

PATENTS AS QUALITY SIGNALS FOR ENTREPRENEURIAL VENTURES*

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ABSTRACT

This study examines the patenting and venture financing activities of 370 semiconductor start-ups that received more than 800 rounds of funding from 1980 through 2005. We find a significant effect of patents on investor estimates of start-up firm value, with a doubling in patent application stock associated with a 28 percent boost in funding-round valuations beyond what would otherwise be expected. We also find that the signaling value of patents is greater in earlier financing rounds and when funds are secured from prominent investors. Finally, our results suggest that having larger patent application stocks increases both the likelihood of sourcing initial capital from a prominent venture capitalist and of achieving liquidity through an initial public offering. We find little evidence, however, for the role of start-up affiliations with prominent partners once patenting activities are taken into account. These findings highlight the important interplay between external resource providers and the patent signaling strategies of entrepreneurial ventures.

If you ask venture capitalists what they think of patents, and in particular, of patent litigation, they'll tell you it's awful. "This is a terrible thing; leave us alone and let us innovate," they will say. And then if you ask them how their companies are doing in the marketplace, they will answer you with reference to patents: "Our company has patented this model"; "our company got twelve patents this year;" "our company has patent applications that cover this, that, and the other thing."

-- Mark Lemley (2000: p. 143)

INTRODUCTION

New ventures are formed to capitalize on real or perceived entrepreneurial opportunities resulting from shortfalls in product or service offerings by existing organizations. Entrepreneurs nonetheless face well-known challenges when securing the financial, organizational and managerial resources required for growth and survival (Stinchcombe, 1965). As Stuart, Hoang and Hybels (1999: p. 317) state: “[b]ecause the quality of young companies often cannot be observed directly, evaluators must appraise the company based on observable attributes that are thought to co-vary with its underlying but unknown quality. Resource holders therefore assess value by estimating the conditional probability that a firm will succeed, given a set of observable characteristics of the organization.”

Bridging this information gap with resource providers is particularly important for new ventures seeking to commercialize unproven technologies (Shane and Cable, 2002; Shane and Stuart, 2002). Successful development of new technologies is a costly and uncertain process that typically requires financial backing and assistance from third parties. Nonetheless, discerning the value and commercial promise of embryonic technologies can be difficult, particularly for outsiders. Recognizing this dilemma, prior studies have investigated a range of mechanisms used to shape outsiders’ expectations about the quality and profit potential of young technology-intensive firms, including entrepreneurial lineage and founder backgrounds (e.g., Eisenhardt and

Schoonhoven 1990; Burton, Sorensen and Beckman, 2002) and affiliations with reputable third parties such as prominent corporate partners (e.g., Stuart et al., 1999; Baum, Calabrese and Silverman, 2000), venture capitalists (e.g., Gulati and Higgins, 2003; Hsu 2004) and investment bankers (Megginson and Weiss, 1991; Carter, Dark and Singh, 1998).

While the entrepreneurship literature has investigated the signaling value of founder backgrounds and third-party affiliations quite extensively, relatively little conceptual or empirical attention has been placed on the role of patents as quality signals for innovation-intensive ventures. In principle, patents conform well to Spence's (1973) original conceptualization of a signal: they are costly to obtain and, through the government certification process, provide a mechanism by which the quality of innovative activities can be sorted. Like other symbolic actions entrepreneurs use to attract external resources (Zott and Huy, 2007), including founder backgrounds and third-party affiliations, patents can simultaneously confer intrinsic value due to the property right. Nonetheless, there is a paucity of information about the extent to which, if at all, patent activities alter the resource trajectories of technology ventures.

The relative efficacy of alternative quality signals in overcoming Stinchcombe's (1965) conceptualization of new organizations' "liability of newness" is also important from an organization theory standpoint. Stinchcombe argues that emergent organizations face a liability of newness for two broad reasons: (1) the costs associated with structuring, coordinating and organizing new enterprises, including establishing organizational policies, procedures and governance systems; and (2) developing new social and economic relationships with the organization's external community. Stinchcombe also identifies three factors that can mitigate these challenges: (1) human capital and training (noting that "the main way to learn to form organizations is to form them," (p. 152); (2) a free market economy that allows resources to flow

to their most productive use; and (3) access to resources via embeddedness in a well-formed social structure. Under Stinchcombe's framework, holding constant the economic system within which new enterprises operate (the second factor), the extant literature has concentrated on entrepreneurial experience (factor one) and social ties (factor three) as strategies of overcoming the liability of newness. While these same factors may be among the inputs into the ongoing accomplishments of the new venture as captured by patenting, organizational progress may serve as an important third factor in a new venture's ability to overcome the liability of newness (see Hallen, 2006 for a related discussion). This paper investigates this issue more fully by placing patents within a broader menu of quality signals for young technology-intensive organizations.

We contribute new insights by examining the use of quality signals—including patents—across multiple stages in the new venture life cycle, from first receipt of venture capital (VC) financing through liquidation or successful exit. More specifically, we investigate the extent to which, if at all, the patenting activities of new ventures alters investor estimates of their economic value. As corroborating analysis, we examine the role of patents in helping start-ups secure funds from prominent VCs in the first funding round (a pivotal event which can shape the resource trajectories of new firms (Hsu, 2004; Hallen, 2006; Hochberg, Ljungqvist and Lu, 2007)) and in achieving an initial public offering (IPO) exit, thereby allowing us to test the importance of patents across multiple developmental stages. As developed more fully below, we predict that the effects of patenting on estimates of start-up value will be greater for entrepreneurially inexperienced founders, in earlier funding rounds, and when securing resources from prominent VCs.

To test these predictions, we assemble a unique database of 370 venture capital-backed semiconductor start-ups, founded between 1975 and 1999, containing information compiled

through 2005 regarding their patenting, venture financing, partnering and exit histories. For 290 of these start-ups, we observe valuations across multiple rounds of financing, collectively totaling over 800 rounds. We use these round-level data to estimate the degree to which patent filings alters investor expectations of start-up firm value. This empirical design allows us to examine the extent to which changes in patenting affect changes in venture valuation by making use of within-firm, across-round variation.

We find a statistically significant and economically large effect of patent filings on investor estimates of start-up value. A doubling in the patent application stock of a new venture is associated with a 28 percent increase in valuation, representing an upward funding-round adjustment of roughly \$16.8 million for the average start-up in our sample. This estimate is net of controls for time invariant unobserved start-up heterogeneity and for alternative factors that could influence investor expectations including measures of patent value, advancements made in product development, environmental conditions affecting exit opportunities, and affiliations with prominent corporations as alliance partners or equity investors. We also find that patents are (a) especially important in the early finding rounds in determining start-up valuation and the likelihood of sourcing a prominent VC firm, (b) particularly valued by more prominent VC investors, and (c) positively correlated with the probability of an IPO.

