STRATEGIC FACTOR MARKETS AND THE FINANCING OF TECHNOLOGY STARTUPS: WHEN DO PATENTS MATTER MORE AS SIGNALING DEVICES?

David H. Hsu*
University of Pennsylvania
Wharton School
2028 Steinberg Hall-Dietrich Hall
Philadelphia, PA 19104
Tel: 215-746-0125
Email: dhsu@wharton.upenn.edu

and

Rosemarie H. Ziedonis
University of Oregon
Lundquist College of Business
1208 University of Oregon
Eugene, OR 97403-1208
Tel: 541-346-8248
Email: rmz@uoregon.edu

June 2011

Keywords: information asymmetry; signaling; entrepreneurship; patents; resource-based theory; entrepreneurial finance

---

*** Corresponding author.** The authors contributed equally to the study; names are listed in alphabetical order. We collectively thank Dow Jones' VentureSource, the Ross School's Zell Lurie Institute for Entrepreneurial Studies, and Yael Hochberg for providing access to venture finance-related data. Susan Woodward of Sand Hill Econometrics kindly verified and improved the accuracy of our data. Matt Daniels, Faria Jabbar, Andrew Song and Lesi Wang provided excellent research assistance. We received useful suggestions on earlier versions of this paper from Rajshree Agarwal, Iain Cockburn, Wes Cohen, Ranjay Gulati, Bronwyn Hall, Francine Lafontaine, Anne Miner, Manju Puri, Michael Roach, Brian Silverman, research group members, and participants in seminars and conferences at DRUID, Duke, London Business School, NBER, Stanford, UC Berkeley, UCLA, Univ. Chicago, Univ. Michigan, Univ. Oregon, Univ. Pennsylvania, Univ. Toronto, and Univ. Wisconsin. We are grateful to the Alfred P. Sloan Foundation, the Mack Center for Technological Innovation at Wharton, and the University of Michigan Law School's Program in Law, Economics, and Technology for financial support of this research. An earlier version of this paper circulated under the title: "Patents as Quality Signals for Entrepreneurial Ventures."

STRATEGIC FACTOR MARKETS AND THE FINANCING OF TECHNOLOGY STARTUPS: WHEN DO PATENTS MATTER MORE AS SIGNALING DEVICES?

ABSTRACT

Prior studies assert that technology startups reduce information gaps with capital suppliers by signaling quality through patents. Empirical evidence nonetheless remains elusive, due in part to the simultaneous role patents play as legal safeguards in product markets. We de-couple these distinctive roles and investigate conditions that affect the signaling value of patents in factor markets for entrepreneurial capital. Consistent with predictions from signaling and resource-based theories, we find that patents "matter more" as signaling devices in earlier rounds of venture financing and for firms otherwise disadvantaged in conveying quality to outside investors. Evidence is based on 370 venture-backed semiconductor startups in both IPO and pre-IPO environments, where information asymmetry problems loom largest.

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 (Penrose, 1959; 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 information gaps 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 for outsiders. When investors find it challenging to sort good projects from bad, financial backing can be more costly or difficult to secure (Leland and Pyle, 1977; Hall, 2008). Recognizing this dilemma, prior studies have investigated a range of mechanisms used to reduce information asymmetries with capital suppliers, including backgrounds "inherited" from founders (e.g., Eisenhardt and Schoonhoven, 1990; Burton et al., 2002) and "leased" through third-party affiliations (e.g., Stuart et al., 1999; Hsu 2004).

This study provides new evidence on the role that patents play in mitigating information asymmetry problems between entrepreneurs and investors. In principle, patents conform well to Spence's (1973) original conceptualization of a quality signal: they are costly to obtain and therefore provide a mechanism by which types can be sorted. The process of patenting also requires inventors to describe their discoveries in considerable detail, thus codifying know-how that otherwise would be more difficult to convey to outsiders (Long, 2002). Despite growing interest in the signaling function of patents (Heeley et al., 2007; Graham et al., 2010), empirical testing has been constrained by both conceptual and methodological problems. Conceptually, patents not only reveal information about the technological and managerial capabilities of startups (Long, 2002); they also confer legal rights that influence profit forecasts (Rumelt, 1984; Teece, 1986). Absent a way to disentangle these roles, it is difficult to attribute advantages from patents solely to their signaling function. Methodologically, prior studies also have struggled to unravel the predicted "signaling effect" from the alternative explanation that "better firms" simply attract more resources and, in turn, file more patents and reap greater profits—an identification problem that we aim to address. Finally, and more generally, little is known about the conditions under which patents are particularly salient in reducing information gaps with capital providers, thus limiting both theoretical understanding and managerial prescription.

To surmount these problems, we employ multiple methods and run complementary sets of analyses with data that integrates time-varying information on the financing and patenting activities of 370 venture-backed semiconductor startups with supplemental data on non-patent resources that could signal quality to outside investors. Our data capture with unusual richness the patent and non-patent resources of startups from initial funding through development and exit. We use this

information to estimate the magnitude with which a startup's patenting activities[1] influence three financing outcomes: (1) receipt of initial backing from a prominent venture capitalist, (2) "within-firm" changes in the cost of capital across rounds of VC financing, and (3) the discounting of first-day share prices for initial public offerings (IPOs). This approach enables us to estimate the signaling value of patents in both IPO and pre-IPO funding environments, where information imperfections are more likely to arise.[2]

Albeit from multiple angles, we pursue a unified research question: if patents function as quality signals in strategic factor markets for entrepreneurial capital, *when* and for *what types of firms* should we expect that function to be particularly important? Consistent with predictions drawn from resource-based and signaling theories, we find that the signaling value of patents is greater for new ventures that (1) lack alternative means for conveying their quality credibly to investors, and (2) are involved in earlier stages of financing. Put differently, we find that patents "matter more" as capital-market signaling devices when the informational disadvantages of startups are greater. In combination, the evidence is difficult to reconcile with simple property-rights explanations, an important point that we return to below.

The study contributes to three literature streams. The first is an extensive body of research in strategy and economics on imperfect information and its implications for firm strategy and performance (e.g., Yao, 1988; Riley, 2001; Ragozzino and Reuer, 2011). Although information problems pervade entrepreneurial capital markets (e.g., Stuart et al., 1999; Hochberg et al., 2007; Dushnitsky and Shaver, 2009), the efficacy of patents as a strategic solution to such problems

[1] Consistent with recent studies (e.g., Heeley et al., 2007; Hauessler et al., 2009), we measure a startup's "patenting activities" based on its annual stock of successful patent applications. Doing so allows private investors to respond to information revealed in patent applications prior to the 3-4 year delay typically required for the review process. Although data on rejected US applications are unavailable for most years included in our sample, Quillen and Webster (2001) report that 90-95% of US patent applications filed since 1980 are eventually awarded patents.

[2] As Raggozzino and Reuer (2011) discuss, the process of launching an initial public offering tends to reveal new information about young companies, whether through "road show" presentations, added disclosures due to more stringent regulatory requirements, or closer scrutiny by investment analysts.

remains unclear. From an entrepreneur's perspective, understanding the causal linkages (if any) between patents and sources of advantage in capital input markets is extremely important. If patenting activities enable new ventures to secure funds on more favorable terms or garner access to superior funding sources, the route to commercialization could become more rapid and fruitful. Prior work nonetheless offers little guidance for understanding when the signaling function of patents might be particularly important for new ventures—a gap that we seek to fill in this study.

The study also is salient to related work on the factors that influence the growth and performance trajectories of young companies. A general consensus in this literature is that startups with superior reputation endowments, as conferred by founder backgrounds or third-party affiliations, are preferentially positioned to attract the resources required for growth and survival (e.g., Eisenhardt and Schoonhoven 1990; Stuart et al., 1999; Gompers et al., 2010). As a prescriptive matter, however, this literature sheds little light on the levers available to entrepreneurs *lacking* these reputational advantages. By investigating the potential value of one such strategic lever, the production of patents, we contribute to a nascent stream of research on how superior technological capabilities and firm-specific accomplishments can be used to shift resource trajectories in innovation-intensive industries (Ahuja, 2000; Hallen, 2008). From a firm-strategy perspective, such work is particularly important given the high costs associated with reputational "leasing" through prominent third-party affiliations (Hsu, 2004; Arikan and Capron, 2010).

Finally, the study makes conceptual and empirical contributions to research on the Resource-Based View (RBV) of the firm, which explores the performance implications of heterogeneous resource bundles (e.g., Barney, 1986, 1991; Wernerfelt, 1984). In the spirit of Penrose (1959), we argue that resources can serve conceptually distinctive functions in strategic factor versus final product markets. To illustrate this point, we develop an integrative framework that links patents, a common metric used to capture the "value" of intangible resources owned by firms (Arikan and

Barney, 2001), to multiple pathways for advantage. Empirically, we show how the importance of patent's signaling function hinges on other resources inherited, owned, or leased by entrepreneurial ventures, thus contributing new evidence on the contingencies that alter the value and productive use of firm-specific resources and capabilities (Brush and Artz, 1999; Coff, 1999; Gulati and Higgins, 2003).

