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RESOURCES AS DUAL SOURCES OF ADVANTAGE: IMPLICATIONS FOR VALUING ENTREPRENEURIAL-FIRM PATENTS

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Why and how do resources provide sources of competitive advantage? This study sheds new light on this central question of resource-based theory by allowing a single resource—entrepreneurial-firm patents—to play distinctive roles in different competitive arenas. As rights to exclude others, patents serve a well-known role as legal safeguards in product markets. As quality signals, patents also could improve access and the terms of trade in factor input markets. Based on the financing activities of 370 venture-backed semiconductor startups, we provide new evidence that patents confer dual advantages in strategic factor markets, improved access and terms of trade, above and beyond their added product-market protection. The study has important implications for empirical tests of resource-based theory and the measurement of resource value. Copyright © 2013 John Wiley & Sons, Ltd.

> It is never the resources that are "inputs" in the production process, but only the services that the resources can render.
>
> Edith Penrose (1959: 25)

INTRODUCTION

A central tenet of resource-based theory (RBT) is that firms with valuable, scarce, and nonsubstitutable resources can gain at least temporary advantages by using those resources to develop and implement product-market strategies. As Barney and Arikan (2001: 138) report, 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." Despite major advances in RBT as a theory of competitive advantage, Priem and Butler (2001) contend that the empirical literature overemphasizes *whether* resources are valuable, thus obscuring deeper understanding of *why* and *how* such resources are advantageous. In a more recent critique, Leiblein (2011) similarly suggests that RBT researchers should better elucidate whether resource value originates in "strategic factor markets" where inputs such as labor and capital are assembled (Barney, 1986), in product markets, or in both.

This study sheds new light on why and how resources provide sources of advantage by decoupling resources from the services they render (Penrose, 1959). To illustrate the salience of this point, we show how one resource type—patents—can serve distinctive roles in different arenas for competition, and consider the implications for resource valuation. As legal rights to exclude others from use of proprietary inventions, patents serve a

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well-known "isolating" role against imitation in markets for final goods and services (Rumelt, 1984; Teece, 1986). By reducing informational imperfections in factor input markets, patents also may serve a signaling function (Haeussler, Harhoff, and Mueller, 2009; Long, 2002) and improve access or terms of trade in this earlier competitive arena. Empirical evidence nonetheless remains limited, largely due to the methodological difficulty of disentangling this potential factor-market effect from the product-market value attributable to the patent right.

To tease apart the signaling function of patents in factor markets, we select an input widely characterized by informational imperfections—entrepreneurial finance—and investigate whether patents alter outcomes in ways difficult to reconcile with traditional property rights predictions. Our data capture with unusual richness the patent and nonpatent resources of 370 venture-backed semiconductor start-ups from initial funding through development and exit. Exploiting heterogeneous information gaps between new ventures and investors, we estimate the magnitude with which a start-up'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 discount on share prices for initial public offerings (IPOs).

Consistent with the view that patents serve a meaningful role as factor-market signaling devices, we find that successful patent filings are more influential determinants of financing outcomes for new ventures that (1) lack alternative means for conveying quality to outside investors, and (2) are in earlier stages of financing. Put differently, patents "matter more" as signaling devices when information imperfections in factor input markets are more severe. Importantly, these findings are inconsistent with the view that patents serve a singular role as product-market safeguards as explained more fully below. The study provides the first systematic evidence that patents confer advantages in strategic factor markets above and beyond their added protection in final markets for goods and services, and has important implications for empirical tests of resource-based theory.

THEORETICAL FRAMING: ONE RESOURCE, MULTIPLE SERVICES

At its core, resource-based theory rejects the idea that external factors sufficiently explain why some firms perform better than others. Wernerfelt (1984) was among the first to recast traditional theories of competitive advantage based on industry and regulatory factors into a resource-based perspective—revealing how sources of advantage in product markets (e.g., barriers to entry) have parallel sources of advantage in markets to acquire or control resources (e.g., barriers to imitation). Influenced by Edith Penrose's *Theory of the Growth of the Firm* (Penrose, 1959), Wernerfelt (1984) and other seminal RBT scholars (Barney, 1986; Rumelt, 1984) highlight internal resources and resource bundles as determinants of performance. Indeed, modern resource-based theory rests on Penrose's conceptualization of the firm as "a collection of productive resources [whose] purpose is to organize the use of its 'own' resources together with resources acquired from outside the firm for the production and sale of goods and services at a profit" (1959: 31).

Despite a proliferation of research on RBT since the mid-1980s, empirical tests of the theory tend to overemphasize whether resources are valuable to firms (Priem and Butler, 2001), often failing to elucidate where and how those resources provide a source of advantage (Leiblein, 2011). Ironically, this criticism of the RBT literature could stem from the use of a firm's resource or resource bundle as the unit of analysis for theory testing. Consider, for example, a highly cited study by Hall (1992). Based on a survey of British executives, Hall (1992) finds that intangible resources such as patents, corporate reputations, and employee know-how provide firms with sustainable sources of advantage. Although the study is often cited for showing the value of intangible resources to firms, the causal linkages between such resources and competitive advantage is unspecified. How

[1] Consistent with recent studies (e.g., Haeussler *et al*., 2009; Heeley *et al*., 2007), we measure a start-up'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 several year delay typically required for the review process. Although data on rejected U.S. applications are unavailable for most years in our sample, Lemley and Sampat (2008) report that only 15–20 percent of U.S. patent applications are rejected by examiners.

