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PATENTS AS QUALITY SIGNALS FOR ENTREPRENEURIAL VENTURES

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Abstract:

This study examines the degree to which patents enable entrepreneurs to acquire financial capital under favorable terms across the new venture life cycle. While taking into account the role of prominent affiliation partners, we argue 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 venture capital investors. To test these predictions, we trace the patenting and venture financing activities of 370 U.S. semiconductor start-ups that receive over 800 rounds of funding from 1980 through 2005.

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ABSTRACT

Signaling quality to external resource providers is an important yet challenging activity for new organizations. This study examines the degree to which patents enable entrepreneurs to acquire financial capital under favorable terms across the new venture life cycle. While taking into account the role of prominent affiliation partners, we argue 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 venture capital (VC) investors. To test these predictions, we trace the patenting and venture financing activities of 370 U.S. semiconductor start-ups that receive 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 24% boost in funding-round valuations beyond what would otherwise be expected. We also find that 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 VC 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.

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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)

1. 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 et al. (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 et al., 2002) and affiliations with reputable third parties such as prominent venture capitalists (e.g., Gulati and Higgins, 2003; Hsu 2004), corporate partners (e.g., Stuart et al., 1999; Baum et al., 2000), and investment bankers (Megginson and Weiss, 1991; Carter et al., 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 original conceptualization of a signal (Spence, 1973): they are costly to obtain and, through the government certification process, provide a mechanism by which the quality of innovative activities can be sorted.¹ Like other symbolic actions entrepreneurs use to attract external resources (Zott and Huy, forthcoming), including founder backgrounds and third-party affiliations, patents can simultaneously confer intrinsic value due to the property right. Nonetheless, we know very little about the extent to which, if at all, the patenting activities of technology-intensive start-ups alter investor expectations about their profit potential.

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 a new technology-intensive venture alters investor estimates of its economic value. We also examine how founder experience, venture funding stage, and VC experience might condition the role of patents as quality signals.

Drawing on insights from signaling theory, we argue 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 venture capital (VC) investors. To test these predictions, we assemble a unique database that merges information about the initial resource endowments of 370 venture-backed semiconductor start-ups, founded between 1975 and 1999, with 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 the filing of patents alters investor expectations of

¹ We define a signal broadly as information capable of altering an observer's probability distribution of unobserved variables.

start-up firm value. This empirical design allows us to examine the extent to which *changes* in patenting affects *changes* in venture valuation by making use of within-firm, across-round variation. We also examine significant performance outcomes across multiple stages in the start-up life cycle (from the probability of receiving initial funding from a reputable VC through the probability of successful exit through an initial public offering).

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 24% increase in valuation, representing an upward funding-round adjustment of roughly \$12 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 alter investor expectations including 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 signaling value of patents is greater in earlier financing rounds and when funds are secured from prominent investors.

In our analyses of the contingent role of patents, we find that the effect of patenting on start-up valuation is more pronounced in earlier financing rounds. We interpret this result as consistent with the view that patents provide a vehicle for overcoming early-stage disclosure problems 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 modest evidence that the signaling value of patents is higher when securing funds from prominent investors.

In supplemental analyses, we find that having larger patent application stocks increases the likelihood that entrepreneurs will attract initial financing from a prominent venture capitalist, a pivotal event that shapes the resource trajectories of new firms (Hsu, 2004; Hallen, 2006; Hochberg et al., 2007). Finally, our results suggest that having larger patent application stocks also increases the likelihood of successful exit through an initial public offering (IPO). For our sample of semiconductor start-ups, however, we find little evidence that having prominent alliance partners or corporate investors improves

the likelihood of exit via IPO, a result that contrasts with evidence from the biotechnology industry (e.g., Stuart et al., 1999; Baum et al., 2000; Gulati and Higgins, 2003).

This study contributes to two main strands of literature. First, we contribute 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 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 these 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) or 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 cleanly identify the 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 provocative baseline for 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 venture-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 et al., 2007). Conceptually, we contribute new insights by exploring how the value of signaling quality through patent filings hinges on the initial reputation 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. The remainder of the paper is organized as follows. Section 2 discusses the related literature and proposes a set of empirical predictions. Section 3 describes our empirical design and data, while section 4 presents our empirical results. A final section discusses the results and limitations of the study.

2. Literature and Empirical Predictions

This section begins by discussing several approaches and themes characterizing the relevant prior literature. Subsequent sections are devoted to reviewing and conceptualizing alternative signals available to new ventures and differential abilities of receivers in interpreting those signals.

2.1. Signaling Quality through Third-Party Affiliations and Founder Characteristics. The challenges that technology-intensive ventures face when securing resources required for their development has motivated a considerable body of research on the mechanisms used to signal the (largely unobservable) value and commercial potential of these nascent organizations. One influential strand of studies shows that organizations affiliated with reputable or high social status partners (such as alliance partners, venture capitalists, or investment banks) can experience enhanced performance because of inter-organizational transfer 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. (forthcoming) 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 venture capital portfolio, to a rival startup. 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 experience, 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).² 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, which have measurable effects in obtaining external financing at the time of founding. 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 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. (forthcoming) show, for example, 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 have previously

² 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 in the population decides to engage in entrepreneurship (e.g., McClelland, 1961; Khilstrom and Laffont, 1979).

failed.³ In turn, this effect can increase the bargaining power of serial entrepreneurs with a demonstrated track record of new venture performance when seeking capital from external sources. Similarly, Hsu (forthcoming) 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.⁴

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).⁵ As suggested earlier, 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) literatures.

2.2. Patents as Quality Signals. While the entrepreneurship literature has investigated the signaling value of third-party affiliations and founder backgrounds quite extensively, relatively little

³ Their corollary finding is that funding by more experienced VCs enhances venture performance, but only for entrepreneurs without a prior track record. Consistent with this argument, Lerner and Tirole (2006: 1107) note further that “[e]xperienced entrepreneurs with successful track records will often turn to alternatives—especially individual ‘angels’—rather than take funds from venture investors. While this may partially be because the management skills that the venture capitalists can contribute are no longer as helpful, in part it reflects the fact that the entrepreneur’s previous success makes the venture capitalist’s certification less essential.”

⁴ 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.’”