THEORETICAL FRAMING AND BACKGROUND

Patents as a Source of Advantage: One Resource, Multiple Services

A central tenet of resource-based theory is that firms with valuable, scarce, and non-substitutable resources can gain at least temporary advantages by using those resources to develop and implement product market strategies. Within the RBV literature, resources are considered valuable if they "enable a firm to develop and implement strategies that have the effect of lowering a firm's net costs and/or increase a firm's net revenues beyond what would otherwise be expected" (Barney and Arikan, 2001: 138). In a literature review, Barney and Arikan (2001) observe that early work in the RBV tradition emphasized the value of resources in shielding firms from product market rivals (Rumelt, 1984; Wernerfelt, 1984). In further development of the theory, Barney (1986, 1991) and Makadok (2001) emphasized instead the value of resources in providing sources of advantage in so-called "strategic factor markets," where inputs like labor and capital are assembled prior to final production.

RBV scholars subsequently have sought numerous ways to measure the "value" of resources owned or controlled by firms[3], often failing to clarify whether such value originates from advantages conferred in product markets, strategic factor markets, or both (Leiblein, 2011). In a critique of the RBV literature, for example, Priem and Butler (2001) argue that an over-emphasis on *whether*

[3] Barney and Arikan (2001) provide a thoughtful overview of the RBV literature and empirical proxies for resource value.

resources are valuable has obscured deeper understanding of *why* and *how* such resources confirm a source of advantage.

Ironically, these limitations in resource-based theory may reflect the use of "resources" as a focal unit of analysis. In a seminal book in the RBV literature, Edith Penrose observed: "it is never the resources themselves that are 'inputs' in the production process, but only the services that the resources can render" (Penrose 1959: 25). This insight receives surprisingly little attention in the modern RBV literature even though it offers (in our view) a conceptual pathway for advancing core aspects of the theory and its empirical testing. For purposes of our study, Penrose's insight implicitly suggests that it is difficult—if not misleading—to attribute "value" to patents as a unified resource category. Rather than asking *whether* patents are valuable for new ventures, we therefore investigate more fully below the *services* that patents render.

"Isolating" mechanisms in product markets

Figure 1 highlights two services attributable to patents in shaping the growth trajectories and profits of young innovation-intensive companies. In line with the traditional view of patents as property rights, most RBV scholars focus on the legal protection that patents offer against product-market rivals. In seminal works, for example, Rumelt (1984) and Teece (1986) respectively discuss how patents can be used to isolate firms from direct competition, therefore enabling innovators to appropriate a greater share of the total profits. Whether viewed as "isolating" (Rumelt, 1984) or "appropropriability" (Teece, 1986) mechanisms, patents are cast as a potential source of product-market advantage by safeguarding distinctive product/service offerings and supporting a price premium, garnering cost advantages through the use of proprietary process technologies, and/or by boosting revenues through patent licenses.

Empirical evidence suggests that the value of patents as isolating mechanisms in product markets differs markedly across and within sectors. In surveys of large manufacturing corporations

(Cohen et al., 2000; Levin et al., 1987) and small technology ventures (Graham et al., 2010), managers from the life science and chemical industries report that patents offer stronger safeguards against product-market rivals than do managers from information technology (IT)-related sectors. Cohen et al. (2000) attribute this sector-level variation to the complexity of linkages between patent rights and profits: in so-called "discrete product" industries such as the life sciences, products are typically covered by small numbers of patents; in contrast, the lines between property rights and products are less transparent in so-called "complex product" industries like semiconductors, where products typically embed thousands of rights (Cohen et al., 2000; Hall and Ziedonis, 2001).

Within sectors, prior work further suggests that established firms with greater access to financial resources likely reap greater benefits from patents as legal shields against rivals than do resource-constrained new ventures. As legal property rights, patents confer the right—but not the obligation—to sue others for infringement. The protection afforded by patents therefore remains ambiguous without legal action, a process that is notoriously costly and can be onerous for entrepreneurs with limited financial resources (Lanjouw and Schankerman, 2001; Lerner, 1995; Agarwal et al., 2009).[4] As Nesheim (2000: 43) notes, "venture capitalists hate investing in a start-up that gets bogged down in lawsuits that drain precious time and cash resources." In combination, this evidence suggests that the value of patents as "isolating mechanisms" in product-markets is lower (a) in "complex" product industries like semiconductors, relative to the life science and chemical sectors and (b) for entrepreneurial ventures, relative to established companies with deeper pockets.

Signaling Devices in Strategic Factor Markets

Of particular importance to our study, Figure 1 also reveals (in the left-most Section II) a second service rendered by patents for technology-based ventures: a mechanism for bridging

[4] The estimated cost of litigating a patent dispute of average complexity hovers between $3 and $5 million (AIPLA, 2007). Small firms are less likely than larger firms to have in-house legal counsel (Lanjouw and Schankerman, 2001; Lerner, 1995), further placing them at a disadvantage when managing legal disputes.

information gaps with factor input providers (i.e., as quality signals[5]). Importantly, the causal linkage between patents and performance in this instance originates in strategic factor markets where resources required for commercialization are exchanged and assembled (Barney, 1986, 1991).

As noted earlier, patents conform well to Spence's (1973) criteria for a quality signal: they are costly and therefore provide a mechanism by which quality "types" can be sorted (Long, 2002). Inclusive of attorney fees, the estimated costs of obtaining a typical US patent is $35,000 (Graham et al., 2010), direct monetary expenses that can be quite high for new ventures. In interviews of software entrepreneurs, for example, Mann (2005) reports managers struggling to decide whether to use limited funds for patent-related activities or for hiring additional programmers. The patenting process also can entail non-trivial indirect costs, including disclosure of information about the underlying invention. The back-and-forth communication between inventors and patent attorneys also tends to be tedious and time-consuming, an opportunity cost that is especially high for firms driven by speed to market.

Relative to the extensive evidence on patents as legal safeguards in product markets, far less is known about the conditions that affect the signaling value of patents in factor markets for entrepreneurial capital. Qualitatively, Lemley (2001: 1505) observes: "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: 646) notes: "patent portfolios can convey information about the lines of research a firm is conducting and how quickly the research is proceeding."

Quantitative evidence on the signaling value of patents is inconclusive. Early work by Deeds et al. (1997) on the funds raised by biotechnology ventures at IPO concludes that the signal cast by

[5] We define a "quality signal" broadly as information that is capable of altering an observer's probability distribution of unobserved variables. This definition is consistent with conceptualizations of quality signals used in the entrepreneurial management (e.g., Stuart et al., 1999), legal (e.g., Long, 2002), and economics (Lafontaine, 1993) literatures.

patent filings is too noisy to affect the expectations of public investors. Separately but also in the biotechnology industry, Stuart et al. (1999) report that although patent applications and awards are advertised prominently in IPO documents they fail to boost the predicted market valuations of new public listings. Lacking a means of estimating startup performance at IPO had fewer (or no) patents been filed, however, it is inappropriate to conclude from this evidence alone that patents fail to alleviate informational problems with capital providers.

Also focusing on new IPO listings, Heeley et al. (2007) estimate the effects of patent filings on the underpricing of new public listings, an outcome variable that better captures information gaps in capital markets. In "discrete product" industries like the life sciences, Heeley et al. (2007) reveal the effect anticipated yet undocumented in prior work: patents significantly reduce information asymmetries with equity investors when life science startups go public. In "complex product" sectors like IT, however, the authors report that patent filings *fail* to reduce information asymmetries with outside investors. In such settings, Heeley et al. (2007) conclude that the information revealed by patents is too noisy to shape the expectations of public equity investors. Left unanswered by this study is whether similar patterns arise in earlier stages of entrepreneurial financing, when uncertainty about the prospects of new ventures looms larger.[6]

To summarize, Figure 1 reveals multiple pathways through which patents can provide a source of advantage: (1) through information advantages in the input markets where resources are exchanged and assembled, and (2) through isolation from rent-dissipating competition in markets for final goods and services. From a resource-based perspective, Figure 1 raises the intriguing implication that patents could be valuable to startups not only as isolating mechanisms against product market competition but also for their use as signaling devices with factor input providers.

[6] Among the few studies of patent signals in pre-IPO environments, Haeussler et al. (2009) show that patent filings significantly accelerate receipt of VC financing—an economically meaningful outcome variable for new ventures. Their evidence is based on surveys of 190 European biotechnology ventures that solicited funds from VCs.

Importantly, this "de-coupling" of services from resources also may help unravel otherwise puzzling findings reported in prior empirical work. In the 2008 Berkeley Patent Survey, for example, CEOs of technology startups report that patents typically provide weak safeguards against product-market rivals but nonetheless facilitate their financing activities (Graham et al., 2010).