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and why do these resources confer sources of advantage? Do such advantages arise in product markets, strategic factor markets, or both?

Shifting the unit of analysis from resources to services helps inform these elusive questions. To repeat our introductory quote by Penrose, "it is never the resources themselves that are 'inputs' in the production process, but only the services that the resources can render" (1959: 25)—an observation that receives surprisingly little attention in the modern RBT literature. The fact that the same resource can be used in different ways and for different purposes is, according to Penrose, of "great importance for the productive opportunity of a firm" (1959: 75–76).

To illustrate the analytical salience of this Penrosian insight, consider the multiple services rendered by "star scientists." Zucker, Darby, and Armstrong (2002) document that new biotechnology companies with star scientists outperform comparable firms lacking scientists of prominent stature. Assuming that scientific expertise is limited in supply and not substitutable through other means, star scientists could enable firms to bring more novel or effective drugs to market and/or speed the costly commercialization process (Agrawal, 2006; Zucker, Darby, and Brewer, 1998). If star scientists fail to capture their total value added through compensation, this human capital resource could yield an important source of relative advantage in the market for pharmaceutical products.

A separate set of star-related advantages could originate in strategic factor markets. As Coff and Kryscynski (2011: 1433) explain, human capital markets are imperfect and laden with hazards. A prominent source of imperfection is asymmetric information between firms and human capital providers. Individuals typically know more about their skills and work ethics than do potential employers. Faced with imperfect information about the true value of a potential recruit, employers will likely discount wages in light of that risk. This dynamic yields the well-known Akerlof "lemons" problem, where more desirable workers opt out of the process and are not available for hiring (Coff and Kryscynski, 2011). If firms with star scientists find it easier to recruit new scientists or to do so for lower wages (Stern, 2004), they could reap added advantages through improved access and/or terms of trade in the market for skilled labor.

Decoupling services from resources allows the same resource—whether star scientists or legal rights such as patents—to serve conceptually distinctive functions in different competitive arenas. In the case of star scientists, we could observe a product-market effect due to superior know-how, a factor-market signaling effect in which (other) scientists wish to align themselves with the firm, or both. Market imperfections, or frictions, are a precondition for resource-based advantage in factor input markets (Mahoney and Qian, 2012; Makadok and Barney, 2001). Otherwise, firms would be unable to exploit such imperfections for strategic gain (Barney, 1986; Yao, 1988). An intriguing question, then, is under what circumstances is each source of advantage important?

Implications for valuing entrepreneurial-firm patents

The Penrosian emphasis on resource functions allows a unified resource category to confer multiple sources of strategic advantage. Rather than asking whether patents are valuable for new ventures, we therefore ask how and when they are valuable. We highlight two functions attributable to patents: as isolating mechanisms in product markets and as signaling devices in strategic factor markets.

"Isolating" mechanisms in product markets

In line with the traditional property rights view of patents, RBV scholars typically focus on the legal protection that patents offer against product rivals (see Barney and Arikan, 2001). By allowing greater control over distinctive product offerings, patents can help isolate or buffer firms from competitors (Rumelt, 1984). In turn, firms may be able to appropriate greater returns from R&D and human capital investments by supporting a price premium, ensuring cost advantages through use of superior methods, and/or enhancing revenues through license agreements (Teece, 1986).

The isolating benefit of patents likely varies across sectors (Cohen, 2010). For U.S. manufacturing corporations, patents generally offer stronger product-market advantages in life science and chemical industries than is true in information technology (IT) sectors (Cohen, Nelson, and Walsh, 2000; Levin *et al*., 1987). For U.S. technology start-ups, however, Graham *et al*. (2010)

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find the product-market advantages attributable to patents are more comparable in biotechnology and hardware sectors, including but not limited to semiconductor devices. Consistent with that view, Ziedonis (2003) finds that young semiconductor device companies in the United States enforce one out of every 100 patents they own after going public, an enforcement rate on par with that reported in biotechnology (Lerner, 1995).

Signaling devices in strategic factor markets

If patents serve as quality signals[2] to resource providers, they could confer a separate set of advantages in strategic factor markets where resources required for commercialization are exchanged and assembled (Barney, 1986, 1991). Much like human capital markets, the market for entrepreneurial financing is rife with informational imperfections (Hall and Lerner, 2010). Developing new technologies is a costly and uncertain process typically requiring financial capital and assistance from third parties. When investors find it difficult to sort good projects from bad, financial backing can be more costly or difficult to secure (Hall and Lerner, 2010; Leland and Pyle, 1977). As Stuart, Hoang, and Hybels (1999: 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."

Patents conform well to Spence's (1973) criteria for a quality signal: they are costly and provide a mechanism by which quality types can be sorted (Long, 2002). Inclusive of attorney fees, the estimated cost of obtaining a typical U.S. patent is $35,000 (Graham *et al*., 2010), direct monetary expenses that are 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 programmers. In addition, there are indirect costs, including disclosure of information about the underlying invention. Moreover, the communication between inventors and patent attorneys is tedious and time consuming, amplifying the opportunity costs for firms (like semiconductor start-ups) fueled by speed to market.

Qualitative evidence is consistent with the view that patents bridge information gaps in entrepreneurial capital markets. 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 that "patent portfolios can convey information about the lines of research a firm is conducting and how quickly the research is proceeding." In combination, these quotes imply that investors use patenting activities not simply to assess the monetary value directly attributable to the right, but also to gauge the broader potential of the firm and its human capital.