This study contributes to two main strands of literature. First, it contributes to a large body of research in organizations and entrepreneurial management on the mechanisms firms use to overcome the “liability of newness” (or “smallness”) highlighted in Stinchcombe’s (1965) pioneering work. As discussed more fully in the following section, the heterogeneous effects of founder backgrounds and especially third-party affiliations have been subjected to intensive study. We contribute new insights by examining, both conceptually and empirically, the extent to

which patents confer similar informational advantages in markets for entrepreneurial resources while taking into account the effects of alternative signals. In general, prior studies within this literature also suffer from a difficult identification problem: it is often unclear, for example, whether start-ups with prominent third-party affiliations are more successful due to “certification effects” (e.g., Stuart et al., 1999) and access to superior resources (e.g., Baum et al., 2000) or whether higher quality start-ups are more likely to attract prominent third-parties, in which case they would be more likely to succeed even absent the formation of such ties. Like most prior studies in this literature, we lack a natural experiment with which to identify cleanly the causal effects of focal interest in our study. We take an important step closer, however, by testing for marginal effects using changes in a given start-up’s valuation trajectory. Finally, much of the prior empirical evidence on the use of quality signals by innovation-intensive firms is generated from studies of the biotechnology sector. Our findings provide a useful point of comparison.

Our study also builds on and contributes to a second strand of research that focuses on the strategic and economic value of intellectual property (IP) rights to entrepreneurial firms. Empirical evidence on the effects of patents on VC financing activities remains both limited and inconclusive. Kortum and Lerner (2000) show, for example, that VC-backed start-ups file patents at three times the rate of their publicly traded counterparts. They do not, however, consider the potential signaling value of patents and do not assess the effects on new venture valuations. A handful of recent papers by management and legal scholars acknowledge that, in addition to their intrinsic value, patents may help reduce information asymmetries in markets for entrepreneurial financing (e.g., Stuart et al., 1999; Lemley 2000; Long 2002; Mann 2005; Heeley, Matusik and Jain, 2007). Conceptually, we contribute new insights by exploring how the value of signaling quality through patent filings hinges on the initial resource endowments of the

founding team, on characteristics of their investors and on the staging of VC investing. We also provide the first large-scale empirical tests of these predictions. In the remainder of the paper, we discuss the related literature, develop and propose a set of predictions, describe our empirical design and data, and report our main findings. A final section discusses the results and limitations of the study.

LITERATURE AND THEORY DEVELOPMENT

Signaling Quality through Third-Party Affiliations and Founder Characteristics

The challenges that technology-intensive ventures face when securing the resources required for development has motivated a considerable body of research on the mechanisms used to signal their (largely unobservable) value and commercial potential. One influential strand of studies shows that organizations affiliated with reputable or high status partners (such as alliance partners, venture capitalists or investment banks) can experience enhanced performance due to inter-organizational transfers of status, certification or endorsement by discriminating evaluators and/or superior resources transferred to the enterprise (e.g., Baum and Oliver, 1991; Megginson and Weiss, 1991; Rao, 1994; Podolny, 1994; Stuart et al., 1999; Gulati and Higgins, 2003).

Despite the benefits widely attributed to such third-party affiliations, recent studies show that entrepreneurs often pay a price to use this mechanism, both voluntarily and otherwise. Hsu (2004) and Gompers et al. (2007) find, for example, that reputable parties earn returns from their status by pricing their financial capital at a premium. In addition, in the course of negotiating or interacting with resource providers who offer complementary resources, entrepreneurs risk the inadvertent leakage or misappropriation of proprietary ideas and discoveries (Hellmann, 2002; Dushnitsky, 2004). In 2005, for example, Toshiba was found guilty of illegally transferring trade secrets from Lexar Media, a start-up in its corporate VC portfolio, to a rival start-up. The dispute

resulted in one of largest intellectual property awards in California history, with almost \$500 million in damages awarded by the jury (Strasburg, 2005).

Founders also differ in their prior entrepreneurial founding experiences, which can confer advantages to the new enterprise. That is, senders may differ in their ability to signal quality to external resource providers absent third-party affiliations. A second stream of research investigates this role of entrepreneurial “pre-history”—the experience, assets and social ties accumulated through founders’ activities prior to founding the focal enterprise—in garnering resources in earlier stages of the new venture life cycle (e.g., Burton et al., 2002; Shane and Stuart 2002).¹ Prior studies suggest two distinct mechanisms by which performance heterogeneity can arise: via spawning from prominent “parents” and via entrepreneurial experience. Burton et al. (2002) find, for example, that entrepreneurs with prior career experience in higher status firms derive information and reputation advantages when securing external financing. Agarwal et al. (2004) find further evidence of knowledge and capability transfer (in both the technical and commercial realms) from “parent” to “progeny,” which affects new ventures’ probability of survival. A number of studies have documented skill inheritance and transfer in organizational spin-offs in a wide variety of industry settings (e.g., Klepper and Simons, 2000; Phillips, 2002; Chatterji, 2005).

A related strand of studies examines the effects of the entrepreneurial experience on resource acquisition more directly, suggesting that resources can be sourced from entrepreneurs’ own network rather than VCs’ networks, with implications for division of rents and start-up performance. Gompers, et al. (2007) show that founders with prior IPO success are more likely to realize successful IPO exits in new ventures than are first time entrepreneurs or founders who

¹ This stream of literature stands in contrast to the “traditional” view that entrepreneurs are relatively homogenous in psychological or preference orientation, and these orientations determines who is most likely to engage in entrepreneurship (e.g., McClelland, 1961; Khilstrom and Laffont, 1979).

have previously failed, and that experienced VCs enhance venture performance, but only for those entrepreneurs without prior experience. In turn, these effects can increase the bargaining power of serial entrepreneurs with a demonstrated track record of new venture performance when seeking capital from external sources. Hsu (2007) finds that experienced entrepreneurial founders are more likely to be able to recruit executive officers from their own social networks, which also has valuation consequences for venture capital funding. Such experience can have a direct productivity role by the development of specialized skills and know-how associated with successfully navigating the resource acquisition, assembly and deployment processes. Furthermore, there may be a signaling component in that the opportunity costs of individuals with rich entrepreneurial experience may be high, and so holders of external resources may make inferences about venture quality knowing that the value of the next best alternative is high.²

Both streams of research—third-party endorsements and entrepreneurial experience—explicitly or implicitly draw from signaling theory, which suggests that in situations of asymmetric information, actions that are differentially costly for the party subject to uncertainty can act as quality signals to external observers (Spence, 1973).³ We define a “quality signal” broadly as information capable of altering an observer’s probability distribution of unobserved variables. This definition is consistent with conceptualizations of quality signals used both in the entrepreneurial management (e.g., Stuart et al., 1999) and legal (e.g., Long, 2002) literature.

Patents as Quality Signals

² The thesis that “people matter most” in new venture success is also a strongly held view in the practitioner literature. For example, Sahlman (1997) writes: “Investors also look favorably on a team that is known because the real world often prefers not to deal with start-ups. They’re too unpredictable. That changes, however, when the new company is run by people well known to suppliers, customers and employees...As [prominent venture capitalist] Arthur Rock states, ‘I invest in people, not ideas.’”

³ Put differently, to provide a sorting mechanism, low quality actors must find it more difficult or more costly to send the signal than do high quality actors. Interestingly, the action serving as a signal need not have an independent productive component (e.g., an educational degree does not have to confer a training role) in order to act as a quality signal so long as entities of differing abilities face different costs associated with sending the signal.

The traditional justification for the patent system is the *quid pro quo* system of exchanging a temporary monopoly (patent rights) for invention disclosure (with a significant number of details and diagrams in the patent application). The hope is that a “building on the shoulders of giants” phenomenon of cumulative invention in society will be fostered as a result of enhanced financial incentives to disclose inventions rather than keeping them secret. In essence, patent applications represent attempts to secure market advantage through distinctive product/service offerings, cost advantages via proprietary process technologies, or revenues through patent licensing activities.