HYPOTHESES

Do patents provide an economically meaningful "service" to entrepreneurs as quality signals to capital providers? To investigate this issue, we identify below conditions under which patents are likely to fall in row IIB (strong) versus row IIA (weak) as factor-market quality signals in Figure 1, holding constant their separable role (in columns) as product-market means of isolation. Our core argument is that the signaling value of patents should be contingent on the strength of alternative quality signals in a startup's resource bundle, whether inherited from founders or leased from affiliates. Given the uncertainty that pervades early stages of new venture development, we also should expect patents to "matter more" in early (rather than later) rounds of VC funding. Recognizing that non-patent signals and key financing activities change during the new venture lifecycle and to provide multiple vantage points for our analysis, we derive below three sets of predictions that are empirically testable with our data.

Reputation Endowments "Inherited" from Founders

Among financing outcomes, perhaps the most consequential for new technology ventures is to receive early-stage funding from a prominent VC (Hsu, 2004). While the financial capital supplied by venture capital is a relatively homogenous product, VCs differ significantly in the quality of "extra-financial" services they provide that aid in the growth and development of innovation-intensive companies. Prior studies show, for example, that prominent VCs provide access to inputs that trade imperfectly in strategic factor markets, including alliance partners (Hsu, 2006), legal

counsel and management talent (Hellmann and Puri, 2002), and the tacit know-how of when best to time entrepreneurial exits (Gompers, 1996). Although the precise sources of advantage are difficult to disentangle, financial backing from prominent VCs has been shown to significantly increase the likelihood of a successful IPO exit (Hochberg et al., 2007).

In securing funds from prominent VC investors, however, powerful matching forces arise. As Hallen (2008) and others have noted, initial ties are important as there may be upward or downward trajectories for startups depending on their initial placement in the network structure. Similarly, recent work by Gompers et al. (2010) provides compelling evidence that founders with IPO experience are more likely to realize successful IPO exits in new ventures than are first-time entrepreneurs or founders who have previously failed. In turn, Gompers et al. (2010) show that serial entrepreneurs with prior IPOs are advantaged when seeking capital from external sources. Hsu (2007) shows further that experienced entrepreneurs are more successful in recruiting executive officers from their social networks, further contributing to the success of their new ventures. 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). Network positions therefore tend to be stable, which bodes well for founding teams with track records of success. The literature strongly suggests that organizational strength begets further advantage, which accounts for path dependencies in both resource access and performance.

The prior literature nonetheless offers little recourse or prescriptive guidance for venture teams lacking prior track records of entrepreneurial success. The same critique holds true for other contexts in which resource-providers face uncertainty about entrepreneurial quality: early stages of venture development and ventures lacking prominent VC affiliation at the time of IPO. Particularly in these contexts, which span the entrepreneurial lifecycle, we contend that patents can serve as important sources of information by which resource providers make assessments about venture

quality.

As Zott and Huy (2007) and Hallen (2008) suggest, venture accomplishments relative to peers can act as important symbols of venture legitimacy, thus helping overturn path dependencies in the resource attainment process. By codifying information about the technological pursuits of startups and representing a costly activity for entrepreneurs (both in direct and opportunity costs), patents may similarly reveal information to investors about the underlying quality of new ventures and their management teams. As suggested above, however, new ventures with high initial reputation endowments should be better positioned to signal quality absent patent-based signals. If patents serve a signaling function in securing funds from prominent VC investors, we should therefore expect them to matter *more* for startups that otherwise lack alternative vehicles for conveying quality credibly to investors. Based on this logic and using prior IPO experience of founders to proxy "high initial reputation endowment" (as per Gompers et al. 2010), we therefore predict:

- *Hypothesis 1a: Patents will be more important for startups with low (vs. high) initial reputation endowments (as "inherited" from their founders) in securing initial funding from prominent VCs, holding other startup characteristics constant.*

Building on studies highlighting the importance of entrepreneurial experience, the thesis that "people matter most" in new venture success is also a strongly held view in the practitioner literature. As 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 VC] Arthur Rock states, 'I invest in people, not ideas.'" The oft-heard VC mantra that "having an 'A' team and a 'B' idea is preferred to having a 'B' team with an 'A' idea."

These quotes capture the logic that on an ongoing basis, more experienced and skilled entrepreneurs will ultimately be more important in value creation/appropriation, as there is rarely a

linear path towards venture success. Instead, venture team experience and judgment are important in explaining venture success (even relative to what conventional wisdom might suggest is another important factor, a brilliant venture idea). As "chunky" and time-varying streams of information about technological progress, patents should be more important for startup teams lacking successful entrepreneurial track records. We therefore predict:

- *Hypothesis 1b: Increases in patenting activity will induce steeper upward adjustments in valuations of startups with low initial reputation endowments (as "inherited" from their founders) across rounds of VC funding.*

Stage of Financing

The early stages of funding for startups are characterized by greater technical and demand uncertainty in new venture product development. As such, patent-related activities should convey more information about venture quality to outsiders in the early stages of venture development relative to later stages. The empirical prediction for the signaling role of patents is that they will be associated with a larger boost in venture value in earlier funding rounds relative to later rounds. If patents act exclusively as an isolating mechanism for product market exclusion or markets for technology facilitation, the empirical relationship would be reversed. As enterprises develop and receive added funding, it is likely that the value of excluding competition and/or the value of transferring patent rights will rise, or at least remain constant. Under the isolating mechanism effect, a given stock of patents will be either equally valuable across the enterprise lifecycle, or more likely increase in value with funding stage.[7] We therefore predict:

- *Hypothesis 2: Increases in patenting activity will induce steeper upward adjustments in valuations of startups in earlier (vs. later) funding rounds.*

Reputations "Leased" from Investors

[7] Prior work has not examined this effect, both because the different functions of resources are not examined and also because most studies concentrate on either the early life stage of new ventures (e.g., Hsu, 2004), or more commonly, the late stages at IPO (e.g., Heeley et al. 2007). The data section elaborates on this discussion.

Finally, in the event of an IPO exit, an important outcome for new ventures is minimizing the discount placed on their equity offering (Heeley et al., 2007). Such discounting or "underpricing" occurs when the initial price at which shares are offered to public investors is significantly lower than the actual share price at the end of the first day of trading. From an entrepreneur's perspective, underpricing at IPO is akin to "leaving money on the table."

A leading theory for equity IPO underpricing is that potential shareholders have to be compensated for an offering in which there is a great deal of asymmetric information (Rock, 1986). The entity going public does so only once, which makes it difficult for the focal entity itself to develop a reputation for the accurate disclosure of information. In light of this challenge, prior studies suggest that new listings "lease" reputations of VC investors when going public. As Hellmann and Puri (2002) and others suggest, VCs assist startups in attaining business and financial resources (such as alliance partners, management teams, and reputable investment bankers) and have repeated interactions in public equity markets.

Whether by providing superior access to resource bundles or by leasing their reputations as superior investors, prominent VC investors provide a powerful signal of new venture quality to outside investors (Hsu, 2004). Since new ventures with prominent VC backing are better positioned to convey quality credibly at IPO *absent* the filing of patents, patents should serve a more important signaling function (in reducing information-asymmetry problems) for startups *lacking* such affiliations. Using IPO underpricing as an indicator of information gaps between new ventures and public equity investors, we therefore predict:

- *Hypothesis 3: Conditional on an IPO exit, the magnitude with which patents reduce IPO underpricing will be greater for startups that lack prominent VC affiliations (relative to those with prominent VC backing).*

RESEARCH DESIGN AND METHODS

In this section, we first describe the rationale for selecting the semiconductor industry as the

empirical context for this study and explain the process for identifying venture-backed startups in the industry. We then describe the data and methodology used to test our three predictions.

Sample and Data Sources

The semiconductor industry offers a useful setting for investigating the potential value of patents as signaling devices for entrepreneurial ventures. Semiconductor startups 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 and know-how. The industry therefore provides a strategically meaningful setting for investigating the relationship between patenting and the early-stage financing activities of new ventures. As discussed earlier, patents also are generally viewed as *ineffectual* mechanisms by which firms reap profits from innovation in IT-related product markets relative to alternative mechanisms such as lead-time and design complexity. The semiconductor industry therefore provides a more conservative context in which to examine the efficacy of patents as quality signals in factor input markets relative to sectors such as biotechnology where the link between patents and value capture in product markets is more firmly established.

Finally, the semiconductor industry is an intriguing context for hypothesis testing in light of recent findings by Heeley et al. (2007), suggesting that patents *fail* to reduce information asymmetries when young IT companies seek financing from public equity markets. Left unaddressed is whether patents nonetheless are useful in that capacity in earlier stages of development for IT startups and whether they "matter more" as signaling devices for certain types of companies. Examining these issues within semiconductors—the technological backbone of the IT sector (Jorgenson, 2001)—enables us to build on and extend this prior research.