Quantitative evidence on the signaling value of patents in entrepreneurial capital markets remains sparse, largely due to the methodological challenge of isolating the effect. Based on the funds raised by biotechnology ventures at IPO, Deeds, DeCarolis, and Coombs (2007) conclude that the signal cast by patent filings is too noisy to affect the expectations of public investors. Stuart *et al*. (1999) similarly find no evidence that patent filings boost the valuations of new biotechnology listings, even though the companies advertise patent applications and awards profusely in IPO documents. Heeley, Matusik, and Jain (2007) employ an outcome variable that (as discussed more fully below) is better suited for pinpointing informational value in IPO capital markets—the underpricing of new public listings. Contradicting prior findings, Heeley *et al*. (2007) find that patent filings significantly reduce information asymmetries at IPO, albeit not in IT-related sectors. The authors conclude that in "complex product" sectors like IT, patents fail to convey meaningful information to public investors.

Among the few studies in pre-IPO environments, Baum and Silverman (2004) show that new biotechnology firms with more patent filings raise

[2] 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 (Stuart *et al*., 1999), legal (Long, 2002), and economics (Lafontaine, 1993) literatures. Patents may also serve as signaling devices to competitors (e.g., Anton and Yao, 2004; Horstmann *et al*., 1985) or to end technology users (Gick, 2008), thus reinforcing product-market-related advantages discussed above.

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		I. Provide an 'isolating' or 'appropriability'[a] mechanism in product markets	
		A. weak	**B. strong**
II. Provide a quality signal in strategic factor markets	**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 synonymous 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 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.

Figure 1. Patents as sources of advantage in strategic factor versus product markets—a stylized view

more money prior to exit. Using Kauffman survey data, Audretsch, Boente, and Mahagaonkar (2012) similarly report that entrepreneurs with patent filings and prototypes are more likely to receive equity financing. Based on a survey of European biotechnology firms seeking venture capital (VC) financing, Haeussler *et al*. (2009) further document that patent filings accelerate receipt of financing from venture capitalists. In combination, this evidence is consistent with the view that patents mitigate informational problems in pre-IPO environments, thus promoting trade. Nonetheless, it also could reflect the selection of "better" companies for entrepreneurial financing—an alternative explanation that is difficult to rule out with cross-sectional analyses alone.

To summarize, Figure 1 depicts two conceptually distinctive roles that patents may serve for entrepreneurial firms: appropriability (isolating) mechanisms in product markets and signaling devices with factor input providers. Importantly, patents could serve a meaningful role as signaling devices even if they fail to deter imitation in the product market, and vice versa. In the recent survey of technology start-ups, for example, many CEOs report that patents provide weak protection against product rivals yet simultaneously emphasize that patent rights are important in their financing activities (Graham *et al*. 2010). Decoupling services from resources helps explain these otherwise curious findings.

HYPOTHESES

Do patents provide an economically meaningful "service" to entrepreneurs as quality signals to capital providers? To investigate this issue, we identify conditions under which patents are likely to act as strong or weak quality signals in the factor input market (Figure 1, row IIB versus IIA), holding constant their separable role as means of isolation in the final market for goods and services (the columns of Figure 1). Our aim is therefore to abstract away from cross-sector differences in the value of patents as isolating devices to concentrate on their heterogeneous value as signaling devices within an industry context. Our core argument is that the signaling value of patents is contingent on the strength of alternative quality signals in a start-up'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 nonpatent signals and key financing activities change during

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the new venture life cycle 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 for new technology companies, receipt of funds from a prominent VC is among the most consequential (Hsu, 2004). While the financial capital supplied by venture capitalists is relatively homogenous, VCs differ significantly in the quality of "extra-financial" services they provide that aid in the growth and development of young companies. More specifically, 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 to time entrepreneurial exits (Gompers, 1996). Not surprisingly, Hochberg, Ljungqvist, and Lu (2007) show that prominent VC-backing significantly predicts a successful IPO exit.

In securing funds from prominent VC investors, however, path dependencies arise. As Hallen (2008) and others show, a start-up's initial placement in relational networks influences the pace and direction of future growth trajectories. Gompers *et al*. (2010) provide extensive evidence that founders with IPO experience are more likely to realize successful IPO exits in new ventures than are novice 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) further documents that experienced entrepreneurs are more successful in recruiting executive officers from their social networks, thus contributing to the success of their new ventures. The same resource-attainment 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.

In stark contrast, the prior literature offers little recourse or prescriptive guidance for venture teams *lacking* prior track records of entrepreneurial success. The same critique holds true when resource providers face greater uncertainty about entrepreneurial quality: in early stages of venture development and for ventures lacking prominent VC affiliation at the time of IPO. In these contexts, which span the entrepreneurial life cycle, informational imperfections in input markets should loom particularly large. If patents provide a mechanism by which resource providers assess venture quality, that role should be particularly important in such information-poor contexts—an insight that unifies the hypotheses and empirical tests that follow.

As Zott and Huy (2007) and Hallen (2008) suggest, venture accomplishments relative to peers 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 start-ups 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 patents. If patents serve a signaling function in securing funds from prominent VC investors, we should therefore expect them to matter *more* for start-ups 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" (Gompers *et al*., 2010), we therefore predict:

H1a: Patents will be more important for start-ups with low (versus high) initial reputation endowments (as inherited from their founders) in securing initial funding from prominent VCs, holding other start-up characteristics constant.

