return to the issue of whether information asymmetries at exit can be decomposed into a venture capitalist reputation effect and patenting effect. VC reputations have been calculated extensively in the literature, and together with a reasonable measure of information asymmetries, one could assess the relative importance of these effects. Perhaps patents are not important as signals when the firm has highly reputable venture capitalists? We leave this question to future research.

## References


Amit, Rafael., James A. Brander, and Christoph Zott (1998). "Why do Venture Capital Firms Exist? Theory and Canadian Evidence," Journal of Business Venturing 13, 441-466.

Arora,A. and R.P. Merges (2004), "Specialized supply firms, property rights and firm boundaries", Industrial and Corporate Change, Volume 13, Issue 3, Page 451.

Arrow, K. J. (1962), "Economic welfare and the allocation of resources for invention", R. R. Nelson, ed. The Rate and Direction of Inventive Activity. Princeton University Press, Princeton, NJ, 609-625.

Baker, George P. (1991),"Incentive Contracts And Performance Measurement", Journal of Political Economy

Brander, James A. and Edward J. Egan (2008), "The Role of Venture Capitalists in Acquisitions", University of British Columbia, Working Paper. Currently under review by the Review of Financial Studies.

Brander, James A., Edward J. Egan and Thomas F. Hellmann (2009), "Government Sponsored Venture Capital in Canada: Effects on Value Creation, Competition and Innovation", in International Differences in Entrepreneurship, editted by J.Lerner and A. Schoar, published by the National Bureau of Economic Research.

Brander, James A., Rafael Amit, and Werner Antweiler (2002). "Venture capital syndication: improved venture selection versus the value-added hypothesis," Journal of Economics and Management Strategy 11, 423-451.

Chesbrough, Henry William (2003), "Open innovation", Harvard Business Press.

Cockburn, Iain M. and Megan J. MacGarvie (2009), "Patents, Thickets and the Financing of Early-Stage Firms: Evidence from the Software Industry", Journal of Economics & Management Strategy, Volume 18 Issue 3, Pages 729 - 773

Cockburn, Iain M. and S. Wagner (2007), "Patents and the Survival of Internet-related IPOs", NBER Discussion Paper, No. 13146.

Dechenaux, Emmanuel, Brent Goldfarb, Scott Shane, and Marie Thursby (2008), "Appropriability and Commercialization: Evidence from MIT Inventions", Management Science, May, Vol. 54, pp.893-906.

Dushnitsky, Gary & Michael J. Lenox (2004), "When Do Incumbents Learn from Entrepreneurial Ventures? Corporate Venture Capital and Investing Firm Innovation Rates", Wharton, UPenn.

Egan, Edward J. (2005), “Matching Firm Names For Business Research”, working paper, available from www.edegan.com

Gans, J. S., D. H. Hsu, S. Stern (2003), "When does start-up innovation spur the gale of creative destruction?", Rand Journal of Economics, Winter, Vol.33, pp.571-586.

Gompers, Paul A. and Joshua Lerner (1996), "The Use of Covenants: An Empirical Analysis of Venture Capital Partnership Agreements", Journal of Law & Economics, Vol.39, pp.463-498.

Gompers, Paul A. and Joshua Lerner (1997), "Venture Capital and the Creation of Public Companies: Do Venture Capitalists Really Bring More than Money?", Journal of Private Equity, Vol.1, No.3, pp.15-32.543

Gompers, Paul A. and Joshua Lerner (1998a), "What Drives Venture Capital Fundraising", With Comments by Margaret M. Blair and Thomas Hellmann, Brookings Papers on Economic Activity, Microeconomics, Issue 1998, pp.149-204

Gompers, Paul A. and Joshua Lerner (1998b), "Risk and Reward in Private Equity Investments: The Challenge of Performance Assessment", Journal of Private Equity, Vol.1, Winter, pp.5-12.

Gompers, Paul A. and Joshua Lerner (1999), "An Analysis Of Compensation In The U.S. Venture Capital Partnership", Journal of Financial Economics, Vol.51, pp.3-44

Haeussler, Carolin, Dietmar Harhoff and Elisabeth Müller (2009), "To Be Financed or Not - The Role of Patents for Venture Capital Financing", Discussion Paper, January, Munich School of Management, University of Munich

Hall, B. H., A. B. Jaffe, M. Trajtenberg (2001), "The NBER patent citation data file: Lessons, insights and methodological tools", Working Paper 8498, National Bureau of Economic Research, Cambridge, MA.

Hall, Bronwyn H. (2002), "The Financing of Research and Development", Institute of Business and Economic Research, Paper E02-311, January.