The property rights afforded by patents also can confer transactional value to entrepreneurs and their investors. Arrow’s classic 1962 article explicated the conundrum surrounding markets for technology and resource transfer: buyers, or resource providers more generally, are unwilling to provide funding without first observing the underlying discovery; meanwhile sellers may be reluctant to disclose such information for fear of expropriation if the deal breaks down. More recent studies suggest that the legal rights afforded by patents allow demanders of external resources a way to circumvent Arrow’s disclosure problem. Arora, Fosfuri and Gambardella (2001) show, for example, that the ownership of patents facilitates the exchange of know-how and trade secrets that generally are more difficult to protect. Gans, Hsu and Stern (2002) similarly report that patents facilitate cooperative arrangements between new ventures and established firms. Finally, the property rights afforded by patents can confer additional value to entrepreneurs and their investors either through the sale of rights to third parties or through improved bargaining positions in negotiations with other patent owners (Cohen, Nelson and Walsh, 2000; Ziedonis, 2004).

In principle, patents also conform well to Spence’s (1973) criteria for a quality signal:

they are costly to obtain and provide a mechanism by which quality “types” can be sorted (Long, 2002). The examination process is designed to provide a certification function through the rejection of inventions that fail to meet the standards required for patentability (an invention must be novel, useful, and non-obvious to receive a patent). The direct monetary costs associated with the patenting process, estimated by Lemley (2000) at roughly \$25,000 per patent including attorney fees, also can be quite high for a young company. For example, in interviews conducted by Mann (2006) in the software industry, entrepreneurs report deciding whether to use limited financial resources for patent-related activities or for hiring additional programmers.

The patenting process also can entail non-trivial indirect costs. First, as suggested earlier, patent applicants are required to disclose to the public details regarding the underlying invention that could otherwise be kept secret (Anton and Yao, 1994).⁴ Engineers and scientists also have to be educated about the standards of patentability and to undertake practices that mitigate the likelihood of sacrificing intellectual property (e.g., laboratory notebook documentation and deadlines for patent filings). More importantly, the back-and-forth communication between inventors and patent agents or attorneys can be tedious and time-consuming. This latter opportunity cost can be especially high for start-ups facing pressures for rapid time-to-market (e.g., Eisenhardt and Schoonhoven, 1990; Cohen et al., 2000).

Finally, patents do not necessarily have to lead to direct enhanced productivity to serve as an effective quality signal provided that the signaling costs stratify quality “types.” Lemley (2001: p. 1505), for example, writes: “Venture capitalists use client patents (or more likely,

⁴ U.S. laws governing these disclosure requirements have changed over time. Applicants filing patents prior to 2001 generally were not required to disclose an application unless it resulted in an issued patent. Subsequently, the U.S. Patent and Trademark Office has switched to a regime in which applications are published automatically 18-months following their submission, unless specific exceptions are invoked under the 1999 American Inventor’s Protection Act. The 1999 Act allows inventors to keep U.S. applications secret during the examination process but doing so forecloses international protection.

patent applications) as evidence that the company is well managed, is at a certain stage in development, and has defined and carved out a market niche.” Similarly, Long (2002, p. 646) notes: “patent portfolios can convey information about the lines of research a firm is conducting and how quickly the research is proceeding.” In turn, the patent application activities of new ventures offer steadier streams of information about technical progress than “chunkier” or more static signals such as entrepreneurial experience and prominence of start-up affiliates. This framing is consistent with Hallen’s (2006) assessment of the relative importance of on-going venture accomplishments as compared to entrepreneurial lineage in securing resources from outsiders.

In summary, patents, like other quality signals (including observable third-party affiliations and founder characteristics) can be construed as having a “real” development component, as well as a pure certification component. In light of these combined elements, we predict the following:

Hypothesis 1: The patenting activities of an entrepreneurial venture will positively shape investor estimates of the start-up’s future value.

The null hypothesis—that the patenting activities of entrepreneurial ventures do *not* trigger an upward adjustment in investor estimates of start-up value—warrants brief discussion. Unlike other mechanisms for signaling quality (e.g., whether an entrepreneur has founded a start-up that went public), the information revealed through patents is notoriously “noisy” and can be costly to verify. Most patents end up being worthless or of trivial economic value (Scherer and Harhoff, 2000). Moreover, the threshold for patentability in the United States is quite low, fueling concerns about the “flooding” of low-quality patents in certain sectors, including electronics (Jaffe and Lerner, 2004). The exclusionary rights afforded by patents also remain

ambiguous without ex post legal rulings, a process that can be especially onerous for small firms with limited financial resources (Lanjouw and Lerner, 2001; Lanjouw and Schankerman, 2001). In light of these concerns, failing to reject this null hypothesis would constitute a finding of considerable significance both from managerial and policy perspectives.

The Moderating Effects of Founder, Start-up and Investor Characteristics

In our next predictions, we focus on conditions under which patents are likely to be more or less important for entrepreneurial ventures as signals of quality. As suggested earlier, experienced entrepreneurs will be better able to signal quality and attract resources without patents relative to entrepreneurs without such experience due to the availability of alternate information (regarding quality of management team and/or technology). Such expectations of future success should get “priced into” initial or early stage funding rounds. In shaping the resource trajectories of innovation-intensive ventures, the signaling value of patents therefore is likely to be lower for entrepreneurs with greater relevant “pre-founding” histories. This outcome could be due either to the knowledge that experienced entrepreneurs have higher opportunity costs to their current activities or to expectations of a higher likelihood of success due to enhanced organizational capabilities. In combination, these arguments suggest the following empirical prediction:

Hypothesis 2: The signaling value of patents will be greater for entrepreneurially inexperienced founders relative to their more experienced counterparts.

The early stages of funding for start-ups are characterized by greater technical and demand uncertainty in product development. In such settings, the quality signals they generate such as patents are particularly important as resource providers and external actors face greater challenges when evaluating the venture’s prospects. As suggested earlier, patents also may serve

an important transactional role in the resource acquisition process of technology-intensive ventures. By helping define the scope of intangible assets being transferred between parties, for example, patents may facilitate interactions with outside investors and corporate partners in the early stages of idea development when expropriation hazards loom large (e.g., Arrow 1962; Arora et al., 2001). As Gans et al. (2002) show, without the legal channels afforded by formal intellectual property protection, firms may choose to internalize the commercialization process rather than risk the threat of expropriation. As the venture develops, there may be alternate mechanisms by which the venture can mitigate the threat of expropriation. For example, as a result of being embedded in a larger social network that may be more likely to have “closure” (Coleman, 1990), the threat of reputational damage may act to rein in opportunistic behavior by counterparties of the firm. While it is difficult to distinguish between these two mechanisms of why patents may be disproportionately important in the early funding rounds, the signaling value of patents in the face of venture uncertainty, and the more instrumental value of patents in mitigating the threat of expropriation, their effects are self-reinforcing. We therefore propose:

Hypothesis 3: The signaling value of patents will be greater for ventures during their earlier funding rounds relative to later rounds.