⁵ 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.

conceptual or empirical attention has been placed on the role of patents as quality signals for innovation-intensive ventures. In this section, we first discuss why information revealed through the filing or receipt of patents could alter resource provider estimates of entrepreneurial-firm value, thus conferring advantages in capital markets for early-stage financing. That patent filings will trigger a boost in investor expectations represents our main “first-order” prediction. The null hypothesis—that the patenting activities of an early-stage firm will *fail* to trigger a significant response in investor estimates of its profit potential—is important to consider, so we also discuss it briefly. Finally, we develop three corollary predictions that relate the strength of patents as quality indicators to characteristics of founders, start-ups, and their investors.

Before discussing the role of patents as quality signals, it is useful to review the potential intrinsic value of patents as property rights. As Long (2002) argues, the classic view of patents as intellectual property is their government-sanctioned exclusionary role, as illustrated by Cohen’s (1954) statement: “Keep off *X* unless you have my permission, which I can grant or withhold. Signed: Private citizen. Endorsed: The state.” 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 advantage in future markets 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) are unwilling to provide funding without first observing the underlying discovery; meanwhile sellers may be reluctant to disclose such information for fear of little recourse if the deal breaks down (due to the threat of idea or technology expropriation). 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 et al. (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 et al. (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 et al., 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 (novel inventions that are useful and not obvious to those skilled in the art). 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 the additional filings of patents or for the hiring of more 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).⁶ Engineers and scientists also have to be educated about 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 important, the back-and-forth associated with engineers and scientists communicating with patent agents or attorneys

⁶ 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.

can be tedious and time-consuming. This latter opportunity cost can be especially high for start-ups facing strong pressures for rapid time-to-market, a competitive dynamic widely attributed to information technology-related sectors (e.g., Eisenhardt and Schoonhoven, 1990; Cohen et al., 2000).

Finally, as argued perhaps most forcefully by legal scholars, patents do not necessarily have to lead to direct enhanced productivity to serve as an effective signal provided that the signaling costs stratify quality “types”. Lemley (2001), for example, writes: “Venture capitalists use client patents (or more likely, 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 entrepreneurial lineage as compared to on-going venture accomplishments 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:

- *H1: The patenting activities of an entrepreneurial venture positively shapes 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 patent ability 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 a managerial and a policy perspective.

2.3. The Moderating Effects of Founder, Start-up, and Investor Characteristics. In our final set of 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 availability of alternate information (regarding quality of management team and/or technology). Such expectations of future success can get “priced into” initial or early stage funding rounds, and so patents are likely to be less important signals for relatively experienced entrepreneurs. This can result either from the knowledge by observers that experienced entrepreneurs have a higher opportunity costs to their current activities as well as by the learning/enhanced organizational capital resulting from prior entrepreneurial experience. 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.*

Early stages of funding are characterized by greater technical and demand uncertainty in product development. In such settings, start-up quality signals such as patents are particularly important as resource providers and external actors may have a hard time evaluating the venture’s prospects. Patents in particular may be a particularly important means by which early stage ventures may appropriate returns from their inventive activity. This may take place in the form of licensing intellectual property to firms that will then commercialize technology (e.g., Gans et al., 2002), in which case patents help define the scope of intellectual property being transferred between the parties. Without the legal channel afforded by formal intellectual property protection, firms may choose to internalize the commercialization process rather than risk the threat of expropriation they open themselves up to in the course of disclosing their

inventive activities to more established incumbents (a necessary precondition for bargaining over the terms of technology transfer). As the venture develops, there may be alternate mechanisms by which it 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 entrepreneurial 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 which may have implications for patents as quality signals for start-ups.⁷ Experienced VCs, as a result of their prior interactions with the network of entrepreneurial resource infrastructure, such as other VCs, entrepreneurs, and professional service firms, may face a lower cost of sourcing information useful for, *inter alia*, evaluating patents (for example, Burt, 1992 discusses preferential access as a key informational advantage to central network position).⁸ As a result, experienced VCs 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 more network central VC. This results from experienced VCs valuing patent importance over patent quantity—and so more central/expert evaluators may recognize and place value on a relatively small number of key patents,

⁷ The conceptualization of variation in experience and quality of VCs is consistent with the recent entrepreneurship literature which finds a great deal of variation in VC division of rents and returns to VC funds’ limited partners (Hsu, 2004; Kaplan and Schoar, 2004; Gompers et al., forthcoming).

⁸ 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).

or conversely they may place a low valuation on a large stock of observed start-up patents. 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 value of start-ups' patents, is less ambiguous in its predicted effects. More experienced VCs may value start-up patents more so than their less experienced counterparts because of potential complementarity between start-up and experienced VC 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 VC functions and relationships which may improve the commercialization prospects of their affiliated new enterprises, it is also possible that more prominent VCs 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 patenting (in the spirit of Kortum and Lerner, 2000 and Hellmann and Puri, 2002). We therefore predict:

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

3. Data, Methodology and Variables

To test the predictions, we require an empirical strategy which will allow us to pinpoint the signaling role of patents. This is difficult because unobserved quality differences could spuriously account for an observed relationship between patents and performance outcomes (i.e., higher quality start-ups are more likely to acquire quality signals). We therefore construct a longitudinal dataset based on rounds of VC funding in order to study how changes in patenting are related to changes in venture valuation, holding time invariant start-up effects fixed. Using this framework, our results are less likely to be driven by unobserved quality differences.⁹

⁹ Disentangling the efficacy of various signaling mechanisms is difficult, as there are few empirical contexts to collect data. We know of only one such empirical setting: online auctions marketplaces such as eBay offer a situation in which sellers likely have better information about the quality of the good they wish to sell relative to buyers, and so sellers may wish to signal quality to potential buyers by offering warranties, third party certifications, detailed descriptions and photographs, and high quality approval ratings from their prior customers. For the researcher, these transactions offer variation in signaling mechanisms used, quality of the underlying product, and