Consistent with studies highlighting the importance of entrepreneurial experience (Gompers *et al*., 2010; Hsu, 2007), the view that "people matter" in new venture success is strongly held in the practitioner literature. As Sahlman (1997) writes: "Investors ... look favorably on a team that is known because the real world often prefers not

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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 ...."

If investors correlate entrepreneurial experience with unobservable attributes that improve the odds of success, start-ups lacking such experience should face greater information problems in factor input markets even after receipt of initial VC financing. Put differently, the information gap with investors should be wider for ventures with inexperienced founders not only when they are evaluated for an initial round of financing but also in future rounds, when investors update expectations about the venture's profit potential. Following this logic, the "chunky" and time-varying information provided by patents should play a more prominent role in altering investor expectations of start-ups with inexperienced (relative to experienced) founders. Conditional on initial receipt of VC financing, we therefore predict:

H1b: Increases in patenting activity will induce steeper upward adjustments in valuations of start-ups with low initial reputation endowments (as inherited from founders) across rounds of VC funding.

Stage of financing

For technology start-ups more generally, early stages of funding are characterized by greater technical and demand uncertainty in new venture product development. As start-ups proceed through multiple funding rounds, more information about their profit potential is revealed to investors through multiple mechanisms, including site visits, board meetings, and negotiations over share pricing in future rounds of financing (Hellmann and Puri, 2002). In turn, the information gap with investors should narrow. If patents serve a signaling function in markets for VC financing, this logic suggests that the value of that role should be particularly important in earlier stages of financing. We therefore predict:

H2a: Increases in patenting activity will induce steeper upward adjustments in valuations of start-ups in earlier (versus later) funding rounds.

A related time-varying prediction suggests that the value of patents as signaling devices will be higher for start-ups unable to convey quality through the reputations of their founders. While the average effect of patents on valuation adjustments should be higher in earlier funding rounds (in H2a), this logic suggests heterogeneous effects within the sample.[3] Assume, for example, that start-up A is founded by experienced entrepreneurs while start-up B is not and that investors therefore have greater *ex ante* uncertainty about the profit potential of start-up B. In earlier rounds of financing, the information gap with investors therefore should remain wider for start-up B relative to start-up A, thus amplifying the potential value of patents as signaling devices. This logic suggests that patenting should induce a *steeper* valuation adjustment in early (versus later) funding rounds for enterprises with low (versus high) initial reputation endowments. We therefore predict:

H2b: The valuation boost from patenting activity in earlier funding rounds will be more pronounced for start-ups with low (versus high) initial reputation endowments (as inherited from founders)

Reputations leased from investors

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: had the pricing more accurately reflected the share price at the end of the firm's first trading day as a public company, more funds would have been secured for the same underwriter fee.

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). As suggested earlier, information problems in input markets for entrepreneurial capital should be less pronounced for start-ups with experienced founders. An entity going public does so only once, making it difficult to rely on this mechanism alone. In light of this challenge, prior

[3] We thank an anonymous referee for this insight.

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studies suggest that new listings "lease" reputations of VC investors when going public. As Hellmann and Puri (2002) and others suggest, VCs assist start-ups 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 start-ups *lacking* such affiliations. Using IPO underpricing as an indicator of information gaps between new ventures and public equity investors, we therefore predict:

H3: Conditional on an IPO exit, the magnitude with which patents reduce IPO underpricing will be greater for start-ups with low (versus high) reputation endowments (as inherited from founders or leased through 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 start-ups 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 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 intangible assets and know-how that is inherently difficult to value. The industry therefore provides a meaningful setting for investigating the relationship between patenting and the early-stage financing activities of new ventures. This setting also enables us to revisit the conclusions of Heeley *et al*. (2007): that patents fail to reduce information asymmetries for IPO listings in complex industries such as IT. Even within the IT sector, however, patents could nonetheless reduce information gaps with private equity providers long before funds are sought by a subset of successful ventures in public equity markets. 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.[4] To allow a sufficient window through which to view postfounding activities, start-ups 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. 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, 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. The Appendix table 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.

[4] Imposing the condition of VC-funded enterprises allows us to test for effects with start-ups that exceed a minimum threshold of quality. As discussed below, we also observe changes in start-up 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 start-ups that sought but failed to receive at least one round of venture financing.

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Analytic framework and variables

We focus on the role of patents in raising capital from prominent investors and on the terms of financing. The terms by which start-ups access their financial capital are important from a value capture standpoint: higher venture valuations at each private financing round and smaller changes in the stock trading price at the time of an IPO translate into more value captured by entrepreneurs.

Our first analysis focuses on a pivotal outcome in the early phases of a new venture's development—receipt of initial financing from a prominent VC. The outcome variable, *prominent VC investor*, is 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 H1a, 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 start-up at time *t* that eventually result in the successful award of a U.S. patent. Haeussler *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 start-up patenting activities offers several advantages to measures based on patents awarded. As Haeussler *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 communications with patent attorneys discussed earlier. Due to lengthy delays in the patent examination process, innovative companies also have strong incentives to reveal information to investors about applications pending (Stuart *et al*., 1999). Haeussler *et al*. (2009) show, for example, that the average biotechnology start-up obtains patents long after securing VC financing, with three- to four-year lags. Similar patterns hold for the semiconductor start-ups in our sample.