Hall, Bronwyn H., Adam B. Jaffe, and Manuel Trajtenberg (2005), "Market value and patent citations", The RAND Journal of Economics, Spring, 36, 1, pp.16-38

Hand, John R.M. (2007) "Determinants of the Round-to-round Returns to pre-IPO Venture Capital Investments in U.S. Biotechnology Companies," Journal of Business Venturing 22, 1-28.

Hellmann, Thomas, and Manju Puri (2000). "The Interaction between Product Market and Financing Strategy: The Role of Venture Capital," Review of Financial Studies 13(4), 959-984.

Hellmann, Thomas, and Manju Puri (2002). "Venture Capital and the Professionalization of Start-Up Firms: Empirical Evidence," Journal of Finance 57, 169-197.

Hsu, D.H. and R.H. Ziedonis (2008), "Patents as quality signals for entrepreneurial ventures", Academy of Management Best Paper Proceedings.

Hsu, David and Rosemarie H Ziedonis (2009), "Patents As Quality Signals For Entrepreneurial Ventures", DRUID Summer Conference 2007 on Appropriability, Proximity, Routines And Innovation, Copenhagen, CBS, Denmark, June 18 - 20, 2007, Working Paper

Hsu, David H. (2006), "Venture Capitalists and Cooperative Start-up Commercialization Strategy", Management Science, Vol. 52, No. 2, February, pp. 204-219

Hsu, David H.(2000), "What Do Entrepreneurs Pay for Venture Capital Affiliation?", The Journal of Finance, Volume 59, Issue 4, pp.1805-1844

Hsu, David, (2006). "Why do Entrepreneurs Pay for Venture Capital Affiliation," Journal of Finance, Volumne 61.

Kaplan, S.N., Sensory, B.S., Strömberg, P., (2002), "How well do venture capital databases reflect actual investments", September, Working paper.

Kortum, Samuel and Josh Lerner (2000), "Assessing The Contribution Of Venture Capital To Innovation", The RAND Journal of Economics, Vol.31, No.4, Winter, pp.674-692.

Kreps, D.M. and R. Wilson (1982), "Reputation and imperfect information", Journal of Economic Theory, 27, pp. 253-279.

Lerner, J. (1994) ,"The importance of patent scope: An empirical analysis", Rand Journal of Economics, Vol.25, pp.319-333.

Levin, R.C., A.K, Klevorik, R.R. Nelson, S.G. Winter (1987), "Appropriating the returns from industrial research and development", Brookings Papers on Economic Activity 3/1987 783-820.

Mann, Ronald J. (2005), "Do Patents Facilitate Financing in the Software Industry?", The University Of Texas, School Of Law, Law and Economics Working Paper No. 022, March 2005, Social Science Research Network Electronic Paper Collection: http://ssrn.com/abstract=510103

Mann, Ronald J. and Thomas W. Sager (2007), "Patents, venture capital, and software start-ups", Research Policy, Volume 36, Issue 2, March , Pages 193-208

Mansfield, E. (1986), "Patents and innovation: An empirical study", Management Science, Vol. 32, pp.173-181.

Megginson, William L., and Kathleen A. Weiss (1990). "Venture Capital Certification in Initial Public Offerings," Journal of Finance 46 (3), 879-903.

Mowery, D.C. (2009), "Plus ca change: Industrial R&D in the Third Industrial Revolution", forthcoming, Industrial and Corporate Change.

Nelson, R. R. (1959), "The Simple Economics of Basic Scientific Research", Journal of Political Economy, 67, pp.297-306.

Porter, M.E. (1980), "Competitive Strategy: Techniques for Analyzing Industries and Competitors", The Free Press, New York.

Romain, Astrid & Bruno Van Pottelsberghe (2004), "The Economic Impact of Venture Capital", Discussion Paper, Series 1: Studies of the Economic Research Centre, No 18

Romer, Michael Paul (1990), "Endogenous Technological Change", Journal of Political Economy, Vol. 98, No. 5, Oct., pp.71-102

Sahlman, William A. (1990). "The Structure and Governance of the Venture Capital Organizations," Journal of Financial Economics 27, 473-521.

Shane, Scott (2002), "Selling University Technology: Patterns from MIT", Management Science, Vol. 48, No. 1, Special Issue on University Entrepreneurship and Technology Tranfer.

Spence, A.M. (1974), "Market Signaling", Harvard University Press, Cambridge, MA.

Teece, D.J. (1986), "Profiting from technological innovation: Implications for integration, collaboration, licensing, and public policy," Research Policy.

Williamson, Oliver E. (1971), "The Vertical Integration of Production: Market Failure Considerations," American Economic Review, 61:112-23

Ziedonis, R.H. (2004), "Don't fence me in: Fragmented markets for technology and the patent acquisition strategies of firms", Management Science, June 1, Vol. 50(6), pp.804-820.