3.1 Data and Methodology. As an empirical testing ground, we focus on the signaling value of patents to semiconductor device start-ups, excluding equipment and materials firms in that industry. The semiconductor industry offers several advantages for 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 venture 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 focal start-ups in our sample include 370 U.S. semiconductor companies 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 et al. (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 US 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, we exclude the youngest cohort of start-ups founded after 1999. We restrict the sample to VC-backed firms for several reasons. First, interpreting patents as a signal implies that there is an intended audience or receiver of the signal. VCs are one

price paid for the good. At the same time, there is relative uniformity in the category of objects being auctioned (e.g., multiple copies of “very fine” quality first issues of Spiderman comic books), which allows for tight statistical control. The results from these studies generally conclude that signals of quality are important statistically but not necessarily economically in explaining sales price (e.g., Melnik and Alm, 2002). Dewally and Ederington (2006) assessed the comparative importance of signaling mechanisms in the online comic book market, finding that third party certification was most important in that market. However, these results may be a function of the particular marketplace and associated institutional structures studied. The natural question that arises is whether these results might hold more generally in different market contexts and structures in which the inherent quality of the good may be quite heterogeneous as a result of not being a commodity product.

important audience for such quality signals, as they evaluate and assign valuations to new ventures. Imposing the condition of enterprises funded by VC also allows us to construct a sample which is relatively uniform in quality (this is attractive since the spectrum of start-up quality is wide). Finally, and on a more practical matter, the ability to observe changes in start-up valuations before a liquidity event confers methodological advantages discussed below; we are unable to observe intermediate valuations for start-ups that do not receive VC financing.

We first estimate at the round level the impact of patenting on the valuations of start-ups across funding rounds, holding unobservable time invariant effects constant via start-up fixed effects (γ_i). We estimate the following type of equation for firm i in funding round t :

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

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. We first examine outcomes associated with the first funding 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 VC in the first stage makes it much more likely that a prominent VC will invest in the start-up 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 examine the sub-sample of data corresponding to first funding rounds. We estimate the probability of receiving funding from a prominent VC as a function of patents, founder entrepreneurial experience and a set of controls. By doing so, we will be able to

examine the empirical importance of alternate start-up quality signals in explaining the likelihood that the focal start-up gets funded by a reputable VC firm in their first round of funding.

A final analysis examines the probability that the final funding round involves 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.¹⁰ We therefore 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 variable is indicative that patents serve as quality signals to the IPO market.

3.2 Variables. We conduct the analysis at various stages of the entrepreneurial venture life cycle. A round-level analysis of the 370 firms across over 800 rounds comprises the first set of empirical tables. 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 (mean=\$48.8M). This represents the aggregate value of the firm (used as the basis of calculating the equity stake taken out for a given cash infusion by venture capitalists). The pre-money valuation data are from VentureSource and supplemented by VenturExpert (both for triangulation of data and to fill in missing data from the other data source). For the first funding round analysis, we examine the likelihood of being funded by a high reputation VC, which we proxy with the measure, *high VC eigenvector centrality* (mean=0.35). This measures the Bonacich centrality for the lead VC for each funding round and assigns a dummy=1 if the value is in the upper half of the within-sample distribution of eigenvector values (we calculate network position, as has become standard in this literature, based on VC syndication patterns over time).¹¹ For the sub-sample of final funding rounds, we examine the likelihood of experiencing an *IPO* (mean=0.14).

¹⁰ For entrepreneurial firms, an acquisition can also be an important channel to liquidity, particularly in time periods in which the public markets are “cold”. Due to the variation in the financial arrangement associated with acquisition events—such events can be an indicator of high or low performance (in the case of selling in a distressed state)—we examine a liquidity event which has lower ambiguity in interpretation.

¹¹ 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.

The key independent variables can be clustered into several categories. Patent-based measures were sourced from Delphion and the USPTO. These data include *patent application stock* (mean=8.1) and *forward patent citations stock* (mean=91.4) averaged across all funding rounds.¹² The entrepreneurial experience variables, hand-collected from web searches of founding team biographies, result in two individual dummy measures: *prior start-up founding experience* (mean=0.34) and *prior IPO experience* (mean=0.09). The former dummy variable=1 when at least one member of the founding team had previously been a founder of a start-up. The latter variable=1 when at least one member of the present entrepreneurial team had experience undergoing an IPO.

We employ a number of control variables. The first two measure the number of prominent affiliates. *Cumulative prominent alliances* (mean=0.05) is the number of technologically or commercially prominent alliance partners the focal firm has at the time of the funding round (evaluated on a time varying basis using 5 year windows). *Cumulative prominent corporate equity investors* (mean=0.44) is the number of technologically or commercially prominent corporate equity investors the focal firm has at the time of the funding round. These variables are included as controls because the prominence of strategic alliance partners and corporate equity investors represent important alternate signaling mechanisms that can shape new venture performance (e.g., Stuart et al., 1999; Baum et al., 2000; Gulati and Higgins, 2003).¹³ For the start-ups in our sample, indicators of the commercial and technological prominence of corporate affiliates were highly correlated ($\rho = 0.87$). We therefore constructed a

¹² More specifically, *patent application stock* comprises applications that eventually result in the successful awarding of a U.S. patent. Before 2001, information on U.S. patent applications that were rejected or abandoned during the examination process was not disclosed to the public. Our *forward patent citations stock* 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. The citations-weighted measure provides a closer estimate of the technological importance of these inventions (see Hall et al., 2005).

¹³Following 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 5-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.

composite indicator variable set equal to 1 if an alliance partner or corporate investor was “prominent” in either the commercial or technological dimensions.

We also make use of several other control variables, all of which are coded from the VentureSource database. *Early stage round* is a dummy=1 if a funding round is one of the first three rounds of funding received by the new enterprise (mean=0.68). The variable, *start-up age* is the age of the start-up evaluated at the time of the funding round, aims to control for venture maturity and life stage (mean=4.06). We include a set of stage of development dummies for the following new venture product or service development stages: *start-up stage* (mean=0.07); *product development stage* (mean=0.33); and *profitable stage* (mean=0.09). The excluded product development stage is beta. A set of round type dummies is also included in the analysis. These are dummy variables for *angel round* (mean=0.03), IPO round (mean=0.04), and acquisition round (mean=0.08). Finally, a host of funding year dummies are included for 1980-89 (mean=0.19), 1990-97 (mean=0.30), and 1998-2000 (mean=0.30). The excluded time period is post-2000. These period dummies match years with differing levels of VC capital inflows, an environmental factor that can alter valuations placed on VC-backed firms (Gompers and Lerner, 2000). Finally, we include a set of dummies for round number, round one (0.26); two (0.24); three (0.18); four (0.13); five (0.09); six (0.05); seven (0.03); eight (0.01); and nine (0.01). Excluded are rounds 10-15, which cumulatively total 0.01 of the remaining data.