In the analyses that follow, we therefore employ a time-varying patent application stock measure. In robustness checks, we 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 are noisier with a grant-based measure. Results reported below are also robust to the omission of firms at the 99th 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 young companies, measured as the cumulative count of prominent alliance partners or corporate equity investors[5]), a set of start-up characteristics (*Silicon Valley location* dummy, *start-up age*, and start-up *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 start-ups less able to convey quality through nonpatent means (H1b). We also test whether patenting activities in earlier rather than later stages of financing stimulate a greater shift in valuations (H2a) using a dummy variable, *early funding round*, which denotes first or second rounds. To test whether this effect is amplified for firms less able to convey quality through founder reputations (H2b), we use a three-way interaction term: patent application stock × early funding round × founding team has no IPO experience. Control variables are equivalent to those used in the first analysis, but the time-varying variables are evaluated at the time of a given funding round. For example, prominent

[5] 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

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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*.

The outcome variable in the second analysis, *premoney valuation*, reflects the product of start-ups' share price before the funding round multiplied by the number of shares outstanding.[6] Returns realized depend on the difference between the price paid to buy shares in the company and the liquidation value (see Hsu, 2004; Lerner, 1994). 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, 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. A higher valuation in a focal funding round is therefore good news for existing equity holders, as the wedge between the acquisition and current share price is larger. We use premoney valuation, which reflects investors' valuation prior to capital infusion at the focal round, rather than postmoney valuation. As Lerner (1994) discusses, the former measure is less sensitive to the quantity of funds injected.[7]

The third and final analysis focuses, like most prior research, on the late stage of venture development when successful enterprises and equity holders seek funds from public 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. Unlike other IPO performance metrics such as amount raised or total market valuation, the underpricing of initial share prices gauges the degree of asymmetric information between new listings and potential investors (Beatty and Ritter, 1986). Consistent with the first two sets of analyses, we investigate whether patents are more important as an uncertainty-reducing mechanism for start-ups at a relative disadvantage in conveying their underlying quality to investors. The sample in this analysis is restricted to firms with IPO exits, and the dependent variable is *percentage change in first day stock price*. We operationalize "relative disadvantage" at IPO with two indicator variables discussed above: *not backed by prominent VC investors* (based on median VC eigenvector scores) and *founding team has no IPO experience*. 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*, *start-up 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. Table 2 reports descriptive statistics in the first round of VC funding for start-ups that do (versus do not) have founding teams with prior track records of IPO success. Tables 3–5 report our three sets of results.

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 receive 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

[6] It is natural to question whether funds are raised largely in response to an anticipated need for patenting, which would complicate interpretation of the estimates. The direct cost of patenting in our sample is approximately 5 to 6 percent of the total amount of capital raised in a funding round, suggesting that most funds are used for working capital instead.

[7] Our empirical framework adjusts the valuation measure for risk. Risk adjustments involve both the dependent and independent variables. On the former, valuations are being made in a competitive VC funding environment in the sense that VCs have to compete for deals. As a result, the valuations offered and accepted (reflected in our outcome variable), price in such risk. On the latter, the period dummies allow different risk profiles during preboom (pre-1997), boom (1998–2000), and postboom years, consistent with well-documented shifts in the funding environments for technology companies in these periods (e.g., Gompers *et al*., 2010). In addition, under the social processes of quality attracting quality and prominent venture affiliates having the resources to assist, our control for prominent partner stock further adjusts for such risk. Finally, we include numerous venture-level covariates that correlate with risk profiles, including the prior IPO experience of the founders, start-up age, and profitable phase of development. This approach is consistent with hedonic pricing studies of new venture valuation in the finance literature (e.g., Lerner, 1994).

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Table 1. Summary statistics and correlation matrices

		Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A: variables in analysis of first round financing (360 firm observations)														
(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)	Start-up 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)														
(1)	Premoney 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)	Start-up 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 (sample of IPO firms only; 65 firm observations)														
(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	0.44	−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)	Start-up age	6.51	3.77	0.01	0.29	−0.20	0.15	0.02	−0.27	1.00				
(8)	Start-up 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	0.91	0.33	−0.02	0.21	−0.10	−0.06	−0.01	−0.17	−0.16	0.18	1.00	
(11)	Profitable phase of development	0.17	0.37	−0.08	0.25	0.11	0.08	−0.10	0.00	0.27	−0.06	−0.38	0.06	1.00
(12)	No prior IPO experience	0.09	0.09	0.06	0.16	0.13	−0.00	−0.03	0.12	−0.06	−0.18	0.04	−0.03	−0.01

[a] Variable measured as natural logarithm.

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Table 2. Prior founding team IPO experience and start-up characteristics in initial VC financing round: univariate tests of differences in mean values

	Founding team has prior IPO experience?	
	Yes	No
General start-up characteristics at time of first VC funding		
Start-up age (years since founding)	1.15	1.78†
Percentage with headquarters in Silicon Valley	0.76	0.55**
Patenting activity at time of first VC funding		
Percentage with ≥ 1 patents granted	0.15	0.14
Percentage 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		
Percentage with initial financing from prominent VCs	0.52	0.33**
Percentage with prominent corporate affiliates	0.15	0.10
Premoney valuation in first round of VC financing[a b]	7.63	11.74

†, **, or *** indicates statistical significance at the 10%, 5%, or 1% level, respectively, based on two-tailed *t*-tests. Dollar amounts are constant 2000-year values. Standard errors are in parentheses.
[a] Difference test is based on log-transformed values due to skewness in the measure.
[b] Millions of constant 2000-year dollars.