Our sample comprises all U.S. semiconductor device firms founded between 1975 and 1999 that received at least one round of venture financing by December 2005, as reported in Dow Jones'

VentureOne database.[8] To allow a sufficient window through which to view post-founding activities, startups founded after 1999 were omitted from the sample. A total of 370 companies met these selection criteria. For sample companies, we assembled multifaceted information about their patenting activities, the strength of alternative vehicles through which they could convey quality to investors, and financing outcomes. Importantly, we compiled time-varying information on rounds of financing, valuations, and progress towards product development and profitability using proprietary data from VentureOne. In the event of missing data (e.g., regarding a firm's valuation in a round of financing), we searched for supplemental information from VenturXpert, another leading vendor of venture financing data. To determine the prior IPO experiences of founding teams, we compiled the names and biographies of founders through web-searches and tracked the outcomes of prior companies they had founded, if any. Table A.1 in the Appendix provides more detailed information about these data sources and measures discussed below. In combination, sample firms collectively submitted 3,021 successful U.S. patent applications prior to exit or as of their last VC financing prior to December 2005.

Analytic Framework and Variables. We concentrate our analysis on the role of patents in raising capital from prominent investors and on better financial terms. Prominent investors can facilitate a range of business development services for the venture, such as relationships with other resource providers (e.g., talented engineers, managers, and legal counsel). The terms by which startups access their financial capital are also important from a value capture standpoint: higher venture valuations at each private financing round and smaller changes in the first day stock trading price at the time of an IPO translate into more value captured by entrepreneurs. We further motivate our outcome measures and describe how we operationalize our analyses in this section.

[8] Imposing the condition of VC-funded enterprises allows us to test for effects with startups that exceed a minimum threshold of quality. As discussed below, we also observe changes in startup valuations for many of these firms, which enables us to conduct "within firm" tests in one set of analyses. Unfortunately, we lack data for semiconductor startups that sought but failed to receive at least one round of venture financing.

Our first analysis focuses on a pivotal financing outcome in the early phases of a new venture's development—receipt of initial financing from a prominent VC investor. We therefore restrict attention to the sub-sample of data corresponding to the first round of VC funding. The outcome variable, *prominent VC investor*, is set to one if the lead investor is in the upper half of the within-sample distribution of VC network centrality based on annual VC syndication patterns compiled by Hochberg et al. (2007).

To test our first prediction, we compile and interact two main independent variables: founder entrepreneurial success (via a dummy variable, *founding team has no IPO experience*) and patent application stock. *Patent application stock* is defined as the number of applications filed by a focal startup at time *t* that eventually result in the successful award of a U.S. patent. (Hauesller et al., 2009 and Heeley et al., 2007 employ similar measures.) When testing the signaling value of patents to entrepreneurial capital providers, an applications-based measure of startup patenting activities offers several advantages to measures based on patents awarded. As Hauesller et al. (2009) report, investors tend to respond rapidly to information contained in patent application documents. For investors in private companies, this rapid response likely reflects access to information from the back-and-forth communications with patent attorneys discussed earlier. Due to lengthy delays in the patent examination process, innovation-based companies also have strong incentives to reveal information to investors about applications pending (Stuart et al., 1999). Haeusller et al. (2009) show, for example, that the average biotechnology startup obtains patents long after securing VC financing, with 3-4 year lags. Similar patterns hold for the semiconductor startups in our sample.[9] In the analyses that follow, we therefore employ a time-varying *patent application stock* measure.

[9] In robustness checks, we re-ran estimates using patent grant stocks instead. Consistent with the view that investors in entrepreneurial ventures update expectations prior to the completion of the patent examination process, our estimates grew less precise using the grant-based measure. This finding is consistent with that reported by Haeusller et al. (2009) using European patent filings. Results reported below are also robust to the omission of firms at the 99% percentile of the within-sample distribution of patent filings, thus reducing concerns of outlier effects.

In our first analysis, we also control for factors other than founder backgrounds and patent stocks that are likely to affect the probability of prominent VC funding. The control variables include *prominent partner stock* (an alternative quality signal for early-stage ventures, measured as the cumulative count of prominent alliance partners or corporate equity investors[10]), a set of startup characteristics (*Silicon Valley location* dummy, *startup age*, and startup *profitable phase of development* dummy), and funding period (*pre-1997 funding round* and *1998-2000 funding round*, with post 2000 funding rounds the excluded category).

The second analysis focuses on the trajectories of new ventures during development. Using longitudinal data on the estimates made by investors of entrepreneurial-firm value, we test whether *changes* in patent application stocks between financing rounds induce *steeper* upward adjustment in the valuations of startups less able to convey quality through non-patent means (H1b). We also test whether patenting activities in earlier rather than later stages of financing stimulate a greater shift in a firm's valuation trajectory (H2) using a dummy variable, *early funding round*, which denotes first or second rounds.[11] The outcome variable in the second analysis, *pre-money valuation,* reflects the product of startups' share price before the funding round multiplied by the number of shares outstanding. 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, and is a key outcome variable closely linked to

[10] 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.

[11] We use the same set of control variables as in the first analysis. The major difference being that time-varying variables are evaluated as of the time of the focal funding round. For example, *prominent partner stock* is measured up to the funding round and evaluated on a time-varying basis using five-year windows. The additional control variables are dummies for type of funding round: *angel round*, *acquisition round*, or *IPO round*.

entrepreneurial value capture.[12] A higher valuation in a focal funding round is good news for existing equity holders, as the wedge between share acquisition- and current market price is larger.

The third and final analysis focuses, like much of the prior research, on the late stage of venture development when successful enterprises and their equity holders seek funding from public equity markets. Here, we follow the approach used by Heeley et al. (2007) and estimate the differential effects of patenting on share price underpricing at IPO. As discussed earlier, unlike other performance metrics at IPO (such as amount raised or total market valuation), the underpricing of initial share prices provides a useful means by which to assess the degree of asymmetric information between new listings and potential investors. Consistent with the first two sets of analyses, we investigate whether patents are more important as an uncertainty reducing mechanism for startups that are relatively disadvantaged to credibly convey their underlying quality to investors. The sample in this analysis is restricted to those firms experiencing an IPO, and the dependent variable is *percentage change in first day stock price*. We operationalize "relative disadvantage" at IPO with the indicator variable, *not backed by prominent VC investors*, based on median VC eigenvector scores discussed above. The covariates are similar to those used in the prior analyses, with the addition of the following controls associated with differences in IPO underpricing: *IPO underwriter rank*, *startup size*, *R&D intensity*, and *IPOs in IT sector in exit year*—a proxy for market receptivity to information technology offerings.

RESULTS

Table 1 provides summary statistics and bivariate correlations for the three sets of analyses. Table 2 reports descriptive statistics as of the first round of VC funding for startups that do (versus

[12] To illustrate, consider the funding history of Apple Computer. The first round of VC funding arrived in January 1978, at which time the investors paid nine cents per share, thereby valuing the company at $3.3M. With each successive VC round, price per share and valuations increased. By the time of Apple's IPO in December 1980, investors paid $22 per share, valuing the company at $1.4B. The early stage VCs realized a significant profit, as their shares were acquired at a very low price.

do not) have founding teams with prior track records of IPO success. Tables 3-5 show econometric results that test our hypotheses of when patents should matter more in signaling quality to investors.

Table 2 shows that founding teams with IPO experience are younger at the time of initial VC funding, more likely to be headquartered in Silicon Valley, and more likely to have received initial funding from a prominent VC. With regard to patenting, founding teams with prior IPO experience also tend to have larger stocks of patent applications both overall and when weighted by forward patent citations, a conventional measure of technological quality or importance. These comparisons suggest that as of the initial funding round, teams with prior IPO experience are both more frequently matched with more prominent VCs and have submitted more patent filings. These descriptive statistics illustrate the methodological difficulty of attributing a causal role to patents as quality signals. Serial entrepreneurs with IPO experience could file more patents because they have superior access to legal counsel or financial resources, thus enabling them to secure stronger property rights for their inventions. Alternatively, such entrepreneurs may be able to "cherry pick" more lucrative technologies to pursue in their new ventures. The differential impact of patents in signaling quality to VCs is ambiguous without further examination.

Table 3 reports the results of probit regressions that estimate the probability that a given startup will receive funds from a prominent VC investor in its initial round of funding. Marginal effects are reported. The baseline specification in column 3-1 shows that patents are positively associated with sourcing a reputable VC, while founding teams without IPO experience are less likely to be matched with a prominent VC as would be expected. These effects are net of controls for a range of startup characteristics and time effects discussed in the prior section. Column 3-2 reports the results for our first hypothesis that the magnitude with which patents influence receipt of initial funding from prominent VCs will be greater for founding teams lacking IPO experience. Consistent with H1a, we find a positive and significant coefficient on the interaction term between

lack of founding team IPO experience and patent application stock. This result suggests that while patents are generally important across founding teams, teams without IPO experience benefit *more* from patents in attracting prominent VCs in the initial round of funding. Importantly, this finding is difficult to explain with an alternative property-rights explanation: serial entrepreneurs with prior IPO experience should have systematic advantages over entrepreneurs lacking such track records of performance in securing access to legal counsel. Indeed, Table 2 reveals that founding teams with prior IPO experience bring both more patent filings and more "important" inventions to the table at the time of VC funding.