Not only do senders of signals differ, receivers of signals also differ in ways that may have implications for patents as quality signals for start-ups. This conceptualization of variation in experience and quality of venture capitalists is consistent with the recent entrepreneurship literature that finds a great deal of variation in venture capitalists’ division of rents and returns to VC funds’ limited partners (Hsu, 2004; Kaplan and Schoar, 2004; Gompers et al., 2007). More specifically, experienced venture capitalists, as a result of their prior interactions with the network of entrepreneurial resource infrastructure, such as other venture capitalists,

entrepreneurs and professional service firms, may face a lower cost of sourcing information useful for, *inter alia*, evaluating patents.⁵ As a result, experienced venture capitalists may be differentially advantaged when discerning the informational content revealed by a patent filing. Despite this advantage, however, the predicted imputed signal of a given stock of start-up patents is not clear between a less and a more network central venture capitalist. For example, more central evaluators may recognize and place value on a relatively small number of key patents or conversely they may place a low valuation on a large stock of observed start-up patents. Using a similar line of reasoning, Jensen (2003) argues that quality signals are less important to experienced recipients in the context of commercial banking. As a result, it may be difficult to empirically detect an informational advantage mechanism at work in this setting.

A second mechanism, the value-added potential of more experienced and network central VCs in enhancing the quality of start-ups' patents, is less ambiguous in its predicted effects. More experienced VCs may value start-up patents more highly than their less experienced counterparts because of potential complementarity between start-up and experienced venture capitalists' resources. More experienced VCs have access to superior resources such as specialized legal counsel (Suchman and Cahill, 1996) and collaborative commercialization partners (Hsu, 2006). In addition to discrete venture capitalist functions and relationships that may improve the commercialization prospects of their affiliated new enterprises, more prominent VCs also may help start-ups professionalize their internal and external practices across a range of business functions, which can act in complementary ways to raise the value of entrepreneurial

⁵ As previously mentioned, evaluation costs of interpreting patent signals can be high. Technical invention often is loosely correlated with commercial value. Value capture may also require sector-specific information and knowledge such as the commercial viability of underlying technology, the strategic value of patents, and potential hold-up problems by other patent owners. Assessing the informational content revealed by patents also requires sophisticated understanding of complex legal issues (such as the strength and breadth of patent claims and the likelihood of patents withstanding legal challenge). More generally, Burt (1992) discusses preferential access as a key informational advantage to central network position.

patenting (Kortum and Lerner, 2000; Hellmann and Puri, 2002). We therefore predict:

Hypothesis 4: The signaling value of patents will be more pronounced among more prominent VC investors.

EMPIRICAL ANALYSIS

Data and Methodology

The semiconductor industry offers several advantages for the purposes of our study. First, semiconductor start-ups typically face a simultaneous need to move forward quickly with the development of new technologies (Eisenhardt and Schoonhoven, 1990) while securing resources based largely on difficult-to-value, intangible assets. Knowledge obsolescence is a threat that drives the relentless pace of technological innovation and product market competition in this industry. Thus, resource providers are likely to rely on signals when estimating the underlying value of entrepreneurial activities. Second, while Hall and Ziedonis (2001) find qualitative evidence that patents are important to semiconductor start-ups when securing financing, they also suggest that the issuance of low-quality patents is particularly problematic within this sector. The setting therefore provides an intriguing context in which to examine the value of patents as quality signals for nascent organizations.

The sample includes 370 semiconductor companies in the U.S. that were founded between 1975 and 1999 and that received at least one round of venture financing by September 2005, as reported by VentureSource. As Kaplan, Sensoy and Stromberg (2002) report, VentureSource provides the most comprehensive data on the venture investments in U.S. firms, particularly for investments since the mid-1980s. We triangulate VC information using the other major database of U.S. VC activity, VentureXpert, as the two data sources may offer complementary information. To allow a sufficient window in which to track post-founding

patenting, financing and exit activities through 2005, we exclude start-ups founded after 1999. Our sample firms collectively submitted 5,103 U.S. patent applications prior to exit via IPO or acquisition or through their last VC financing round through December 2005.

The sample is restricted to VC-backed firms for several reasons. First, interpreting patents as a signal implies that there is an intended receiver of the signal. Venture capitalists are one important audience for such quality signals, as they evaluate and assign valuations to new ventures. Imposing the condition of VC-funded enterprises also allows us to test for effects using a sample of start-ups that exceed a minimum threshold of quality, which is useful given the wide spectrum of start-up quality. Finally, the ability to observe changes in start-up valuations before a liquidity event such as an IPO or acquisition confers methodological advantages of observing intermediate start-up valuations, which would otherwise be unobservable. Nevertheless, our estimates should be interpreted with VC receipt selection in mind.

Our main set of regressions estimate the effect of patent filings on the valuations of start-ups across funding rounds, holding unobservable time invariant effects constant via start-up fixed effects (γ_i). More specifically, we estimate the following type of equation for firm i in funding round t :

$$VALUATION_t = \alpha_t + \gamma_i + \beta_1 (PATENT_t) + \beta_2 (EARLY FUNDING ROUND_t) + \beta_3 (PATENT_t * NOFOUNDEREXP_t) + \beta_4 (EARLY FUNDING ROUND_t * PATENT_t) + \beta_5 (VCEXP_t) + \beta_6 (PATENT_t * VCEXP_t) + \beta_7 (CONTROLS_t) + \varepsilon. \quad (1)$$

Using this framework, the test of H1, the signaling value of patents, is whether $\beta_1 > 0$. H2, the prediction that patents will be more important for inexperienced founders, is tested by estimating whether $\beta_3 > 0$. H3, the hypothesis that patents will be more important in early funding rounds, is tested by estimating whether $\beta_4 > 0$. Finally, H4 predicts that more experienced VCs will value patents more so than less experienced VCs, which implies that $\beta_6 > 0$.

Two additional analyses provide supporting information beyond the valuation estimates in testing H1. Both pertain to new venture lifecycle effects. We first examine outcomes associated with the first round of funding. As Hallen (2006) and others have noted, initial ties are important as there may be upward or downward trajectories for start-ups depending on their initial “placement” in the network structure. The suggestion is that path dependencies may hold. For example, a prominent venture capitalist in the first stage makes it much more likely that a prominent venture capitalist will invest in subsequent rounds. The same resource matching dynamic could occur with respect to prominent alliance partners and/or the processes necessary to achieve a favorable liquidity event (e.g., recruiting reputable IPO underwriters). We therefore restrict attention to the sub-sample of data corresponding to first funding rounds and estimate the probability of receiving funding from a prominent venture capitalist as a function of patents, founder entrepreneurial experience and a set of controls. This approach enables estimation of the role of alternate start-up quality signals in explaining the likelihood that a focal start-up receives initial financial backing from a more reputable VC firm.

A final analysis examines the probability that ventures’ final funding round is an IPO. Equity holders do not have liquidity until an “exit” event occurs, and a commonly accepted measure of a successful liquidity event is undergoing an IPO (liquidity events generally can indicate high or low performance, and so we restrict our attention to the IPO to mitigate ambiguity). We estimate the likelihood that a venture’s most recent funding round (as of 2005) is an IPO as a function of patents, entrepreneurial experience and a set of control variables. A positive patent coefficient would indicate that patents serve as quality signals to the IPO market.