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 shows probit regressions of the probability that a given start-up will receive funds from a prominent VC 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 match with a prominent VC as would be expected. These effects are net of controls for a range of start-up 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 reports 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 *premoney valuation*. The estimated effects are driven by variation across funding rounds for a given firm and therefore control for unobserved start-up characteristics that are time invariant. Allowing unobserved firm characteristics to evolve by first-differencing the data yields 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 start-up characteristics (*start-up 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 accord with intuition. For example, while start-up age and angel round are negatively related to start-up valuation, profitable phase of development and IPO round are positively associated. On average, valuations are significantly lower in early funding rounds

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Table 3. Sourcing a prominent VC in the initial round of financing

Estimation method	Dependent variable: Pr (*Prominent VC investor* = 1) Note: marginal effects reported Probit	
	(3-1) Baseline	(3-2) Main results
Main variables and interactions		
Patent application stock[a]	0.068**	0.089***
	(0.030)	(0.033)
Founding team has no prior IPO experience	−0.131†	−0.233**
	(0.087)	(0.108)
Founding team has no prior IPO experience × patent application stock[a]		0.130**
		(0.077)
Controls		
Prominent partner stock	−0.059	−0.036
	(0.100)	(0.100)
Silicon Valley location	0.085	0.093†
	(0.054)	(0.054)
Start-up age	−0.008	−0.009
	(0.012)	(0.013)
Profitable phase of development	−0.052	−0.042
	(0.173)	(0.174)
Pre-1997 funding round?	0.128	0.100
	(0.107)	(0.109)
1998–2000 funding round?	0.056	0.026
	(0.116)	(0.114)
Log likelihood	−224.70	−223.31
Number of observations	360	360

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

[a] Variable measured as natural logarithm

as would be expected. Of particular interest, the coefficient on patent application stock is positive, statistically significant at the 1 percent level, and economically meaningful in magnitude. To elaborate, the mean premoney valuation within the sample is roughly $28.5 million, and the mean patent application stock is 3.5 in a focal round. The most conservative point estimate in column 4-4 of Table 4 therefore suggests that, holding constant other independent variables, a doubling of the mean patent application stock from 3.5 to 7 patent filings boosts investor estimates of start-up value by $5.7 million ($28.5 million × 20%). Based on fees reported by Graham *et al*. (2010), this valuation boost would require roughly $122,500 (at $35,000 × 3.5 new filings) in expenditures, a lucrative return on investment. This finding suggests that the patenting activities of these start-ups significantly boost VC valuations, a result that is consistent with either a signaling or a property rights explanation.

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 lacking IPO experience and in 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 percent level. Consistent with H2a, this finding suggests that, while patents generally lead to increases in start-up valuations, they induce *steeper* upward adjustments in early rounds of financing. Column 4-3 shows that this effect is amplified for start-ups lacking experienced founders. As predicted in H2b, the three-way interaction term, founding team has no prior IPO experience × early funding round × patent application stock, is positive and statistically significant. Although the evidence in Table 4 is consistent with H2a and H2b, it fails to reveal that increases in patenting activities induce steeper upward adjustments in valuations for start-ups with low initial reputation endowments (H1b). The coefficient on the founding team has no prior IPO experience × patent application stock interaction term is statistically insignificant.

The differential impact of patenting on valuation adjustments in earlier financing rounds in Table 4, particularly for start-ups with low initial reputation endowments, is again difficult to reconcile with a pure property rights explanation. The value of patents as isolating mechanisms in product markets should increase (or remain constant) across rounds of financing (Mann, 2005). In earlier rounds, new ventures are less likely to have commercialized products under development, thus making them less vulnerable to reverse engineering and imitation (Cohen *et al*., 2000; Teece, 1986). As Table 2 suggests, founding teams with IPO experience typically bring superior contacts and technologies to their new endeavors (Gompers *et al*., 2010). If patents play a singular role as isolating mechanisms in product markets, we would anticipate higher (rather than lower) across-round valuation adjustments for start-ups with high

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initial reputation endowments. Instead, and consistent with a signaling explanation, Column 4-3 reveals the opposite pattern.

As a robustness check, column 4-4 in Table 4 investigates whether omitted sources of heterogeneity among the subgroups bias the estimates. As noted earlier, start-ups founded by serial entrepreneurs with prior IPOs are more likely to attract prominent VCs who, in turn, provide access to superior legal counsel. Similarly, more successful founders may locate in areas rich in entrepreneurial resources, like the Silicon Valley region, where prominent VCs and legal counsel are more abundant. Column 4-4 provides no evidence that these concerns spuriously explain our main results. Separately, we explored potential biases due to the uneven reporting of valuation data, particularly for unsuccessful ventures. In unreported regressions (available on request), we obtained similar results with subsamples that (1) removed the most successful IPO start-ups from the sample, and (2) 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 Semiconductor Stock Index, and found no difference in the likelihood of reporting. Finally, to address concerns about the accuracy of valuation measures in VC contexts, we restricted the sample to start-ups based in Silicon Valley, where entrepreneurial capital markets are most active, and obtained similar findings.

Table 5 presents the final analysis that conditions the sample on start-ups with IPO exits. As per Heeley *et al*. (2007), we estimate the underpricing of public equity shares using OLS regressions and the dependent variable *percentage change in first-day stock price*. Less change in the first-day stock price (i.e., less underpricing) suggests fewer information asymmetry problems between new listings and public investors. The baseline specification in column 5-1 includes controls for start-up characteristics (*prominent partner stock*, *IPO underwriter rank*, *Silicon Valley location*, *start-up age*, *profitable phase of development, start-up 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, not backed by prominent VC, and founding team has no prior IPO experience variables.