Table 4 estimates the differential impact of patent filings on valuation changes across VC funding rounds using OLS and a fixed effects specification. The dependent variable is log *pre-money valuation*. The estimated effects are driven by "within startup, across funding round" variation and therefore control for unobserved time invariant startup characteristics. As a robustness check, we allowed for unobserved time-varying differences among startups by "first-differencing" the data and obtained similar findings.

The baseline specification in column 4-1 of Table 4 includes a full slate of control variables for alternate quality signals (a time-varying measure of *prominent partner stock*), time varying startup characteristics (*startup age* and *profitable phase of development*), and funding round characteristics (*angel round*, *acquisition round*, *IPO round*, *pre-1997 funding round*, and *1998-2000 funding round*). The estimates of these variables accord with intuition. For example, while *startup age* and *angel round* are negatively related to startup valuation, *profitable phase of development* and *IPO round* are positively associated. On average, valuations are significantly lower in early funding rounds as would be expected. Of particular interest in the baseline model, the coefficient on *patent application stock* is positive and statistically significant at the 1% level. This finding suggests that the patenting activities of these startups significantly boost their valuations by VC investors, a result that is consistent with either

signaling or property rights explanations.

To identify the signaling function of patents more directly, the main specification reported in column 4-2 of Table 4 interacts *patent application stock* with dummy variables for founding teams without IPO experience and early funding rounds, respectively. (Adding these interaction terms sequentially yields equivalent findings.) Turning first to the *early funding round * patent application stock* variable, the coefficient is positive and statistically significant at the 5% level. Consistent with H2, this finding suggests that while patents generally lead to increases in startup valuations, they induce *steeper* upward adjustments in early rounds of financing. As above, this result is difficult to explain with a pure property-rights explanation, under which the value anticipated from patents should be expected to rise as firms move closer to product market competition. Although the evidence in Table 4 is consistent with H2, it fails to corroborate our H1b prediction, which posits that increases in patenting activities should induce steeper upward adjustments in valuations for startups with low initial reputation endowments. The coefficient on the *Founding team has no prior IPO experience * patent application stock* interaction term is statistically insignificant.

A natural concern about the specifications in columns 4-1 and 4-2 of Table 4 is that they omit sources of heterogeneity among sub-groups in ways that bias our estimates. As noted earlier, for example, startups founded by serial entrepreneurs with prior IPOs are more likely to attract prominent VCs who, in turn, confer access to superior legal counsel. Similarly, more successful founders may locate in resource-rich areas, like the Silicon Valley region, where prominent VCs and legal counsel are more abundant. In robustness checks reported in the final two columns of Table 4, we find no evidence these concerns spuriously affect our main results.[13]

[13] A separate concern is that the uneven reporting of valuation data, particularly in cases in which startup firms have been less successful, is driving our results. In unreported regressions (available upon request), we obtained robust findings with subsamples that (a) dropped observations for ventures that eventually conducted an IPO, thus removing the most successful startups from the sample, and (b) omitted firms with two or more missing valuations. We also tested whether valuations are more likely to be reported in hot versus cold semiconductor markets using the Philadelphia

Table 5 presents the final analysis that, much like prior studies, conditions the sample on startups with IPO exits. As per Heeley et al. (2007), we estimate the underpricing of public equity shares using OLS regressions and the dependent variable *% change in first day stock price*. As previously discussed, less change in the first-day stock price (i.e., less underpricing) is used to reveal fewer information asymmetry problems between new listings and public investors. The baseline specification in column 5-1 includes controls for startup characteristics (*prominent partner stock*, *IPO underwriter rank*, *Silicon Valley location*, *startup age*, *startup size*, and *R&D intensity*) and for IPO conditions (*IPOs in IT sector in exit year*). We add to these controls the *patent application stock* and *not backed by prominent VC* variables. The former variable is estimated with a negative effect while the latter is positively related to *% change in first day stock price*, but neither is statistically significant.

To test whether patents are more important for signaling quality in the absence of prominent VC investors, column 5-2 interacts *patent application stock* and *not backed by prominent VC*. Consistent with H3, the coefficient on this interaction term is negative and statistically significant at the 1% level. In line with a signaling function of patents, this result suggests that patents serve a more important informational role for newly public firms when alternative mechanisms for conveying quality are unavailable. In column 5-3 of Table 3 we find no evidence that other (non-VC) affiliates are spuriously driving this effect.

DISCUSSION

This study sheds new light on how one resource category (patents) offers multiple pathways toward advantage. In product markets, the legal rights conferred by patents can help "isolate" firms from the competition (Rumelt, 1984), thus increasing their profit-earning potential. In strategic factor markets, however, patents can serve a conceptually distinctive function by signaling quality to outsider investors.

Semiconductor Stock Index, and found no difference in the likelihood of reporting.

Empirically, we provide the first systematic evidence that patents serve a meaningful role as quality signals in both pre-IPO and IPO environments. We show, however, that their effects are highly contingent on the strength of alternative signals in a startup's resource bundle and on the stage of financing. We offer three pieces of empirical evidence that track the entrepreneurial lifecycle that collectively suggest that patents render valuable "services" to technology startups as signaling devices to capital suppliers. More specifically, we find that (1) patents are more influential for founders lacking prior track records of entrepreneurial success when seeking initial funding from prominent VC investors, (2) patents induce steeper upward adjustments to investor valuations of new ventures in early (relative to late) rounds of VC financing, and (3) patents play a more influential role in narrowing the information gap with investors when new IPO listings lack prominent VC backers.

In combination, these results are difficult to explain if patents serve a singular role in isolating firms from product market rivals. One would expect startups with more reputable founders and investors to be advantaged in securing legal safeguards for their inventions. Indeed, our descriptive evidence is consistent with this view. If the advantages derived from patents stem solely from the legal safeguards they provide against product-market rivals (an exclusively isolating mechanism role), one also would expect these resources to increase in importance as new ventures develop, which runs counter to the empirical pattern we document.

Implications for Theory

In investigating patents as a source of competitive advantage, we gain both conceptual and analytical traction by "de-coupling" resources from their services. For resource-based theory, our study therefore raises an intriguing question about the appropriate unit of analysis for evaluation. As Barney and Ariken (2001) and Leiblein (2011) discuss, RBV scholars typically use a resource category (including but not limited to stocks of patents) as the unit for which to estimate value. Our

study suggests that, at least in the context of patents, this approach is misguided. As Penrose (1959: 25) reminds us: "it is never the resources themselves that are 'inputs' in the production process, but only the services that the resources can render." By building on this insight, we illuminate multiple pathways through which patents confer advantages to new technology companies.

Importantly, our study further suggests that a common resource may provide distinctive services in different arenas for competition—a point that is under-emphasized in the RBV literature. More specifically, the framework we develop suggest that patents could reduce information gaps in strategic factor markets even if they fail to isolate firms from competition in final markets for goods and services. We concentrate our analysis on the role of patents in raising capital from prominent investors and on better financial terms – both important outcomes in strategic financial factor markets. Prominent investors can facilitate a range of business development services for the venture, such as relationships with other resource providers (e.g., talented engineers, managers, and legal counsel). The terms by which startups access their financial capital are also important from a value capture standpoint: higher venture valuations at each private financing round and smaller changes in the first day stock trading price at the time of an IPO translate into more value captured by entrepreneurs. Even if we assume—in the extreme—that patents fail to provide any advantage in product markets, patent production activities could nonetheless shift the resource and growth trajectories of entrepreneurial firms, as well as the degree of value capture by their stakeholders.

Relatedly, a major strand of the entrepreneurship and organizations literature argues that founders leave an indelible and long-lasting mark on the firms they found through the structures, policies, and culture they institute in the early period of new venture development (e.g., Burton et al., 2002). While the role of founders in shaping their enterprises is undoubtedly important, this study indicates that the imprinting effects are far from complete. Consistent with Hallen (2008) and Zott and Huy (2007), our results suggest that the ongoing accomplishments of new enterprises may be as

important (if not more so) in shaping organizational outcomes.

A final implication of this study, in the spirit of advancing theory testing, is how empirical design and context can have drastic implications for causal inference. For new IPO listings in "complex products" industries like IT, Heeley et al. (2007) predict and find that patents *fail* to reduce information gaps with public equity investors, a result they attribute to a lack of transparency between patents and the profits anticipated from sales of products. The semiconductor industry is a canonical IT setting in which "patent thickets" and transparency problems are pervasive (Cohen et al., 2000; Hall and Ziedonis, 2001). By probing deeper into the contingencies affecting the signaling value of new listings and investigating effects in both private and public equity markets, our study suggests that it is inappropriate to conclude from Heeley et al. (2007)'s evidence that patents are universally ineffective as quality signals in the IT sector. Rather, we find they are particularly beneficial to new ventures that need them most.