4. Empirical Results

As previously mentioned, our empirical analysis consists of three analyses. The first examines start-up valuation as the outcome of interest using a VC funding round as the unit of analysis. A second analysis examines the correlates of sourcing a reputable VC investor in the first round of funding. We conclude with an examination of the relative importance of various entrepreneurial signals (patenting, entrepreneurial experience and affiliation with prominent third parties) in explaining an important milestone for entrepreneurial ventures, a liquidity event via an IPO.

4.1 Valuation. Table 3 presents regressions in which the dependent variable is the natural log of ventures' *pre-money valuation*.¹⁴ All specifications in this table, which takes the funding round as the unit of analysis, includes start-up fixed effects. This allows us to mitigate the risk that unobserved time-invariant differences across firms are driving the empirical results (rather than our independent variables of interest). Note that all variables in the analysis (summarized in Table 1) are round varying, with the exception of the two entrepreneurial experience variables, *prior start-up founding experience* and *prior IPO experience*. 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. Therefore, these effects can only be estimated when interacted with other independent variables of interest.

The first column of Table 3 shows a parsimonious specification with only *patent application stock* and start-up fixed effects on the right hand side. The coefficient is statistically significant at the 1% level, with a large implied effect: a doubling of patent application stock for a given firm is on average associated with a 92% increase in pre-money valuation. A similar result holds if patent grants or forward citation weighted patents is substituted for the measure of patenting. The latter variable is not contemporaneously available to the signal recipients, however, as the information of patent importance as measured by forward patent citation is only known in the future.¹⁵ In addition, we elect to use patent applications rather than grants to conform to the majority of studies in the patent literature (e.g., Hall et al., 2005). The second column of Table 3 reports the estimated effects of *prominent alliance stock* and *prominent corporate investor stock* (together with start-up fixed effects). Controlling for time-invariant qualities of the start-up firm, a doubling of these third party affiliations are each correlated with over a doubling of *pre-money valuation* (these effects are significant at the conventional levels). A third specification combines these two affiliation variables with *patent application stock* and includes an

¹⁴ We use a translog 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.

¹⁵ Table 2, a correlation matrix of the independent variables, shows that *patent application stock* is highly correlated (83%) with *forward patent citations stock*, which suggests that empirical results using the two variables are also highly correlated.

interaction term for each of these entrepreneurial signaling variables with a measure of entrepreneurial experience, *prior start-up founding experience*. The statistical and economic significance of the *patent application stock* variable is maintained, as is the effect of affiliation with *prominent corporate investors*. The *prominent alliance stock* effect, however, is eliminated. The interactions of each of the main effects with *prior start-up founding experience* yield either no or weak statistically significant correlation.

A final specification in Table 3 retains all of the variables from the third specification and adds a wide range of control variables. A set of VC round fixed effects, *funding period* dummies (corresponding to funding rounds between 1980-1989, 1990-1997, and 1998-2000), and *start-up age* are included in the regression. The motivation is that valuation is likely related to the stage of VC funding, time period effects, and corporate development as proxied by the passage of calendar time. A second group of variables control for firms' stage of product development, spanning the *start-up phase of development*, *product shipment phase of development*, and a *profitable phase of development*. Kaplan and Strömberg (2003), for example, find that the pre-revenue stage of start-up development is associated with different outcomes and contractual structure relative to firms which have a stream of revenues from product or service sales. A final set of controls are for whether the funding round involves *angel investors* or is an *acquisition* or *IPO round*. With this full specification, we see that of the three entrepreneurial signaling mechanisms, only *patent application stock* retains statistical and economic significance. The estimated coefficient implies that a doubling of *patent application stock*, holding constant all the other independent variables, is associated with a 24% increase in *pre-money valuation*.¹⁶ We find little evidence, however, 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:

¹⁶ As shown in Table 1, the mean pre-money valuation in the sample is roughly \$50 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 \$12 million (\$50 million * 24%). 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.

the coefficient on the *patent application stock * prior start-up founding experience* is statistically indistinguishable from zero.

Table 4 examines whether the signaling value of patents will be greater for ventures during their earlier funding rounds relative to later rounds in explaining the variation in *pre-money valuation*, allowing a test of H3. We start in the first column with *patent application stock*, *early funding round*, and two interactions of *early funding round* (with *patent application stock* and *prior start-up founding experience*). The patenting variable is positive and significant, as before. The *early funding round* dummy is negative and significant, as would be expected. The variable of interest, *early funding round * patent application stock*, is positive and significant, which suggests that patenting is a particularly important correlate of valuation in the early funding rounds. The second column of the table examines the two affiliation variables, *early funding round*, the interaction between each of the prominent affiliation early variables with *early funding round*, and *early funding round * prior start-up founding experience*. As before, *early funding round* is negative and significant. The direct effect of *prominent corporate equity investor stock* is positive and significant, as is the interaction effect of this variable with *early funding round*, suggesting that this form of affiliation boosts start-up valuations, particularly in the early stage rounds.¹⁷ The other affiliation variable, *prominent alliance stock*, is neither significant in its direct effect nor in its interaction with *early funding round*. A final column puts the variables from the first two columns together, along with the same set of control variables from Table 3 (except the round fixed effects, which are subsumed by the *early funding round* dummy). The main patent application stock effect persists, as does the primary variable of interest, *early funding round * patent application stock*.¹⁸

Table 5 concludes our valuation analyses by examining the role of VC experience heterogeneity in valuing start-up patents. We use our same empirical framework as before. In the first column of Table

¹⁷ An alternate interpretation is that corporate VCs tend to be more generous with their valuations (Gompers and Lerner, 1999).

¹⁸ Neither of the direct affiliation variables are significant, though *early funding round * prominent corporate equity investor stock* remains positive and significant. Interestingly, the *prominent alliance stock * prior start-up founding experience* interaction effect is weakly negative in this specification (the effect is noisy, however, so we hesitate to over-interpret the coefficient).