To test whether patents are more important as signaling devices when prominent VCs are absent, column 5-2 interacts patent application stock and not backed by prominent VC. Column 5-3 adds the interaction between patent application stock and an alternative nonpatent means for conveying information to public investors via founder reputations. Consistent with H3, the coefficients on both interaction terms are negative and significant at the 5 percent level. The result is stable when including product segment controls (i.e., application-specific versus general purpose chips) for the subset of firms where such data were reported. In line with a signaling function of patents, this evidence suggests that patents serve a more important informational role for new public listings when alternative mechanisms for conveying quality are unavailable.

DISCUSSION

This study sheds new light on a central question of resource-based theory: Why and how do resources provide sources of competitive advantage? We do so by allowing a single resource—entrepreneurial-firm patents—to play distinctive roles in different competitive arenas. As legal rights to exclude others, patents serve a well-known role as legal safeguards in product markets. As quality signals, patents also could improve both access and the terms of trade in factor input markets when informational frictions exist in those markets.

Based on the financing activities of 370 venture-backed semiconductor start-ups, we provide new evidence that patents confer dual advantages in strategic factor markets above and beyond their added protection in product markets. More specifically, we find that (1) patents are more influential for founders lacking prior entrepreneurial success in securing initial funds from prominent VCs; (2) patents induce steeper valuation adjustments in earlier rounds of VC financing; and (3) conditioned on an IPO exit, patents play a more influential role in bridging information gaps with public investors when start-ups lack prominent VC investors.

In combination, these results are difficult to reconcile with the view that patents serve a singular role in isolating firms from product-market rivals. One would expect start-ups 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

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Table 4. Premoney valuation fixed-effects OLS regressions (VC round level of analysis)

	Dependent variable = *L premoney valuation*			
	(4-1) Baseline	(4-2) Main results (H2a)	(4-3) Main results (H2b)	(4-4) Robustness check
Main variables and interactions				
Patent application stock[a]	0.413***	0.340***	0.351***	0.200**
	(0.069)	(0.078)	(0.075)	(0.120)
Early funding round	−1.023***	−1.183***	−1.171***	−1.153***
	(0.096)	(0.122)	(0.117)	(0.124)
Founding team has no prior IPO experience × patent application stock[a]	—	−0.046	—	−0.024
		(0.123)		(0.124)
Early funding round × patent application stock[a]	—	0.161**	—	0.148**
		(0.075)		(0.076)
Founding team has no prior IPO experience × early funding round × patent application stock[a]	—	—	0.179**	—
			(0.081)	
Controls				
Prominent partner stock[a]	0.159	0.173	0.164	0.198†
	(0.111)	(0.112)	(0.111)	(0.119)
Start-up age	−0.063**	−0.059**	−0.057**	−0.058**
	(0.027)	(0.028)	(0.028)	(0.028)
Profitable phase of development	0.265†	0.277†	0.277†	0.293†
	(0.152)	(0.152)	(0.151)	(0.151)
Angel round	−0.523†	−0.565†	−0.562†	−0.674**
	(0.297)	(0.297)	(0.297)	(0.305)
Acquisition round	0.145	0.121	0.127	0.014
	(0.152)	(0.152)	(0.152)	(0.178)
IPO round	0.826***	0.843***	0.841***	0.829***
	(0.161)	(0.162)	(0.161)	(0.197)
Pre-1997 funding round?	−0.448**	−0.467**	−0.461**	−0.449**
	(0.204)	(0.203)	(0.203)	(0.204)
1998–2000 funding round?	0.210†	0.188	0.190	0.212†
	(0.126)	(0.127)	(0.127)	(0.127)
VC prominence × patent application stock[a]	—	—	—	0.052**
				(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**	2.426**	2.351**
	(1.159)	(1.157)	(1.157)	(1.187)
Adj. *R*-squared	0.600	0.602	0.603	0.605
Number of observations (Firms)	845	845	845	845
	(290)	(290)	(290)	(290)

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

against product-market rivals (an exclusively isolating mechanism role), one also would expect these resources to increase in importance as new ventures develop. We do not observe such an empirical pattern.

The study contributes to an extensive body of research in strategy and economics on imperfect information and its implications for firm strategy and performance (e.g., Ragozzino and Reuer, 2011; Riley, 2001; Yao, 1988). Although information problems pervade entrepreneurial capital markets (e.g., Dushnitsky and Shaver, 2009; Hochberg *et al*., 2007; Stuart *et al*., 1999), the efficacy of patents as a strategic solution to such problems was previously unclear. From an entrepreneur's perspective, understanding the causal linkages (if

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Table 5. Underpricing at IPO OLS regressions (within-IPO sample)