Managerial and Policy Implications

One managerial implication stems directly from the contingent role of patent resources. Patents as signaling resources are particularly important for ventures without alternate means of conveying quality: those lacking successful prior startup experience in sourcing a reputable VC in the initial financing round and those without the backing of prominent VCs at the time of an IPO. In contrast to the majority of the academic entrepreneurship literature, our framing considers the resource investments and possible payoffs associated with ventures *without* the luxury of a reputation endowment (such as through successful founding experience). Our lack of empirical support for the hypothesis that patents should be particularly important for entrepreneurially inexperienced founding teams in venture valuation across funding rounds sheds interesting light on the popular view that people matter most when predicting venture success. The conventional wisdom is that financial resource providers like to minimize their risk when investing in new ventures by backing

entrepreneurs who have successfully launched a venture in the past. Moreover, these commentators believe that such experience is more important than the sheer power of a venture idea ("I would rather invest in an 'A' team with a 'B' idea than an 'A' idea with a 'B' team") under the thesis that venture success is rarely a linear path, and so having a seasoned entrepreneurial team will increase the likelihood that the maximal value is being created and captured at each enterprise development milestone. Our empirical results instead suggest that patents are equally important in explaining valuation increases across financing rounds for experienced and inexperienced entrepreneurs.

In addition, managerial policy decisions turn on the answer to whether patents offer primarily a product market exclusion role, or whether they also act as quality signaling devices for startups. If the former were true, the optimal action for managers would be to seek patent protection immediately prior to product market introduction (or when their innovation is likely to be infringed) in order to maximize the 20-year period of legal protection. If there is a significant signaling component to patent resources, an additional set of considerations such as those discussed in the hypothesis development section may factor into the timing of patent filing decisions.

Limitations and opportunities for future research

The findings and limitations of our study open several avenues for future research. Because our theoretical interest was in better understanding the functional role of resources together with a deeper understanding of when, why and how a resource can provide organizational advantage, we focused on variation in patents' effectiveness in signaling quality to financial factor markets while implicitly holding the isolating mechanism role of patents constant (within the semiconductor device industry). Future work could investigate the signaling value of patents across multiple appropriability regimes, both within and across industries. Doing so would test the richer set of implications set forth in Figure 1 for the off-diagonal cells.

Future studies also could probe more deeply into what information investors glean from

patent filings, how they do so, and whether that information-gathering process varies systematically across sectors, countries, or funding climates (e.g., "cold" vs. "hot" investment periods). In combination with Hauesller et al. (2009)'s recent findings, our study raises the intriguing possibility that VC investors internalize information contained in patent filings very quickly—without waiting for feedback from the government review process. Lacking archival data on US applications filed by our sample startups that were rejected in the examination process, we were unable to fully examine this issue in the US context. A priori, it is unclear whether the US context is an appropriate setting in which to examine trade-offs between patent filings and awards as sources of information to investors. As noted earlier, the US patent system is criticized for "rubberstamping" applications, with the vast majority of applications receiving patents (Quillen and Webster, 2001). A more rigorous review system like that in place in Europe may offer a more fruitful arena in which to explore these important these issues.

Conclusion

This study sheds new light on when, why, and how patents confer advantages to new technology companies. Integrating insights from resource-based and signaling theories, we predict and find that patenting activities "matter more" as signaling devices in early financing stages and for startups otherwise lacking credible means of conveying quality to investors. Based on evidence from 370 venture-backed startups, this study challenges the assumption that the information revealed in patent filings is too "noisy" to alter capital-market expectations in the IT sector. We show further that the signaling value of patents hinges critically on other attributes of entrepreneurial resource bundles. For RBV scholars, our study underscores the importance of continued research on the contingencies that affect the value and productive use of strategic resources.

REFERENCES

Agarwal R., Ganco M, Ziedonis RH. 2009. Reputations for toughness in patent enforcement: implications for knowledge spillovers via inventor mobility. *Strategic Management Journal* **30**(13): 1349–1374.

Ahuja G. 2000. The duality of collaboration: inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal* **21**: 317–343.

American Intellectual Property Law Association (AIPLA). 2007. *Report of Annual Economic Survey*. AIPLA: Arlington, VA.

Arikan AM, Capron L. 2010. Do newly public acquirers benefit or suffer from their pre-IPO affiliations with underwriters and vcs? *Strategic Management Journal* **31**: 1257–1289

Barney JB. 1986. Strategic factor markets: expectations, luck, and business strategy. *Management Science* **32**(10): 1231–1241.

Barney JB. 1991. Firm resources and sustained competitive advantage. *Journal of Management* **17**: 99–120.

Barney JB, Arikan AM. 2001. The resource-based view: origins and implications. In M.A. Hitt, R.E. Freeman and J.S. Harrison (eds.). *Handbook of Strategic Management,* 124–288. Oxford: Blackwell.

Brush TH, Artz KA. 1999. Toward a contingent resource-based theory: the impact of information asymmetry on the value of capabilities in veterinary medicine. *Strategic Management Journal* **20**: 223–250.

Burton MD, Sorensen J, Beckman, C. 2002. Coming from good stock: career histories and new venture formation. *Research in the Sociology of Organizations* **19**: 229–262.

Carter RB, Dark FH, Singh AK. 1998. Underwriter reputation, initial returns and long run performance of IPO stocks. *Journal of Finance* **53**: 285–311.

Cockburn IM, MacGarvie, MJ. Forthcoming. Entry and patenting in the software industry. *Management Science.*

Cohen WM, Nelson RR, Walsh J. 2000. Protecting their intellectual assets: appropriability conditions and why U.S. manufacturing firms patent (or not). NBER Working Paper 7552 (Feb).

DeCarolis DM, Deeds DL. 1999. The impact of stocks and flows of organizational knowledge on firm performance: an empirical investigation of the biotechnology industry. *Strategic Management Journal* **20**: 953–968.

Deeds DL, DeCarolis DM, Coombs JE. 2007. The impact of firm-specific capabilities on the amount of capital raised in an initial public filing: evidence from the biotechnology industry. *Journal of Business Venturing* **12**: 31–46.

Dushnitsky G, Shaver JM. 2009. Limitations to inter-organizational knowledge acquisition: the paradox of corporate venture capital. *Strategic Management Journal* **30**(10): 1045-1067.

Eisenhardt KM, Schoonhoven CB. 1990. Organizational growth: linking founding team, strategy, environment, and growth among U.S. semiconductor ventures, 1978-1988. *Administrative Science Quarterly* **35**: 504-529.

Gompers PA. 1996. Grandstanding in the venture capital industry. *Journal of Financial Economics* **42**: 133–156.

Gompers PA, Kovner A, Lerner J, Scharfstein D. 2010. Performance persistence in entrepreneurship. *Journal of Financial Economics* **96**: 18–32.

Graham SJH, Merges RP, Samuelson P, Sichelman T. 2010. High technology entrepreneurs and the patent system: results of the 2008 Berkeley patent survey. *Berkeley Technology Law Review* **24**: 1258–1328.

Haeussler C, Harhoff D, Mueller E. 2009. To be financed or not…The role of patents for venture capital financing. ZEW Discussion Paper No. 09-003.

Hall BH. 2008. The financing of innovation. In S. Shane (ed.), *Blackwell Handbook on Technology and Innovation Management,* Oxford UK: Blackwell Publishing.

Hall BH, Ziedonis RH. 2001. The patent paradox revisited: an empirical study of patenting in the US semiconductor industry. *RAND Journal of Economics* **32**: 101–128.

Hallen B. 2008. The origin of the network positions of new organizations: from whom are entrepreneurs likely to receive their first investments. *Administrative Science Quarterly* **53**: 685–718.

Heeley MB, Matusik SF, Jain N. 2007. Innovation, appropriability and the underpricing of initial public offerings. *Academy of Management Journal* **50**: 209–225.

Hellmann T, Puri M. 2002. Venture capital and the professionalization of startup firms: empirical evidence. *Journal of Finance* **57**: 169–197.

Hochberg Y, Ljungqvist AP, Lu Y. 2007. Whom you know matters: Venture capital networks and investment performance. *Journal of Finance* **62**: 251–301.

Hsu DH. 2004. What do entrepreneurs pay for venture capital affiliation? *Journal of Finance* **59**: 1805–1844.

Hsu DH. 2006. Venture capitalists and cooperative start-up commercialization strategy. *Management Science* **52**: 204–219.

Hsu DH. 2007. Experienced entrepreneurial founders, organizational capital, and venture capital funding. *Research Policy* **36**: 722–741.

Jorgenson DW. 1991. Information technology and the US economy. *American Economic Review* **91**: 1–31.

Lafontaine F. 1993. Contractual arrangements as signaling devices: evidence from franchising. *Journal of Law, Economics, and Organization* **9**(2): 256–289.

Lanjouw JO, Schankerman M. 2001. Protecting intellectual property rights: are small firms handicapped? *Journal of Law and Economics* **47**: 45–74.

Leiblein M. 2011. What do resource- and capability-based theories propose? *Journal of Management* **37**(4): 909-932.