5 we enter *patent application stock*, *high VC eigenvector centrality*, together with the interaction of the VC experience variable with *patent application stock* and with *prior start-up founding experience*. While the patent application stock effect remains positive and significant, the *high VC eigenvector centrality* variable is estimated with a negative and statistically significant coefficient. The latter result is consistent with the phenomenon of high reputation VCs (who may be able to offer superior resources and/or signaling value to their affiliate start-ups) earning a return to their investment in reputation by charging a premium for their capital (Hsu, 2004). The main variable of interest, *high VC eigenvector centrality * patent application stock*, is positive but not statistically significant. A second specification examines direct effects of affiliation with alliance and corporate equity investor partners, together with these two variables interacted with the VC experience variable and an additional interaction term, *high VC eigenvector centrality * prior start-up founding experience*. The two affiliation effects are positive and significant, though of the three interaction effects, only the *high VC eigenvector centrality * prominent corporate equity investor stock* effect is positive and significant. A final specification puts the variables from the prior two columns together and adds the full set of control variables. The *patent application stock* and *high VC eigenvector centrality* effects persist. The main variable of interest, the *high VC eigenvector centrality * patent application stock* interaction, is now positive and weakly significant at the 10% level.¹⁹ We interpret this as moderate evidence for *H4*. 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,

Overall, the valuation results suggest that patents serve as an important signal of entrepreneurial quality, even more so than affiliation with prominent third parties. Patent signals are particularly 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 in this section, we do not find evidence that patents are more important signals for entrepreneurially inexperienced founders. Finally, the results

¹⁹ This interaction effect becomes statistically significant at the 2% level if the affiliation with prominent alliance and corporate equity investor interaction effects with *high VC eigenvector centrality* are omitted from the specification (thereby interpreting the affiliation variables as true control variables).

provide moderate support for the proposition that more prominent VCs value start-up patents more highly.

4.2 Sourcing a Reputable 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. While the above analysis suggests that patents play an important role in explaining the variation in valuations, particularly in early stage funding rounds, another aspect they may care about is the ability to source a reputable VC in their first funding round. We therefore examine the correlates of sourcing a network central VC in the venture's first funding round.²⁰ Table 7 reports probit regression results (marginal effects are reported). The dependent variable is the likelihood that *high VC eigenvector centrality* = 1, and the sample consists of all first funding rounds. We see that the results from Table 6 largely hold here. *Patent application stock* is positive across the specifications, and *prior start-up founding experience* is negatively associated with *high VC eigenvector centrality*. These results hold after controlling for stage of product development, start-up age, and funding round period effects. *Prior IPO experience* is positively associated with the dependent variable, which suggests either that such entrepreneurial experience facilitates matchmaking with central VCs, or that IPO-experienced entrepreneurs see the value of affiliating with more central VC firms. The main result in this analysis is the strong positive association between patents and the likelihood of receiving funding from network central VCs in the first professional funding round, reinforcing the signaling interpretation of patents.

²⁰ A brief review of some descriptive statistics is instructive. Table 6, panel A splits the sample of first funding rounds by whether the VC had high VC eigenvector centrality. Of the 360 observations, 126 of the first funding rounds were funded by high centrality VC firms. The conditional means of several variables are then reported, split by VC centrality. The table also lists a *t*-test of the null hypothesis that the conditional means are the same across VC status. From this simple analysis, we see that start-ups receiving funding from highly central VCs had a higher patent application stock, a higher fraction of prior IPO experience, and a lower fraction of prior start-up founding experience (the other differences are not statistically significant). The negative correlation between high VC centrality and prior start-up founding experience may suggest that such entrepreneurs may have the resources they would otherwise need to source from venture capitalists' networks (Hsu, forthcoming).

4.3 IPO Likelihood. Our final empirical analysis examines the probability that a venture's final funding round was an IPO round.²¹ Table 8 examines these relationships in the context of IPO likelihood probits (marginal effects are reported). Not surprisingly, those ventures which were in the profitable stage of development were more likely to experience an IPO in their last observed funding round. In addition, while *prior IPO experience* is marginally significant (at the 10% level) in a parsimonious model, it is not significant once other factors are controlled for. The main results of the table are that both *patent application stock* and *forward patent citations stock* are each individually positively associated with IPO likelihood (we do not enter these two variables into a single specification due to their high correlation), even after controlling for other signaling mechanisms (entrepreneurial experience and prominent partners), as well as for a host of product development stage and timing effects. Therefore, patents serve as an important signal to not only VC audiences (the VC valuation regressions) but also to IPO audiences.

5. Conclusion and Discussion

Our 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 both intermediate venture valuations as well as the likelihood of an IPO. In our analyses of the contingent role of patents, we find that the effect of patenting on start-up valuation is more pronounced in earlier financing rounds. We interpret this result as consistent with the view that patents provide a vehicle for overcoming early-stage disclosure problems 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 modest evidence that the signaling value of patents is higher when securing funds from prominent investors. Start-ups

²¹ Descriptive statistics are presented in Table 6, panel B. Of the 363 final rounds, 51 of them were IPO rounds. Conditional means of several entrepreneurial characteristics are reported, together with a t-test of the null hypothesis that the conditional means are the same across the IPO and non-IPO final rounds. Of the patent, entrepreneurial experience, prominent affiliation relationships, and start-up age characteristics, only two variables display statistically significant differences. Firms with an IPO round had a higher forward patent citation stock and were older on average than those firms without an IPO round.

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 VC. Prior studies show that, relative to ventures backed by less reputable investors, entrepreneurial ventures that receive initial funds from prominent VCs are more likely to survive (Hochberg et al., 2007), to develop successful products (Hellman and Puri, 2002), and to receive higher valuations in initial public offerings (Gulati and Higgins, 2003; Hochberg et al., 2007), thus explaining why entrepreneurs often are willing to pay a premium for affiliations with prominent venture capitalists (Hsu, 2004). 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 VCs, these results also relate to survey evidence provided by Eckhardt et al. (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.²² These issues warrant further study, ideally through use of complementary case- or field-based methodologies.