Variables

The key dependent variable for the round-level analysis is *pre-money valuation*, which

reflects the product of the share price before the funding round multiplied by the number of outstanding shares of the firms (see Table 1). This estimate of the aggregate value of the firm is used as the basis of calculating the equity stake taken out for a given cash infusion by VCs. This measure of the terms under which external resources are accessible represents an intermediate outcome to entrepreneurial survival (e.g., Romanelli, 1989), but is more generally a measure of entrepreneurial value capture. The pre-money valuation data are from VentureSource and are supplemented with information from VentureXpert for purposes of triangulation. For the first funding round analysis, we examine the likelihood of being funded by a prominent, or network central, venture capitalist. We calculate network position, as has become standard in this literature, based on VC syndication patterns over time and the Bonacich centrality of the lead venture capitalist in a funding round.⁶ *High VC eigenvector centrality* is set equal to one if the value is in the upper half of the within-sample distribution of eigenvector values. For the subsample of final funding rounds, we examine the likelihood of experiencing an *IPO*.

The key independent variables can be clustered into several categories. The variable *patent application stock* was sourced from Delphion and the United States Patent and Trademark Office (USPTO), and is collected as of the time of VC funding rounds.⁷ The primary entrepreneurial experience variable, hand-collected from web searches of founding team biographies, result in the variable, *prior start-up founding & IPO experience*, which take the value one when at least one member of the founding team had previously been a founder of a

⁶ Hochberg et al. (2007) evaluate alternative measures of VC centrality and conclude that co-investment ties revealed by eigenvector centrality have the strongest power in predicting VC fund performance.

⁷ *Patent application stock* comprises applications that eventually result in the successful awarding of a U.S. patent. We prefer to examine applications rather than grants due to contemporaneous observability by outsiders (the results are similar but noisier if we use patent grants instead), and also to conform to the majority of studies in the patent literature (e.g., Hall, Jaffe and Trajtenberg, 2005). Before 2001, information on U.S. patent applications that were rejected or abandoned during the examination process was not disclosed to the public. In practice, the vast majority of patent applications are granted (Quillen and Webster, 2001), so the main uncertainty to the patent applicant is the claims allowed, which importantly determines patent scope. It is not possible to examine differing patent scopes between application and grant before 2001, and so our results should properly be interpreted with this issue in mind.

start-up and had experience undergoing an IPO. To measure new venture affiliation with prominent third parties, we construct *prominent partner stock*, which is the cumulative count (up to the funding round) of technologically or commercially prominent alliance or corporate equity partners (evaluated on a time-varying basis using five-year windows).⁸ A final important independent variable is a measure of patent value. When entered into the specification at the same time as *patent application stock*, the estimated coefficient of *patent application stock* should reflect the non-economic value effect of patenting on the outcome variable, *pre-money valuation*. We use *lapsed patent stock*, the cumulative count of patents which have either expired or have not been renewed before the full patent term, as our main measure of patent value. US patents are subject to intermediate term renewal/maintenance fees, and so non-renewal represents self-revelation about perceived patent value.⁹

We also make use of several other control variables, all of which are coded from the VentureSource database. *Early stage round* is a dummy equal to 1 if a funding round is one of the first two rounds of funding received by the new enterprise. The variable, *start-up age* is the age of the start-up evaluated at the time of the funding round, which aims to control for venture maturity and life stage. We include a measure of product development progress, *profitable phase of development*, a dummy variable set to one if the firm as of the focal VC round has attained a profit. Related to this variable, Kaplan and Strömberg (2003) find that the pre-revenue stage of start-up development is associated with different outcomes and contractual structure relative to

⁸ Following Stuart et al. (1999), “commercial prominence” is based on revenues in relevant product markets. To construct the measure, we used data from Integrated Circuits Engineering (ICE, 1975-2000) to identify the top 25 worldwide semiconductor producers at five-year intervals from 1980 through 2000. An alliance partner or corporate investor is coded as commercially prominent if it ranks among these top 25 worldwide producers. “Technological prominence” was identified using top 25 rankings of firms with influential patents within the semiconductor industry, first compiled in Ziedonis (2004). A list of these technologically prominent firms is available at: http://mansci.pubs.informs.org/ecompanion_04.html.

⁹ Forward patent counts is the traditional measure of patent value, but because of the high correlation between that measure (both in stocks and in the single most highly cited patent as of the focal funding round) and *patent application stock*, we elected to use *lapsed patent stock*.

firms which have a stream of revenues from product or service sales. A set of round-type dummies is also included in the analysis. These are dummy variables for *angel round*, *IPO round* and *acquisition round*. Finally, two funding year dummies are included for the pre-1997 time period and the 1998-2000 time period (the excluded time period is post-2000). These period dummies match years with differing levels of VC inflows, an environmental factor that can alter valuations placed on VC-backed firms (Gompers and Lerner, 2000). Table 1 summarizes information about variables used in our round-level regressions. Table 2 reports bivariate correlations.

*** Insert Tables 1 and 2 about here ***

Before discussing the regression results, it will be useful to examine some univariate comparisons in the data. In Table 3 panel A, we divide the data between those founders who have prior *start-up founding & IPO experience* and those who do not, and examine the conditional means of various first VC funding round characteristics. New venture age at the time of receiving the first round of VC, the log number of prominent partners, and the log pre-money valuation of experienced versus non-experienced founders are statistically the same between the two sub-samples. On the other hand, experienced entrepreneurs had more patent applications and were more likely to be funded by network central VCs in the first funding round. In panel B, we examine the univariate correlation between patent applications (non-zero applications and being in the top 5 percent of that distribution) and pre-money valuation. We look both at the first round and at all VC funding rounds in the table. The same analysis is repeated for prominent partners and pre-money valuation. In all cases, mean valuations are greater for higher levels in the patent and partner distributions, and most all of these differences are statistically significant. Finally, in panel C, we examine the likelihood of observing an IPO by the end of the time period

conditional on prior entrepreneurial experience, having non-zero prominent partners, having non-zero patent applications, and being in the top 5 percent of the patent application distribution as of the final funding round. Possessing the quality in each case is associated with an increase in IPO likelihood.

*** Insert Table 3 about here ***

RESULTS

Sourcing a Reputable Venture Capitalist in the First Funding Round

We now move on to the multivariate results by first examining the likelihood of being funded by a network central VC in the first funding round. To the extent that early signals and resource commitments can have long-lasting effects for start-ups by influencing future resource access, entrepreneurs will pay particular attention to their early stage signaling efforts. The first two columns of Table 4 report probit regressions of the likelihood that *high VC eigenvector centrality* equals 1 in the sample of all first funding rounds (marginal effects are reported). These results hold after controlling for stage of product development, start-up age and funding round period effects. The first column considers two signals of entrepreneurial quality: *prior start-up founding & IPO experience* and *prominent partner stock*. Both are estimated with a positive coefficient, though only the former is (weakly) statistically significant. These results are net of controls for patent value, start-up characteristics, and timing effects. The second column adds *patent application stock* to the specification, and the estimate, which is statistically significant, suggests a seven percent increase in the probability of sourcing a network central VC in the first funding round. The other two signals of entrepreneurial quality are not statistically significant.

A final column of Table 4 examines the same independent variables but changes the dependent variable to be the log of *pre-money valuation*. Again, patent application stock is

positive and statistically significant (unlike the entrepreneurial experience and *prominent partner stock* measures). *Lapsed patent stock* and *pre-1997 funding round dummy* are negative, while *profitable phase of development* is positive, as would be expected.