	Dependent variable = *% change in first-day stock price*		
	(5-1) Baseline	(5-2) Add VC prominence	(5-3) Main results
Main variables and interactions			
Patent application stock[a]	−0.045	−1.347***	−1.091**
	(0.092)	(0.520)	(0.489)
Not backed by prominent VC[a]	0.106	1.486***	1.157**
	(0.210)	(0.579)	(0.547)
Not backed by prominent VC × patent application stock[a]		−0.504***	−0.418**
		(0.198)	(0.186)
No prior IPO experience			2.177***
			(0.676)
No prior IPO experience × patent application stock			−0.737***
			(0.233)
Controls			
Prominent partner stock[a]	−0.192	−0.213	−0.150
	(0.147)	(0.141)	(0.133)
IPO underwriter rank[a]	0.730	0.534	0.496
	(0.465)	(0.450)	(0.418)
Silicon Valley location?	−0.210	−0.257	−0.266
	(0.211)	(0.202)	(0.191)
Start-up age	0.024	0.022	0.040
	(0.028)	(0.027)	(0.025)
Profitable phase of development	−0.275	−0.214	−0.207
	(0.212)	(0.204)	(0.191)
Start-up size[a]	−0.122	−0.091	0.014
	(0.141)	(0.135)	(0.131)
R&D intensity[a]	0.074	0.137	0.127
	(0.134)	(0.130)	(0.122)
IPOs in IT sector in exit year[a]	0.267***	0.234**	0.221**
	(0.102)	(0.098)	(0.091)
Constant	−1.266	2.553	1.140
	(1.270)	(1.931)	(1.854)
Adj. *R*-squared	0.117	0.198	0.309
Number of observations (firms)	65	65	65

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

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 is particularly important for new ventures—a gap this study helps fill.

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 start-ups 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; Gompers *et al*., 2010; Stuart *et al*., 1999). 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

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and firm-specific accomplishments can be used to shift resource trajectories (Ahuja, 2000; Hallen, 2008). From a strategic management perspective, such work is particularly important given the high costs associated with reputational leasing through prominent third-party affiliations (Arikan and Capron, 2010; Hsu, 2004).

Finally, a major strand of the entrepreneurship and organizations literature argues that founders leave an indelible mark on firms through the structures, policies, and culture they institute in the early period of new venture development (e.g., Burton, Sorensen, and Beckman, 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), we find that the ongoing accomplishments of new ventures are significant determinants of organizational outcomes.

Implications for theory

In investigating patents as a source of competitive advantage, we gain both conceptual and analytical traction by decoupling 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 Arikan (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. Directing attention instead to the *services* those resources render not only illuminates why and how resources are advantageous to firms but also casts brighter light on the origins of competitive advantage.

Importantly, our study further suggests that a common resource may provide distinctive services in different arenas for competition—a point that is underemphasized in the RBV literature. 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. Even if we assume—in the extreme—that patents provide *no* advantage in product markets, in the presence of informational imperfections 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. To illustrate this point, we concentrate our analysis on the role of patents in raising capital from prominent investors and on better financial terms, two sources of relative advantage in entrepreneurial capital markets. Prominent investors 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 start-ups access their financial capital are also important from a value capture standpoint: higher valuations at each private financing round and smaller changes in the share prices at IPO translate into more value captured by entrepreneurs.

Managerial and policy implications

Findings from our study have both managerial and policy implications. For entrepreneurs, our results show that patents serve an economically meaningful role as signaling devices to capital providers, thus contradicting prior claims that they fail to do so in information technology sectors (Heeley *et al*., 2007). If patents serve a singular role as isolating mechanisms in product markets, managers may postpone the filing of patents as long as possible to maximize the 20 years of legal protection (Mann, 2005). If there is a significant signaling component to patent resources, however, terms of trade in entrepreneurial capital markets could be negatively affected by such postponement.

Our findings further suggest that this latter signaling value of patents is particularly important for ventures without alternate means of conveying quality: those lacking successful prior start-up 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).

From a policy perspective, our study contributes to ongoing debate over the functioning of the U.S. patent system. Due in part to a proliferation of patenting in IT sectors, there is growing concern on whether the patent system is stifling innovative activity in key sectors of the economy. While aspects of the system may indeed warrant reform

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(see Cohen, 2010), our findings suggest that the ability to file and secure patent protection is economically important for young semiconductor device companies. It is therefore imperative that efforts to reform the U.S. patent system consider the ramifications on entrepreneurial firms and the financial markets that support them.

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 capital markets for firms in one sector. 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 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. Recent work by Hoenig and Henkel (2012) represents a laudable step in this direction. In addition, a host of team and founder contingencies may be interesting to explore. For example, some successful experienced founders may have other signaling options available, such as contributing their own capital to a venture. Conti, Thursby, and Rothaermel (forthcoming) explore such a context and compare a founder capital channel of signaling with a patent-based one. They find that patents signal value to VCs but founder funds do not; on the other hand, founder funds signal value to angel investors while patents do not.

In combination with Haeussler *et al*.'s (2009) findings, our study also 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 U.S. applications of sample start-ups that were rejected in the examination process, we were unable to fully examine this issue. It is unclear whether the U.S. context is an appropriate setting in which to examine tradeoffs between patent filings and awards as sources of information to investors. As noted earlier, the U.S. patent system is criticized for rubber stamping applications, with the vast majority of applications receiving patents (Lemley and Sampat, 2008). A more rigorous review system like that in Europe may offer a fruitful arena in which to explore these issues.

CONCLUSION

This study shows how a single resource type—entrepreneurial-firm patents—can provide dual sources of advantage as isolating mechanisms in product markets and as signaling devices in an earlier resource market where financial capital is sought and traded. 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 start-ups otherwise lacking credible means of conveying quality to investors. The study has important implications for empirical tests of resource-based theory and the measurement of resource value.

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APPENDIX A1. Variable descriptions 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)
Premoney valuation	Premoney valuation (*share price* × *shares outstanding prior to venture round*) in focal round	VentureOne; VenturXpert
Percentage 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 round one 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 start-up headquarters located in California's Silicon Valley region	VentureOne
Start-up age	Age of the start-up based on number of years since founding	VentureOne
Profitable phase of development	Dummy = 1 if start-up 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 (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
Start-up 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

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