Finally, in line with prior studies (e.g., Stuart et al. 1999; Mann and Sager, 2007), we also find that start-ups with larger numbers of patent applications are more likely to exit successfully through an initial public offering (IPO). Interestingly, we find little evidence that having prominent alliance partners

²² These conclusions are based on a survey the authors conducted regarding the development and financing activities of 221 Swedish ventures formed in 1998. According to the authors, their survey instrument included a yes/no question on whether the new venture had sought to obtain a patent, copyright, or trademark (Eckhardt et al., 2006: p. 225). Interestingly, the authors bundle responses to this intellectual property-related question with responses to questions regarding other “organizing activities,” including the filing of tax forms and requests for government permits.

or corporate investors significantly improves the likelihood that semiconductor start-ups will exit via IPO. This result contrasts with evidence reported in the biotechnology sector (e.g., Stuart et al., 1999; Gulati and Higgins, 2003). For example, in the Stuart et al. (1999) 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 IPO, though their measures of third party affiliation effects remain positive in a fully-specified model. This comparison raises questions of whether the difference in results reflect sector-specific dynamics between new ventures and corporate alliance and equity partners and/or divergent effects of corporate affiliations in earlier stages of new venture development (our study spans earlier stages of the venture life cycle whereas the Stuart et al. article focuses on performance in later stages when start-ups seek funding from public equity markets). While beyond the scope of our study, 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 entrepreneurial quality signals in securing resources required for growth and survival.

A few other interpretational issues merit discussion. The first refers to the use of the term “signaling” throughout the paper. It is important to interpret the patent effect as a composite effect including both an exclusionary intellectual property effect as well as a signaling effect. As in other studies of signaling (i.e., Stuart et al., 1999), we are unable to separate these two effects empirically. In a limited effort at addressing this issue, we have experimented with including in the valuation regressions *forward citations stock*, a standard measure correlated with the economic value of patents (e.g., Hall et al., 2005). After including this regressor in the specification, the *patent application stock* variable is still positive and statistically significant in almost all specifications, suggesting that patent applications may proxy for pure signaling value, above and beyond economic value effects associated with exclusionary rights. Due to the high correlation between patent applications and forward patent citations ($\rho = 0.84$), however, as well as the potentially endogenous nature of forward patent citations, we are cautious in our interpretation of

those results.²³ Similarly, are our empirical proxies for the main empirical concepts including entrepreneurial experience and affiliation with prominent third parties adequate? We have to the extent possible followed the prior literature in measuring each of these key concepts, yet because the number of empirical studies in these domains is limited, further studies would be welcome.

Finally, an important implication of our results is that patents play a meaningful role in facilitating the technological and market pursuits of young companies in the semiconductor industry. 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). While patents are widely viewed as an important vehicle for financing innovations within the life science arena (e.g., Stuart et al., 1999; Gans et al., 2002), they also appear influential in the entrepreneurial resource acquisitions process within the information technology (IT) sector. Future research could assess more fully the relative strength of patents as quality signals in other IT segments, such as software.

We end with a discussion of the possible policy implications of this type of work. For entrepreneurs, the implications are straightforward: with a range of signaling mechanisms possibly available, which signals are the most effective? Which are the most preferred from a benefit/cost perspective? Is it possible to “make up” for lack of one signal such as entrepreneurial experience by investing heavily in another? It is important to note that we do not claim that this study identifies all the inputs necessary to come to policy conclusions. Most notably, our analysis primarily concerns the benefits side of a potential benefit/cost analysis of alternate signals of entrepreneurial quality. This research also may touch upon some public policy issues. For example, to what extent is there social inefficiency associated with a system in which entrepreneurs are using patents as pure quality signals? A more comprehensive examination of the types of signaling issues discussed here may help us deepen our understanding of this arena.

²³ In future drafts of the paper, we plan to incorporate variables from the NBER data file, aggregated to the firm-portfolio level of analysis, as they may also proxy for patent quality. We especially seek to identify variables which may not suffer from the issues mentioned above, and believe that the patent originality variable may be a good preliminary candidate.

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Table 1
Summary Statistics and Variable Definitions*

VARIABLE	DEFINITION	MEAN	STD. DEV.
Dependent variables			
<i>Pre-money valuation</i>	VC pre-money valuation (share price * shares outstanding prior to venture round) of the focal round.	48.76	75.19
<i>IPO</i>	Dummy = 1 if the venture achieved an initial public offering by 2006.	0.14	0.35
Independent variables			
Patent variables			
<i>(1) 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
<i>(2) Forward patent citations stock</i>	Cumulative patent forward citation stock at the time of the funding round (or for the firm level analysis, at the time of the latest funding round)	91.42	262.48
Entrepreneurial experience variables			
<i>(3) Prior start-up founding experience</i>	Dummy = 1 if at least one member of the founding team had prior start-up founding experience.	0.34	0.47
<i>(4) Prior IPO experience</i>	Dummy = 1 if at least one member of the founding team had prior IPO experience.	0.09	0.29
Venture capital experience variable			
<i>(5) 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
Control variables			
<i>(6) Cumulative prominent alliances</i>	Cumulative count of technologically or commercially prominent strategic alliances as of the VC funding round (see text).	0.05	0.22
<i>(7) Cumulative prominent corporate equity investors</i>	Cumulative count of technologically or commercially prominent corporate equity investors as of the VC funding round (see text).	0.44	0.96
<i>(8) Early stage round</i>	Dummy = 1 if funding round is classified as round 1, 2, or 3.	0.68	0.47
<i>(9) 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
<i>(10-12) Venture phase of development controls</i>	Set of dummies indicating start-up/development phase of development (0.07), product development phase of development (0.33), or profitable phase of development (0.09). Excluded category is development in beta stage.		
<i>(13-15) Round type controls</i>	Set of dummies indicating angel round (0.03), acquisition round (0.08), or IPO round (0.04)		
<i>Funding year controls</i>	Dummies for each of the following funding round time periods: (1) 1980-89 (0.19); (2) 1990-97 (0.30); and (3) 1998-2000 (0.30) [excluded time period is post 2000 time period]		
<i>Round number controls</i>	Dummies for funding round numbers: (1) one (0.26); (2) two (0.24); (3) three (0.18); (4) four (0.13); (5) five (0.09); (6) six (.05); (7) seven (0.03); (8) eight (0.01); and (9) nine (0.01) [excluded are rounds 10-15 which cumulatively total .01 of the remaining data]		