Investor Estimates of Start-up Value

Table 5 presents regressions in which the dependent variable is the natural log of ventures' *pre-money valuation*. We use a trans-log functional form specification in the valuation analyses, with both the dependent variable and continuous independent variables specified in natural logs, due to the right-skewed distributions associated with these variables. All specifications in this table, which takes the funding round as the unit of analysis, include start-up fixed effects. This approach allows us to reduce the risk that unobserved time-invariant differences across firms are driving the empirical results rather than our independent variables of interest. All variables in the analysis are round varying, with the exception of the entrepreneurial experience variable. The direct effects of these entrepreneurial experience variables are not statistically identified in the round-level framework with start-up fixed effects, as they are time invariant. These effects therefore are estimated using interaction terms.

*** Insert Table 5 here ***

The first column of Table 5 shows the estimated effect of reputable third party affiliations in a specification with the control variables from the prior table, together with controls for whether the funding round involves *angel investors* or is an *acquisition* or *IPO round*. *Prominent partner stock* is not significant in the regression. The second column adds two additional signaling mechanisms: patent application stock (positive and significant at the one percent level) and the interaction between *patent application stock* and *prior start-up founding & IPO experience* (not significant). *Prominent partner stock* remains insignificant, and due to the

inclusion of the patent value measure in each specification, we interpret the patent application stock result as a signaling effect.

A final specification in Table 5 retains all of the variables from the second specification and adds the interaction of *early funding round* and *patent application stock* (positive and significant), *high VC eigenvector centrality* (negative and significant), and the interaction between *high VC eigenvector centrality* and *patent application stock* (positive and significant). The estimated coefficient of the patent variable implies that a doubling of *patent application stock*, holding constant all the other independent variables, is associated with a 28 percent increase in *pre-money valuation*, thus supporting H1.¹⁰ As in the prior specification, we do not find evidence that patent filings trigger a greater upward adjustment in valuations for start-ups founded by less experienced entrepreneurs than they do for start-ups with more experienced founders, as predicted by H2.

The positive interaction effect between *early funding round* and *patent application stock* suggests that the effects of patents on investor estimates of start-up value are more pronounced during earlier funding rounds relative to later rounds, providing support for H3 (the estimated direct effect of *early funding round* is negative and significant across all of the specifications in this table). Finally, the positive and significant estimate of the interaction between *high VC eigenvector centrality* and *patent application stock* suggests that more network central VC investors value a given patent stock more highly relative to less central VCs.¹¹

¹⁰ As shown in Table 1, the mean pre-money valuation in the sample is roughly \$60 million and the mean patent application stock is 8 in a focal round. This result therefore suggests that, holding constant all other independent variables, a doubling of the mean patent application stock from 8 to 16 patent filings is associated with a boost in investor estimates of start-up value by \$16.8 million (\$60 million * 28 percent). As suggested earlier, Lemley (2001) estimates that direct costs, including attorney fees, per patent filing. Thus, this additional valuation boost of \$12 million would require roughly \$200,000 (at \$25,000 * 8 new filings) in patent-related expenditures, an economically important return on investment for an early-stage company.

¹¹ The appendix table provides a supplemental test of the VC centrality effect. We conceptualize the presence of central VCs as a “treatment” effect for new ventures by specifying two derivative variables of VC centrality.

The *high VC eigenvector centrality* direct effect is estimated with a negative and statistically significant coefficient. This is consistent with high reputation VCs being able to offer superior resources and/or signaling value to their affiliate start-ups, thereby earning a return to their investment in reputation by charging a premium for their capital (Hsu, 2004). These results suggest that while prominent VCs are able to command a price premium generally, they make greater upward adjustments in start-up valuations upon the filing of patents relative to less network central investors. At the same time, across the specifications in Table 5, the direct *patent application stock* effect remains positive and significant at the one percent level.

Overall, the valuation results suggest that patents serve as an important signal of start-up firm quality, even more so than affiliation with prominent third parties. Patent signals are especially potent in the early funding rounds for new enterprises. While we cannot infer the direct importance of prior entrepreneurial experience as a signal of quality from the analysis here, we do not find support for patents holding more weight for entrepreneurially inexperienced founders. Finally, the results provide support for the proposition that more prominent venture capitalists value start-up patents more highly.¹²

IPO Likelihood

Table 6 examines the probability that a venture's final funding round was an IPO.

Transition to central VC is a dummy set to one if relative to the prior funding round for a given firm, the investing VC had *high VC eigenvector centrality* (*transition away from central VC* is defined similarly, with the excluded variable being rounds in which there was no upward or downward adjustment in investing firms' VC centrality). In fixed effects negative binomial regressions at the VC round level of analysis, we examine the dependent variable, *number of forward patent citations*. This measure follows standard practice in the literature and weights patents by the number of citations they receive in other U.S. patents during the four years following their issuance date, which has been used to proxy the economic importance of these inventions (see Hall, Jaffe and Trajtenberg, 2005). In the regression, *transition to central VC* is positively associated with *number of forward patent citations* (but not with a dependent variable, *number of lapsed patents*, which may proxy for patent assertiveness).

¹² We tested the robustness of these results using alternate functional forms (a percentage change specification and a lagged dependent variable specification using patent application flows rather than stocks) and definitions of the key independent variable (a composite measure of signal strength consistency and differential patent signal strength depending on patent legal counsel). The results in all cases are consistent with those presented.

Marginal effects are reported. Not surprisingly, those ventures in the profitable stage of development are more likely to experience an IPO in their last observed funding round. In addition, while *prior start-up founding & IPO experience* is marginally significant (at the 10 percent level) in the first column of the table, it is not significant once other factors are controlled for (in the second column). On the other hand, *patent application stock* is strongly positively associated with IPO likelihood even after controlling for alternative signaling mechanisms, such as entrepreneurial experience, prominent partner affiliations and other factors. This finding suggests that patents cast an important signal not only to VC audiences but also to investors in public equity markets (Heeley et al., 2007).

*** Insert Table 6 here ***

DISCUSSION AND CONCLUSION

This study provides new evidence that patenting can positively affect investors' perceptions of start-up quality across multiple stages of the entrepreneurial life cycle, as measured through the likelihood of being funded in the first VC round by a network central VC, venture valuations, and IPO probabilities. We find that the effect of patenting on start-up valuation is more pronounced in earlier financing rounds. This is consistent with the view that patents provide a vehicle for overcoming early-stage disclosure issues in the market for new ideas (e.g., Arrow, 1962; Arora et al., 2001; Gans et al., 2002). We fail to find, however, that the signaling effect of patents is larger for novices than it is for more experienced entrepreneurs. Finally, our round-level analyses provide evidence that the signaling value of patents is higher when securing funds from prominent investors. Start-ups backed by prominent VCs may tap into superior complementary legal and organizational resources, thus improving the odds that the patents they file will confer greater economic value to entrepreneurs and their investors.

Our findings also suggest that, for start-ups in technology-intensive sectors, having a larger patent application stock increases the likelihood of securing initial funding from a prominent venture capitalist. Prior studies show that, relative to ventures backed by less reputable investors, entrepreneurial ventures that receive initial funds from prominent venture capitalists are more likely to survive (Hochberg et al., 2007), to develop successful products (Hellmann and Puri, 2002) and to receive higher valuations in IPOs (Gulati and Higgins, 2003; Hochberg et al., 2007). Our findings raise the intriguing possibility that patents help shape the initial network position of innovation-intensive ventures and, in doing so, affect their future resource trajectories. These results resonate with those reported in Hallen (2006), where the early resource advantages of venture-backed security software companies are shown to have enduring performance implications. To the extent that patent filings affect the probability of securing financing from prominent venture capitalists, these results also relate to survey evidence provided by Eckhardt, Shane and Delmar (2006). These authors conclude that, under some circumstances, founders could be better off by postponing solicitations for outside financing until objective information on the prospects of their venture has been generated. These issues warrant further study, ideally through use of complementary case- or field-based methodologies.