Leland HE, Pyle DH. 1977. Information asymmetries, financial structure, and financial intermediation. *The Journal of Finance* (May): 371–387.

Lemley MA. 2000. Reconceiving patents in the age of venture capital. *Journal of Small and Emerging Business Law* **4**: 137–148.

Lemley MA. 2001. Rational ignorance at the Patent Office. *Northwestern University Law Review* **95**: 1495–1532.

Lerner J. 1995. Patenting in the shadow of competitors. *Journal of Law and Economics* **38**: 563–595.

Levin RC, Klevorick AK, Nelson RR, Winter SG. 1987. Appropriating the returns from industrial research and development. *Brookings Papers on Economic Activity* **3**: 783–820.

Long C. 2002. Patent signals. *University of Chicago Law Review* **69**: 625–679.

Makadok R. 2001. Toward a synthesis of the resource-based and dynamic-capability views of rent creation. *Strategic Management Journal* **22**: 387–401.

Mann RJ. 2005. Do patents facilitate financing in the software industry? *Texas Law Review* **83**: 961–1030.

Nesheim J. 2000. *High Tech Startup: The Complete Handbook for Creating Successful New High Tech Companies*. The Free Press of Simon and Schuster: New York, NY.

Penrose E. 1959. *The Theory of the Growth of the Firm*. Oxford, UK. Oxford University Press.

Priem RL, Butler JE. 2001. Is the resource-based "view" a useful perspective for strategic management research? *Academy of Management Review* **26**(1): 22–40.

Quillen CD, Webster OH. 2001. Continuing patent applications and performance of the US Patent Office. *Federal Circuit Bar Journal* **11**: 1–21.

Ragozzino R, Reuer, JJ. 2011. Geographic distance and corporate acquisitions: signals from IPO firms. *Strategic Management Journal* **32**: 876-894.

Riley JC. 2001. Silver signals: twenty-five years of screening and signaling. *Journal of Economic Literature* **39**: 432–478.

Rock K. 1986. Why new issues are underpriced. *Journal of Financial Economics* **15**: 187–212.

Rumelt RP 1984. Towards a strategic theory of the firm. In B. Lamb (ed.). *Competitive Strategic Management* (pp. 556–570). Englewood Cliffs, NJ: Prentice-Hall.

Sahlman WA. 1997. How to write a great business plan. *Harvard Business Review* **75** (January-February).

Shane S, Cable D. 2002. Network ties, reputation, and the financing of new ventures. *Management Science* **48**(3): 364–381.

Shane S, Stuart T. 2002. Organizational endowments and the performance of university start-ups. *Management Science* **48**(1): 154–170.

Spence M. 1973. Job market signaling. *Quarterly Journal of Economics* **87**: 355–374.

Stuart TE, Hoang H., Hybels R. 1999. Interorganizational endorsements and the performance of entrepreneurial ventures. *Administrative Science Quarterly* **44**: 315–349.

Teece DJ. 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy* **15**: 285–305.

Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* **5**: 171–180.

Yao, D. 1988. Beyond the reach of the invisible hand: impediments to economic activity, market failures, and profitability. *Strategic Management Journal* **9:** 59–70.

Ziedonis RH. 2004. Don't fence me in: fragmented markets for technology and the patent acquisition strategies of firms. *Management Science* **50**: 804–820.

Zott C, Huy QN. 2007. How entrepreneurs use symbolic management to acquire resources. *Administrative Science Quarterly* **52**: 70–105.

Figure 1: Patents as Sources of Advantage in Strategic Factor vs. Product Markets—A Stylized View

		I. Provide an "Isolating" or "Appropriability" [a] **Mechanism in <u>Product Markets</u>**	
		A. Weak	**B. Strong**
II. Provide a Quality Signal in <u>Strategic Factor Markets</u>	**A. Weak**	Limited value	Ability to price at a premium or sustain a cost advantage[b]
	B. Strong	Access to superior or lower-cost inputs to production	Reinforcing effect (improved position in both factor and product markets[b])

a. Within the resource-based literature, the term "isolating mechanism" refers to resources that help shield or "isolate" firms from competition in product markets, thus increasing a firm's profit-earning potential (Rumelt, 1984). A synomyous term, "appropriability mechanism," is used in the related technology strategy literature (e.g., Teece, 1986; Cohen et al., 2000): similarly, it refers to the extent to which patents and other levers enable firms to capture (or "appropriate") a greater share of value from new goods or services created.

b. Value can be captured directly (through sales of goods and services), indirectly (through licensing to third parties), or both.

Table 1: Summary Statistics and Correlation Matrices

Panel A: Variables in Analysis of First Round Financing (360 firm-level observations)

		Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	*Prominent VC investor*	0.45	0.50	1.00							
(2)	*Patent application stock*[a]	0.54	0.90	0.10	1.00						
(3)	*Founder has prior IPO*	0.10	0.30	0.09	0.14	1.00					
(4)	*Prominent partner stock*[a]	0.09	0.27	-0.03	0.20	0.08	1.00				
(5)	*Silicon Valley location*	0.57	0.50	0.12	-0.07	0.11	-0.12	1.00			
(6)	*Startup age*	1.70	2.60	-0.04	0.33	-0.06	0.26	-0.26	1.00		
(7)	*Profitable*	0.03	0.16	0.00	0.07	0.08	0.05	-0.04	0.23	1.00	
(8)	*Pre 1997 funding round*	0.59	0.50	0.09	-0.15	0.00	-0.12	0.24	-0.17	-0.12	1.00
(9)	*1998-2000 funding round*	0.33	0.47	-0.07	0.08	0.05	0.10	-0.18	0.05	0.10	-0.85

Panel B: Variables in Analysis of "Within Firm" Valuation Changes Across Rounds (845 funding-round observations)

		Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	*Pre-money valuation*[a]	3.35	1.29	1.00									
(2)	*Patent application stock*[a]	1.26	1.19	0.40	1.00								
(3)	*Early funding round*	0.50	0.50	-0.47	-0.41	1.00							
(4)	*Prominent partner stock*[a]	0.36	0.56	0.33	0.37	-0.34	1.00						
(5)	*Startup age*	4.05	3.54	0.29	0.44	-0.42	0.34	1.00					
(6)	*Profitable phase of development*	0.09	0.29	0.22	0.23	-0.16	0.15	0.29	1.00				
(7)	*Angel round*	0.03	0.17	-0.07	-0.02	0.10	-0.04	-0.09	-0.01	1.00			
(8)	*Acquisition round*	0.09	0.28	0.23	-0.02	-0.12	0.08	0.11	-0.02	0.16	1.00		
(9)	*IPO round*	0.04	0.19	0.32	0.25	-0.18	0.11	0.25	0.34	0.20	0.04	1.00	
(10)	*Pre 1997 funding round*	0.49	0.50	-0.27	-0.12	0.03	-0.12	-0.05	0.05	-0.03	-0.24	0.09	1.00
(11)	*1998-2000 funding round*	0.30	0.46	0.18	-0.03	0.14	0.00	-0.14	-0.04	0.04	0.08	-0.06	-0.69

Panel C: Variables in Analysis of Underpricing at IPO (Within-IPO Sample; 65 firm-level observations)

		Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	*Underpricing (%)*	0.51	0.72	1.00								
(2)	*Patent application stock*[a]	2.51	1.07	-0.12	1.00							
(3)	*VC prominence*[a]	2.63	0.435	-0.08	0.07	1.00						
(4)	*Prominent partner stock*[a]	0.77	0.67	-0.22	0.31	0.18	1.00					
(5)	*Underwriter rank*[a]	2.22	0.22	0.16	0.12	-0.11	-0.09	1.00				
(6)	*Silicon Valley location*	0.71	0.45	-0.08	-0.01	0.09	0.12	0.23	1.00			
(7)	*Startup age*	6.51	3.77	0.01	0.29	-0.20	0.15	0.02	-0.27	1.00		
(8)	*Startup size*[a]	4.35	0.72	-0.09	0.24	0.01	0.01	0.45	0.07	-0.12	1.00	
(9)	*Research intensity*[a]	3.23	0.72	0.14	-0.07	0.07	0.21	-0.07	0.03	-0.10	-0.03	1.00
(10)	*# IT IPOs in exit year*[a]	4.2	0.913	0.33	-0.02	0.21	-0.10	-0.06	-0.01	-0.17	-0.16	0.18

[a] Variable measured as natural logarithm.

Table 2: Prior Founding Team IPO Experience and Startup Characteristics in Initial VC Financing Round: Univariate Tests of Differences in Mean Values

	Founding team has prior IPO experience?	
	Yes	No
General startup characteristics at time of first VC funding		
Startup age (years since founding)	1.15	1.78†
% with headquarters in Silicon Valley	0.76	0.55**
Patenting activity at time of first VC funding		
% with ≥ 1 patents granted	0.15	0.14
% with ≥ 1 patents pending	0.46	0.33†
Patent application stock[a]	5.61	2.69**
Citation-weighted patent application stock[a]	37.72	22.08**
Prominent third-party affiliations at time of first VC funding		
% with initial financing from prominent VCs	0.52	0.33**
% with prominent corporate affiliates	0.15	0.10
Pre-money valuation in first round of VC financing[a] [b]	7.63	11.74

[a] Difference test is based on log-transformed values due to skewness in the measure.
[b] Millions of constant 2000-year dollars
†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively, based on t-tests of one-sided difference in mean values.