* 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)	(15)
(1)	1														
(2)	0.83	1													
(3)	0.15	0.08	1												
(4)	0.13	0.14	0.44	1											
(5)	-0.01	0.03	-0.08	0.07	1										
(6)	0.20	0.20	0.09	0.08	0.00	1									
(7)	0.28	0.20	-0.05	0.04	-0.02	0.24	1								
(8)	-0.42	-0.38	0.00	0.05	0.03	-0.17	-0.31	1							
(9)	0.43	0.37	-0.11	-0.09	-0.08	0.09	0.25	-0.51	1						
(10)	-0.24	-0.22	-0.02	0.02	0.03	-0.06	-0.14	0.18	-0.26	1					
(11)	0.21	0.15	0.00	-0.03	-0.05	0.15	0.19	-0.30	0.32	-0.27	1				
(12)	0.16	0.19	-0.04	-0.04	-0.03	-0.02	0.05	-0.19	0.28	-0.08	-0.33	1			
(13)	0.02	-0.02	-0.01	0.01	-0.23	-0.01	0.09	-0.13	0.16	-0.08	0.09	0.05	1		
(14)	0.19	0.22	0.00	0.05	-0.15	0.04	0.01	-0.22	0.19	-0.05	-0.07	0.38	-0.06	1	
(15)	-0.08	-0.04	0.09	0.02	-0.13	-0.04	-0.09	0.09	-0.09	0.08	-0.05	-0.04	-0.05	-0.03	1

Note: independent variable numbering corresponds to Table 1 numbering.

Table 3
Pre-money Valuation Fixed-Effects OLS Regressions
Role of Patents and Entrepreneurial Experience
(VC round level of analysis)

Independent variable	Dependent Variable = <i>L pre-money valuation</i>			
	(3-1)	(3-2)	(3-3)	(3-4)
<i>L patent application stock</i>	0.921*** (0.047)		0.826*** (0.068)	0.239*** (0.067)
<i>L prominent alliance stock</i>		1.120** (0.516)	-0.875 (0.655)	-0.677 (0.473)
<i>L prominent corporate equity investor stock</i>		1.532*** (0.176)	0.485*** (0.195)	-0.072 (0.150)
<i>L patent application stock * prior start-up founding exp.</i>			0.081 (0.120)	-0.046 (0.085)
<i>L prominent alliance stock * prior start-up founding exp.</i>			1.584* (0.877)	0.892 (0.637)
<i>L prom. corp. equity investor stock * prior founding exp.</i>			0.095 (0.345)	0.428* (0.246)
<i>Start-up phase of development</i>				-1.131 (0.147)
<i>Product shipment phase of development</i>				0.091 (0.086)
<i>Profitable phase of development</i>				0.318** (0.146)
<i>Angel round</i>				-0.314 (0.278)
<i>Acquisition round</i>				0.090 (0.128)
<i>IPO round</i>				0.831*** (0.147)
<i>Funding round 1980-1989 dummy</i>				-0.079 (0.296)
<i>Funding round 1990-1997 dummy</i>				0.052 (0.197)
<i>Funding round 1998-2000 dummy</i>				0.421*** (0.117)
<i>Start-up age</i>				-0.105*** (0.038)
<i>Round fixed effects</i>	No	No	No	Yes
<i>Firm fixed effects</i>	Yes	Yes	Yes	Yes
<i>Constant</i>	2.052*** (0.070)	2.870*** (0.058)	2.026*** (0.076)	3.509*** (0.874)
R-squared	0.66	0.50	0.66	0.84
Num. Observations	845	805	777	777

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

Table 4
Pre-money Valuation Fixed-Effects OLS Regressions
Early vs. Late Funding Rounds
(VC round level of analysis)

Independent Variable	Dependent Variable = <i>L Pre-money valuation</i>		
	(4-1)	(4-2)	(4-3)
<i>L patent application stock</i>	0.553*** (0.079)		0.187** (0.094)
<i>L prominent alliance stock</i>		0.540 (0.484)	0.020 (0.396)
<i>L prominent corporate equity investor stock</i>		0.479*** (0.181)	0.065 (0.161)
<i>Early funding round</i>	-1.024*** (0.172)	-1.420*** (0.139)	-0.860*** (0.170)
<i>Early funding round * L patent application stock</i>	0.303*** (0.086)		0.326*** (0.087)
<i>Early funding round * prior start-up founding exp.</i>	-0.122 (0.183)	-0.003 (0.208)	-0.114 (0.173)
<i>Early funding round * L prominent alliance stock</i>		-0.504 (0.709)	-0.999* (0.583)
<i>Early funding round * L prom. corp. equity investor stock</i>		1.118*** (0.227)	0.450** (0.192)
<i>Start-up phase of development</i>			-0.988*** (0.162)
<i>Product shipment phase of development</i>			0.394*** (0.102)
<i>Profitable phase of development</i>			0.704*** (0.175)
<i>Angel round</i>			-0.002 (0.037)
<i>Acquisition round</i>			0.255* (0.156)
<i>IPO round</i>			0.960*** (0.178)
<i>Funding round 1980-1989 dummy</i>			-0.516 (0.358)
<i>Funding round 1990-1997 dummy</i>			-0.555** (0.236)
<i>Funding round 1998-2000 dummy</i>			0.035 (0.140)
<i>Start-up age</i>			-0.002 (0.224)
<i>Firm fixed effects</i>	Yes	Yes	Yes
<i>Constant</i>	3.047*** (0.172)	3.998*** (0.109)	1.492*** (0.865)
<i>R-squared</i>	0.68	0.61	0.75
<i>Num. Observations</i>	812	777	777

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

Table 5
Firm Valuation Firm Fixed-Effects OLS Regressions
Role of VC firm experience
(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>	0.880*** (0.058)		0.181*** (0.067)
<i>L prominent alliance stock</i>		1.122** (0.556)	-0.115 (0.335)
<i>L prominent corporate equity investor stock</i>		1.257*** (0.193)	-0.002 (0.136)
<i>High VC eigenvector centrality</i>	-0.413*** (0.150)	-0.595*** (0.151)	-0.277*** (0.113)
<i>High VC eigenvector centrality * L patent application stock</i>	0.076 (0.075)		0.104* (0.059)
<i>High VC eigenvector centrality * prior start-up founding exp.</i>	0.060 (0.187)	0.105 (0.231)	0.006 (0.139)
<i>High VC eigenvector centrality * L prominent alliance stock</i>		0.257 (0.740)	0.112 (0.445)
<i>High VC eigenvector centrality * L prom. corp. equity investor stock</i>		0.502** (0.241)	0.173 (0.154)
<i>Start-up phase of development</i>			-0.092 (0.146)
<i>Product shipment phase of development</i>			0.080 (0.086)
<i>Profitable phase of development</i>			0.311** (0.146)
<i>Angel round</i>			-0.291 (0.274)
<i>Acquisition round</i>			0.051 (0.133)
<i>IPO round</i>			0.826*** (0.154)
<i>Funding round 1980-1989 dummy</i>			-0.048 (0.296)
<i>Funding round 1990-1997 dummy</i>			0.037 (0.198)
<i>Funding round 1998-2000 dummy</i>			0.425*** (0.117)
<i>Start-up age</i>			-0.105*** (0.038)
<i>Round fixed effects</i>	No	No	Yes
<i>Firm fixed effects</i>	Yes	Yes	Yes
<i>Constant</i>	2.221*** (0.098)	3.129*** (0.081)	3.695*** (0.874)
R-squared	0.67	0.52	0.84
Num. Observations	812	777	777

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

Table 6
Overall and Conditional Means for Firms' First and Final Round of Funding

Panel A: Overall and Conditional Means by VC Reputation Status for Firms' First Round of Funding (std. deviation in parentheses)

	Patent application stock	Prior start-up founding experience	Prior IPO experience	Prominent corporate equity investor stock	Start-up age
Overall Mean [N=360]	2.98 (16.40)	0.33 (0.47)	0.10 (0.30)	0.07 (0.31)	1.71 (2.61)
High VC eigenvector centrality = 0 [N = 234]	1.46 (3.70)	0.37 (0.49)	0.08 (0.27)	0.09 (0.02)	1.82 (2.73)
High VC eigenvector centrality = 1 [N = 126]	5.81 (27.11)	0.25 (0.44)	0.15 (0.36)	0.03 (0.02)	1.52 (2.38)
t-stat : diff.	2.42	2.23	2.08	1.65	1.01

Panel B: Overall and Conditional Means by IPO Status for Firms' Final Round of Funding (std. deviation in parentheses)

	Patent application stock	Forward patent citation stock	Prior start-up founding experience	Prior IPO experience	Prominent alliance stock	Prominent corporate equity investor stock	Start-up age
Overall Mean [N=363]	12.57 (63.55)	116.30 (334.58)	0.33 (0.47)	0.10 (0.30)	0.06 (0.26)	0.60 (1.19)	5.96 (3.93)
IPO = 0 [N = 312]	11.46 (67.92)	61.97 (173.45)	0.33 (0.47)	0.09 (0.29)	0.06 (0.25)	0.67 (1.27)	5.66 (3.90)
IPO = 1 [N = 51]	19.57 (20.11)	456.38 (706.10)	0.33 (0.48)	0.17 (0.38)	0.08 (0.27)	0.45 (0.12)	7.82 (3.65)
t-stat : diff.	0.83	8.46	0.02	1.63	0.50	1.11	3.66

Table 7: Sourcing Reputable VC Probit Regressions (Sample=Firms' First Round of Funding)

	Dependent Variable: Pr (<i>High VC Eigenvector Centrality</i> = 1) Note: Marginal effects reported			
	(7-1)	(7-2)	(7-3)	(7-4)
<i>L patent application stock</i>	0.090** (0.039)	0.171*** (0.045)	0.061** (0.031)	0.114*** (0.035)
<i>Prior start-up founding experience</i>	-0.105 (0.066)	-0.117* (0.070)		
<i>Prior IPO experience</i>			0.266** (0.110)	0.246** (0.117)
<i>L prominent corporate equity investor stock</i>		-0.303 (0.189)		-0.278 (0.184)
<i>L patent application stock * prior start-up founding exp.</i>	-0.069 (0.058)	-0.114* (0.062)	-0.118 (0.076)	
<i>L patent application stock * prior IPO experience</i>				-0.123 (0.079)
<i>Start-up phase of development</i>		-0.030 (0.076)		-0.020 (0.076)
<i>Product shipment phase of development</i>		-0.126 (0.080)		-0.098 (0.079)
<i>Profitable phase of development</i>		0.031 (0.195)		0.045 (0.193)
<i>Funding round 1980-1989 dummy</i>		0.189 (0.151)		0.230 (0.149)
<i>Funding round 1990-1997 dummy</i>		0.018 (0.137)		0.041 (0.138)
<i>Funding round 1998-2000 dummy</i>		0.035 (0.133)		0.044 (0.133)
<i>Start-up age</i>		-0.030 (0.016)		-0.019 (0.015)
Log likelihood	-203.78	-182.18	-204.99	-186.26
Number Obs.	322	309	322	309

*, ** or *** indicates statistical significance at the 10%, 5%, and 1% levels, respectively. Note: The variable *prominent alliance stock* could not be included in these specifications because there are only two observations for which this variable is positive.

Table 8
IPO Likelihood Probits
(Sample=Firms' Final Round of Funding)

	Dependent variable = Pr (<i>IPO</i> = 1) Note: Marginal effects reported		
Independent Variable	(8-1)	(8-2)	(8-3)
<i>L patent application stock</i>		0.035*** (0.014)	
<i>L forward patent citations stock</i>			0.023*** (0.009)
<i>Prior IPO experience</i>	0.102* (0.054)	0.053 (0.128)	0.048 (0.127)
<i>L prominent alliance stock</i>		0.015 (0.065)	0.011 (0.058)
<i>L prominent corporate equity investor stock</i>		-0.028 (0.026)	-0.026 (0.024)
<i>L patent application stock * prior IPO experience</i>		-0.004 (0.028)	
<i>L forward patent citations stock * prior IPO experience</i>			-0.002 (0.016)
<i>Start-up phase of development</i>		-0.022 (0.265)	-0.008 (0.317)
<i>Product shipment phase of development</i>		0.081 (0.043)	0.076 (0.042)
<i>Profitable phase of development</i>		0.160*** (0.051)	0.153*** (0.053)
<i>Funding round 1980-1989 dummy</i>		0.238** (0.177)	0.072 (0.111)
<i>Funding round 1990-1997 dummy</i>		0.291*** (0.090)	0.157*** (0.076)
<i>Funding round 1998-2000 dummy</i>		0.054 (0.046)	0.022 (0.036)
<i>Start-up age</i>	0.017*** (0.004)	0.002 (0.004)	0.000 (0.003)
Log likelihood	-134.47	-81.24	-78.84
Num. Observations	354	326	326

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