In line with prior studies (e.g., Stuart et al., 1999; Mann and Sager, 2007), we also find that start-ups with a larger numbers of patent applications are more likely to exit successfully through an IPO. Interestingly, we find little evidence that having prominent alliance partners or corporate investors significantly improves the likelihood that semiconductor start-ups will exit via an IPO (except via an interaction effect with prior successful entrepreneurial experience). This result contrasts with considerable evidence reported in the biotechnology sector (e.g., Stuart et al., 1999; Gulati and Higgins, 2003). For example, in the Stuart et al. study, which analyzes

endorsement effects for ventures in the biotechnology industry, the authors report a significant effect of patents in firm valuation at the time of an IPO, though their measures of third-party affiliation effects remain positive in a fully-specified model. Our contrasting findings raise the possibility of sector-specific dynamics that could alter the dynamics between new ventures and corporate alliance or equity partners or the magnitude of endorsement effects that stem from affiliations with prominent corporations. Our empirical context also differs from the Stuart et al. study in that we test for effects across earlier stages of new venture development when the beneficial effects of corporate affiliations may be counteracted by elevated concerns of expropriation. Future studies could examine more explicitly the trade-offs associated with alternative quality signals at different stages of development and the extent to which sector-specific dynamics alter the use and relative importance of those signals.

A few other interpretational issues merit discussion. The first refers to the use of the term “signaling” throughout the paper. We rely on our empirical strategy of including a measure of patent value and interpreting the patent applications coefficient as a signaling effect. Patent applications, of course, proxy for both productive effects (exclusionary and/or markets for technology effects) as well as signaling effects, and so a clean separation is not possible (as in prior empirical studies—though our empirical context allows for improvement relative to previous efforts). A second interpretational issue stems from proxies for the main empirical concepts including entrepreneurial experience and affiliation with prominent third parties. We have to the extent possible followed the prior literature in measuring each of these key concepts. Given the limited number of empirical studies in these domains, however, further study is needed.¹³

¹³ In unreported regressions, we have also tested other measures of entrepreneurial experience (in the spirit of Eisenhardt and Schoonhoven, 1990) such as number of founders on the start-up team, whether a founder had been

While not without limitations, our study shows that patents play a meaningful role in facilitating the technological and market pursuits of young companies in the semiconductor industry. It is widely recognized that patents provide an important vehicle for financing innovation within the life science arena (e.g., Stuart et al., 1999; Gans et al., 2002). Our study provides new evidence that patents also appear influential in the entrepreneurial resource acquisitions process within the semiconductor sector. These results are important from a policy perspective given concerns about patent hold-up problems in this sector and the noise introduced by numerous filings of low-quality patents (Jaffe and Lerner, 2004). Future research could assess more fully the relative strength of patents as quality signals in other segments, such as software.

In summary, this study was motivated by a gap in the entrepreneurial management and organizations literature on the mechanisms used by nascent organizations to secure the resources required for growth and survival. The role of patents as quality signals for young technology-intensive firms has received little systematic treatment, particularly when compared to prominent affiliations and entrepreneurial experience. We provide new insights by positioning patents within the menu of quality signals available to entrepreneurs and by estimating their effects across multiple stages of the new venture life cycle. Our findings reveal an important interplay between the patent strategies and resource trajectories of young, technology-intensive organizations. Future research is needed to test the generalizability of these results to other innovation-intensive settings. More broadly, the net benefits of alternative signaling mechanisms at different stages in the entrepreneurial development process represents an understudied yet promising avenue for further study.

an executive officer in a prior firm and the educational characteristics of the founders (holding a PhD and/or an MBA degree). These variables when taken in composite or individually yield similar or weaker results than those reported.

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Table 1
Summary Statistics and Variable Definitions*

VARIABLE	DEFINITION	MEAN	STD. DEV.
(1) <i>Pre-money valuation</i>	VC pre-money valuation (<i>share price * shares outstanding prior to venture round</i>) of the focal round	60.43	108.87
(2) <i>IPO</i>	Dummy = 1 if the venture achieved an initial public offering by 2006	0.04	0.19
(3) <i>Patent application stock</i>	Cumulative patent application stock at the time of the funding round (or for the firm level analysis, at the time of the latest funding round)	8.08	40.52
(4) <i>Prior start-up founding & IPO experience</i>	Dummy = 1 if at least one member of the founding team had prior IPO experience	0.09	0.29
(5) <i>Prominent partner stock</i>	Cumulative count of technologically or commercially prominent strategic alliance or corporate equity partners as of the VC funding round (see text)	0.33	0.87
(6) <i>High VC eigenvector centrality</i>	Dummy = 1 if the VC firm falls in the upper half of the within-sample distribution of VC network eigenvector centrality	0.35	0.48
(7) <i>Lapsed patent stock</i>	Cumulative count of lapsed patents (as a result of expiration / failure to pay maintenance fees) as of the VC funding round	0.71	3.99
(8) <i>Early stage round</i>	Dummy = 1 if funding round is classified as round 1 or 2.	0.50	0.50
(9) <i>Start-up age at time of VC round</i>	Age of the start-up in years at the time of the VC funding round.	4.06	3.55
(10) <i>Profitable phase of development</i>	Dummy indicating profitable start-up phase of development.	0.09	0.29
(11) <i>Angel round</i>	Dummy = 1 if the focal funding round was led by angel investors	0.03	0.17
(12) <i>Acquisition round</i>	Dummy = 1 if the focal funding round involved a merger / acquisition	0.08	0.29
(13-14) <i>Funding year controls</i>	Dummies for the pre-1997 (0.49) and 1998-2000 funding round time periods (0.30) [the excluded time period is post 2000 time period]		

* The natural logarithm of a variable, X, will be denoted L X.

Table 2
Correlation Matrix of Independent Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	1													
(2)	0.29	1												
(3)	0.15	0.06	1											
(4)	0.00	0.06	0.03	1										
(5)	0.14	0.16	0.14	0.11	1									
(6)	-0.17	-0.21	-0.04	0.04	-0.03	1								
(7)	-0.03	0.02	0.08	-0.05	0.10	0.04	1							
(8)	-0.22	-0.19	-0.10	0.04	-0.23	0.07	-0.02	1						
(9)	0.15	0.29	0.09	-0.08	0.32	-0.11	0.21	-0.44	1					
(10)	0.08	0.41	0.05	-0.03	0.17	-0.05	0.17	-0.17	0.31	1				
(11)	-0.05	-0.03	-0.02	0.06	-0.03	-0.10	-0.01	0.12	-0.05	-0.01	1			
(12)	0.33	-0.09	0.10	-0.01	0.03	-0.27	-0.04	-0.12	0.14	-0.01	-0.04	1		
(13)	-0.22	0.13	-0.06	0.07	0.08	0.22	0.10	0.02	-0.08	0.20	0.00	-0.25	1	
(14)	0.19	-0.09	0.04	-0.06	-0.06	-0.13	-0.07	0.16	-0.13	-0.15	0.00	0.07	-0.68	1

Note: variable numbering corresponds to Table 1 numbering.