Table 3: Sourcing a Prominent VC in the Initial Round of Financing

	Dependent Variable: Pr (*Prominent VC investor* = 1) Note: Marginal effects reported	
Estimation method	Probit	
	(3-1) Baseline Model	**(3-2) Main Results**
Main Variables & Interactions		
Patent application stock[a]	0.068** (0.030)	0.089*** (0.033)
Founding team has no prior IPO experience	-0.131† (0.087)	-0.233** (0.108)
*Founding team has no prior IPO experience * patent application stock*[a]		0.130** (0.077)
Controls		
Prominent partner stock[a]	-0.059 (0.100)	-0.036 (0.100)
Silicon Valley location	0.085 (0.054)	0.093† (0.054)
Startup age	-0.008 (0.012)	-0.009 (0.013)
Profitable phase of development	-0.052 (0.173)	-0.042 (0.174)
Pre-1997 funding round?	0.128 (0.107)	0.100 (0.109)
1998-2000 funding round?	0.056 (0.116)	0.026 (0.114)
Log likelihood	-224.70	-223.31
Num. Observations	360	360

[a] Variable measured as natural logarithm.

†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively, based on one-tailed tests. Dollar amounts are constant 2000-year values. Standard errors are in parentheses.

Table 4: **Pre-money Valuation Fixed-Effects OLS Regressions (VC round level of analysis)**

	Dependent Variable = *L pre-money valuation*			
	(4-1) Baseline Model	**(4-2) Main Results**	**(4-3) Robustness Check: VC Prominence**	**(4-4) Robustness Check: Silicon Valley Effect**
Main Variables & Interactions				
Patent application stock[a]	0.413***	0.340***	0.266***	0.200**
	(0.069)	(0.078)	(0.087)	(0.120)
Early funding round	-1.023***	-1.183***	-1.144***	-1.153***
	(0.096)	(0.122)	(0.123)	(0.124)
*Founding team has no prior IPO experience * patent application stock*[a]		-0.046	-0.030	-0.024
		(0.123)	(0.123)	(0.124)
*Early funding round * patent application stock*[a]		0.161**	0.140**	0.148**
		(0.075)	(0.075)	(0.076)
Controls				
Prominent partner stock[a]	0.159	0.173	0.202†	0.198†
	(0.111)	(0.112)	(0.111)	(0.119)
Startup age	-0.063**	-0.059**	-0.060**	-0.058**
	(0.027)	(0.028)	(0.027)	(0.028)
Profitable phase of development	0.265†	0.277†	0.290†	0.293†
	(0.152)	(0.152)	(0.152)	(0.151)
Angel round	-0.523†	-0.565†	-0.682**	-0.674**
	(0.297)	(0.297)	(0.305)	(0.305)
Acquisition round	0.145	0.121	0.015	0.014
	(0.152)	(0.152)	(0.178)	(0.178)
IPO round	0.826***	0.843***	0.817***	0.829***
	(0.161)	(0.162)	(0.196)	(0.197)
Pre-1997 funding round?	-0.448**	-0.467**	-0.462**	-0.449**
	(0.204)	(0.203)	(0.203)	(0.204)
1998-2000 funding round?	0.210†	0.188	0.213†	0.212†
	(0.126)	(0.127)	(0.127)	(0.127)
*VC prominence * patent application stock*[a]			0.051**	0.052**
			(0.023)	(0.024)
*Silicon Valley location * patent application stock*[a]				0.077
				(0.099)
Firm fixed effects	Yes	Yes	Yes	Yes
Constant	2.575**	2.467**	2.352**	2.351**
	(1.159)	(1.157)	(1.187)	(1.187)
Adj. R-squared	0.600	0.602	0.606	0.605
Num. Observations (Firms)	845 (290)	845 (290)	845 (290)	845 (290)

[a] Variable measured as natural logarithm.

†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively, based on one-tailed tests. Dollar amounts are constant 2000-year values. Standard errors are in parentheses.

Table 5
Underpricing at IPO OLS Regressions (Within-IPO Sample)

	Dependent Variable = *% change in first-day stock price*		
	(5-1) Baseline Model	**(5-2) Main Results**	**(5-3) Robustness Check**
Main Variables & Interactions			
Patent application stock [a]	-0.047 (0.092)	-1.412*** (0.516)	-1.400*** (0.522)
Not backed by prominent VC [a]	0.127 (0.211)	1.567*** (0.571)	1.513*** (0.598)
*Not backed by prominent VC * patent application stock* [a]		-0.528*** (0.197)	-0.509*** (0.205)
Controls			
Prominent partner stock [a]	-0.168 (0.147)	-0.196 (0.139)	-0.326 (0.378)
IPO underwriter rank [a]	0.829† (0.462)	0.594 (0.446)	0.571 (0.454)
Silicon Valley location?	-0.143 (0.205)	-0.208 (0.196)	-0.211 (0.198)
Startup age	0.012 (0.027)	0.013 (0.025)	0.014 (0.026)
Startup size [a]	-0.118 (0.142)	-0.086 (0.135)	-0.075 (0.140)
R&D Intensity [a]	0.139 (0.124)	0.190 (0.119)	0.194 (0.121)
IPOs in IT sector in exit year [a]	0.248** (0.101)	0.228** (0.097)	0.216** (0.098)
*Prominent partner stock * patent application stock* [a]			0.047 (0.125)
Constant	-1.608 (1.229)	2.415 (1.923)	2.361 (1.949)
Adj. R-squared	0.106	0.196	0.183
Num. Observations (Firms)	65	65	65

[a] Variable measured as natural logarithm.
†, ** or *** indicate statistical significance at the 10%, 5% or 1% level, respectively, based on one-tailed tests. Dollar amounts are constant 2000-year values. Standard errors are in parentheses.

APPENDIX

Table A.1: Description of Regression-Model Variables and Data Sources

	Definition	Data Source
Dependent Variables		
Prominent VC investor	Dummy=1 if lead VC firm in round 1 financing falls in the upper half of within-sample distribution of VC network eigenvector centrality	VentureOne; Hochberg et al. (2007)
Pre-money valuation	Pre-money valuation (*share price * shares outstanding prior to venture round*) in focal round	VentureOne; VenturXpert
% change in first day stock price	Percentage change from offer to closing price on the first day of public trading (IPO subsample only)	VenturXpert
Main Independent Variables in First-Round Regressions		
Patent application stock	Cumulative stock of successful patent applications at the time of the funding round (or for the firm level analysis, at the time of the latest funding round).	Delphion
Founding team has no prior IPO experience	Dummy = 1 if no members of the founding team had prior entrepreneurial IPO experience	Web searches
Prominent partner stock	Cumulative count of technologically or commercially prominent strategic alliance or corporate equity partners as of focal round (see text)	ICE Status reports; Ziedonis (2004)
Silicon Valley location	Dummy = 1 if startup headquarters located in California's Silicon Valley region	VentureOne
Startup age	Age of the startup based on number of years since founding	VentureOne
Profitable phase of development	Dummy = 1 if startup reported as profitable by the focal round	VentureOne
Pre-1997 funding round?	Dummy = 1 if funding round is pre-1997; excluded period is post-2000.	VentureOne
1998-2000 funding round?	Dummy = 1 if funding round is 1998-2000 time period; excluded period is post-2000.	VentureOne
Additional Variables in Across-Round Regressions		
Not backed by prominent VC	Dummy = 1 if the prominence of the lead VC investor in the focal round, is in the lower half of the within-sample distribution of VC network eigenvector centrality (see text)	VentureOne; Hochberg et al. (2007)
Early funding round	Dummy = 1 if the focal funding round is a first or second funding round	VentureOne
Angel round	Dummy = 1 if the focal funding round was led by angels	VentureOne
Acquisition round	Dummy = 1 if the focal funding round involved a merger/acquisition	VentureOne
IPO round	Dummy = 1 if the focal funding round was an IPO	VentureOne
Additional Variables in Underpricing Regressions (observable within-IPO sample only)		
IPO underwriter rank	Carter-Dark-Singh reputation rankings of IPO underwriters, measured on a 1 (worst) to 9 (best) scale, downloaded from J. Ritter's website at: http://bear.cba.ufl.edu/ritter/Rank.htm.	Ritter website
Startup size	Value of assets at IPO, in millions of constant-year dollars	Compustat
R&D intensity	R&D expenses in IPO year normalized by value of assets	Compustat
IPOs in IT sector in exit year	An indicator used to capture "hot markets", measured as the number of IPOs in the information technology (IT) sector in the year of the focal firm's initial public offering	VenturXpert