Table 3: Univariate difference in means tests

Panel A: Successful entrepreneurial experience and the first VC funding round characteristics

		Firm age at time of first VC round	Log prominent partners	Log patent applications	Network central VC partner?	Log pre-money valuation
Prior start-up founding & IPO?	Yes	1.15	0.06	0.84	0.52	1.91
	No	1.77	0.05	0.50	0.33	1.77
t-stat difference		1.30	0.44	2.05**	2.12**	0.58

Panel B: Patents, prominent affiliates and valuations

	Log pre-money valuation							
	>0 patent applications?		In top 5% of patent distribution?		>0 prominent partners?		In top 5% of prom. partner distribution?	
	Yes	No	Yes	No	Yes	No	Yes	No
First VC Funding Round	2.20	1.70	2.96	1.82	2.21	1.87	2.69	1.87
t-stat difference	3.39***		4.02***		1.08		1.71†	
All VC Funding Rounds	3.54	2.68	4.53	3.20	3.90	3.11	3.98	3.21
t-stat difference	9.11***		6.70***		7.34***		4.91***	

Panel C: Entrepreneurial characteristics and exit outcomes

	Prior new venture founding & IPO?		>0 prominent partners?		>0 patent applications?		In top 5% of patent distribution?	
	Yes	No	Yes	No	Yes	No	Yes	No
Probability of an IPO	0.24	0.13	0.25	0.10	0.18	0.03	0.42	0.12
t-stat difference	1.83†		3.72***		3.58***		3.74***	

†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively.

Table 4
Firms' First Round of Funding Outcomes

	Dependent Variable: Pr (<i>High VC Eigenvector Centrality</i> = 1) Note: Marginal effects reported		Dependent Variable: <i>L pre-money valuation</i>
Estimation method	Probit		OLS
Independent variable	(4-1)	(4-2)	(4-3)
<i>L patent application stock</i>		0.072** (0.033)	0.267*** (0.081)
<i>Prior start-up founding & IPO experience</i>	0.166† (0.087)	0.140 (0.088)	0.012 (0.193)
<i>L prominent partner stock</i>	0.174 (0.134)	0.162 (0.134)	0.241 (0.299)
<i>L lapsed patent stock</i>	0.013 (0.090)	-0.071 (0.098)	-0.472** (0.209)
<i>Profitable phase of development</i>	-0.068 (0.177)	0.001 (0.184)	0.838** (0.375)
<i>Pre 1997 funding round dummy</i>	0.127 (0.105)	0.153 (0.108)	-1.063*** (0.076)
<i>Funding round 1998-2000 dummy</i>	0.047 (0.113)	0.058 (0.117)	-0.467 (0.368)
<i>Start-up age</i>	-0.010 (0.012)	-0.015 (0.012)	0.103 (0.030)
Log likelihood / Adj. R-squared	-225.91	-224.88	0.33
Num. Observations	360	358	168

†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively.

Table 5
Pre-money Valuation Fixed-Effects OLS Regressions
(VC round level of analysis)

Independent Variable	Dependent Variable = <i>L pre-money valuation</i>		
	(5-1)	(5-2)	(5-3)
<i>L patent application stock</i>		0.421*** (0.073)	0.284*** (0.067)
<i>L patent application stock * prior start-up founding & IPO exp.</i>		0.012 (0.122)	0.007 (0.122)
<i>L prominent partner stock</i>	0.204 (0.143)	0.092 (0.141)	0.138 (0.141)
<i>L lapsed patent stock</i>	0.089 (0.149)	-0.019 (0.152)	-0.027 (0.151)
<i>Early funding round</i>	-1.155*** (0.096)	-0.977*** (0.096)	-1.135*** (0.121)
<i>Early funding round * L patent application stock</i>			0.178** (0.075)
<i>High VC eigenvector centrality</i>			-0.242** (0.123)
<i>High VC eigenvector centrality * L patent application stock</i>			0.129** (0.065)
<i>Profitable phase of development</i>	0.330** (0.156)	0.254† (0.153)	0.246 (0.152)
<i>Angel round</i>	-0.648** (0.304)	-0.507† (0.303)	-0.586 (0.302)
<i>Acquisition round</i>	-0.018 (0.153)	0.216 (0.150)	0.161 (0.154)
<i>IPO round</i>	0.869*** (0.167)	0.801*** (0.162)	0.844*** (0.168)
<i>Pre 1997 funding round dummy</i>	-0.520*** (0.209)	-0.321 (0.206)	-0.380† (0.206)
<i>Funding round 1998-2000 dummy</i>	0.181 (0.131)	0.271** (0.128)	0.234† (0.128)
<i>Start-up age</i>	0.051** (0.026)	-0.009 (0.030)	-0.002 (0.029)
<i>Firm fixed effects</i>	Yes	Yes	Yes
<i>Constant</i>	2.980** (1.215)	2.534** (1.194)	2.480** (1.191)
Adj. R-squared	0.60	0.63	0.64
Num. Observations (Firms)	846 (290)	813 (269)	813 (269)

†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively.

Table 6
IPO Likelihood Probits
(Sample: Firms' final round of funding)

	Dependent Variable = Pr (<i>IPO</i> = 1) Note: Marginal effects reported	
Independent Variable	(6-1)	(6-2)
<i>L patent application stock</i>		0.051*** (0.014)
<i>Prior start-up founding & IPO experience</i>	0.082† (0.049)	0.128 (0.185)
<i>L prominent partner stock</i>	0.029 (0.029)	-0.027 (0.033)
<i>L patent application stock * prior start-up & IPO experience</i>		-0.048 (0.039)
<i>L prominent partner stock * prior start-up & IPO experience</i>		0.192** (0.101)
<i>Profitable phase of development</i>	0.222*** (0.071)	0.176*** (0.071)
<i>Pre 1997 funding round dummy</i>	0.277*** (0.071)	0.342*** (0.081)
<i>Funding round 1998-2000 dummy</i>	0.073 (0.054)	0.067 (0.055)
<i>Start-up age</i>	0.008** (0.004)	0.004 (0.004)
Log likelihood	-91.90	-81.03
Num. Observations	333	306

†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively.

Appendix Table
Patent Value Fixed-Effects Negative Binomial Regressions
(VC round level of analysis)

	Dependent variable: Number of forward patent citations
Independent Variable	(A-1)
<i>Transition to central VC</i>	0.157** (0.074)
<i>Transition away from central VC</i>	0.045 (0.066)
<i>L patent application stock</i>	0.001† (0.001)
<i>L prominent partner stock</i>	0.158*** (0.038)
<i>Early funding round</i>	-0.921*** (0.081)
<i>Angel round</i>	0.273 (0.158)
<i>Acquisition round</i>	-0.226*** (0.088)
<i>IPO round</i>	0.115 (0.096)
<i>Profitable phase of development</i>	0.160† (0.094)
<i>Pre 1997 funding round dummy</i>	-0.319** (0.147)
<i>Funding round 1998-2000 dummy</i>	0.221*** (0.088)
<i>Start-up age</i>	0.100*** (0.012)
<i>Firm fixed effects</i>	Yes
<i>Constant</i>	0.633 (0.594)
Log likelihood	-3152.97
Num. Observations (Firms)	1060 (234)

†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively.