Small Firms, Big Patents? Estimating Patent Value Using Data on Israeli Start-Up Firms' Financing Rounds

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ABSTRACT

This paper considers the impact of the intellectual property (IP) system on the market for entrepreneurial finance. If the market for entrepreneurial finance were efficient, investors' valuations of start-up firms should be independent of whether their patents' were pending or granted. However, during the pre-grant period, the need to disclose unprotected knowledge, asymmetric information and adverse selection could result in lower valuations. This study therefore estimates whether patent grant, which reduces uncertainty about the scope of the IP rights conferred, enhances start-up valuations by venture capitalists. Original panel data pertaining to 188 Israeli technological start-ups, who received more than 600 financing rounds, enter a fixed-effects analysis that controls for firms' unobserved heterogeneity. The results show a positive association between patent applications and firm valuations. The additional impact of granted patents is positive and significant for younger firms and during early financing rounds but small and insignificant for more mature start-ups. These findings suggest that, in the case of younger start-ups, uncertainty about patent scope, coupled with imperfections in the entrepreneurial finance market, adversely affect the relationship between entrepreneurs and investors. A more speedy examination process of younger firms' patent applications therefore could enhance their ability to attract financing.

1. Introduction

The ability of start-up firms to survive, grow, and commercialize their technology depends on their capacity to secure financing from external resource providers. In the absence of tangible assets, new ventures must provide credible signals about the quality of their innovations to potential investors. Yet imperfections in the market for entrepreneurial finance, which are particularly ubiquitous in the case of younger firms (Sahlman 1990; MacIntosh 1994; Amit et al. 1998), may prevent them from doing so. Entrepreneurs who fear the expropriation of their ideas by prospective investors may choose to limit their information disclosure, which can exacerbate asymmetric information and adverse selection problems. As a result, investments may shrink, and some investor–entrepreneur relationships may never form (Dushnitsky and Shaver 2009).

The availability of formal intellectual property right (IPR) protection may help reduce information asymmetries (Long 2002), but it is not a panacea for these problems. Patents are probabilistic property rights (Lemley and Shapiro 2005), and uncertainty continues to characterize them during their pending and pre-litigation periods. Recent empirical research indicates that most patent applications are granted in some form (Quillen and Webster 2001; Graham and Harhoff 2006), but significant uncertainty about the scope of the eventually granted patent rights persists throughout the pre-granting period, and the patent's ultimate enforceability becomes known only after it has been litigated.

These types of uncertainty have varying implications for asymmetric information. Uncertainty during the pre-grant period involves important information asymmetries between entrepreneurs and investors, whereas uncertainties about litigation are symmetric, such that neither party has an advantage in predicting final judgments (Gans et al. 2008). Therefore, in the presence of asymmetric information, mitigating uncertainty about the patent's ultimate scope,

which occurs once patents are granted, may induce information disclosure by entrepreneurs and enhance investors' estimates of the start-up's value. This study tests this hypothesis by estimating the difference in the impacts of granted patents and patent applications on venture capitalists' (VC) valuations of technological start-ups.

With their liquidity constraints, most start-up firms seek financing while their patents are still pending. In the absence of asymmetric information and adverse selection, uncertainty about patent scope will not affect investors' valuations of new ventures; each forward-looking investor appraises the start-up's IP according to its expected patent scope. Although some investors may over- or underestimate this scope, on average, there would be no observable difference in the value associated with pending patents compared with granted ones. However, in the presence of market imperfections, patent grants can make a difference. The conferral of formal IPR should reduce entrepreneurs' fears of expropriation and enhance their willingness to disclose complementary tacit knowledge to existing investors, as well as approach additional investors, such as corporate VCs and corporations in the same field. It can also reduce the transaction costs associated with the stipulation of binding nondisclosure agreements. The smaller overall information asymmetries between entrepreneurs and investors then should mitigate the problem of adverse selection and enhance investments and valuations.

Bridging the information gap with resource providers is particularly important for new ventures that seek to commercialize unproven technologies (Shane and Cable 2002; Shane and Stuart 2002). These companies suffer a disadvantage in terms of their reputation and bargaining power—alternative mechanisms for ensuring the protection of IPR. Therefore, the impact of patent grants and information disclosure should be even stronger among younger start-up firms.

To test whether granted patents, compared with patent applications, have a greater positive impact on start-up firms' valuations, I assembled data about the financing and patenting activities of 188 VC-backed Israeli technological start-ups founded between 1987 and 2005. These data contain information compiled through 2010 about the stock of patent applications, granted patents, venture financing, partnering, and exit histories. For all companies, I observe valuations across more than 600 financing rounds. By using panel data, I control for unobserved firm heterogeneity, which likely affects both patenting and valuations, and achieve a more accurate estimation of the different economic values associated with granted patents compared with patent applications.

Specifically, I find a large and significant effect of patent filings on investor estimates of start-up value. A doubling of a start-up's patent application stock is associated with a 45% increase in valuation, or an upward adjustment of roughly $3.2 million per patent application for the median start-up in the sample. Moreover, doubling the granted patent stock is associated with an additional 28% increase in valuation in the case of younger (less than six years) start-ups and during early financing rounds. This increase represents approximately $4 million per granted patent for the median start-up in an early financing round or $5.3 million for a start-up that has been in existence for less than six years. The additional positive value associated with granted patent applications dissipates in later financing rounds and as firms mature, such that in the overall sample, it does not differ from 0. These estimates are net of controls for time-invariant, unobserved start-up heterogeneity and alternative factors that could influence investor expectations, such as advances in product commercialization and affiliations with prominent corporations as alliance partners or equity investors.

The study therefore contributes to three literature streams. First, it extends research on the economic value of patents (Schankerman and Pakes 1986; Hall et al. 2005; Gambardella et al. 2008). Second, it adds to the handful of studies that relate start-ups' patenting to VC financing (Hsu and Ziedonis 2008; Haeussler et al. 2009; T. Hall 2006). Third, it contributes to literature on imperfections in the markets for technology and entrepreneurial finance and the role of IPR in such settings (Arora et al. 2001; Gans et al., 2008; Long 2002; Dushnitsky and Shaver 2004; Amit et al. 1998).

Previous studies that have estimated the impact of start-ups' patenting activities on investors' estimates of their value have used measures of granted patents or patent applications; they do not consider the possible impact of patent grants on uncertainty and thus on valuations. This article is the first to demonstrate the existence of this impact and estimate its magnitude in cases in which asymmetric information and adverse selection likely characterize the market for entrepreneurial finance. In turn, the results have important policy implications. Granting patent rights has an important positive impact on younger start-ups' valuations, which implies that long, variable grant lags can adversely affect their ability to attract funds. The allocation of supplementary resources to the review of younger companies' applications could reduce grant lags and mitigate market imperfections, which decrease early-stage investments. From a societal point of view, this shift in resources would increase the value created by patent-granting institutions.

I next discuss related literature on imperfections and signaling in the market for entrepreneurial finance, then develop and propose testable predictions about the role of patent grants in the presence of market frictions. After I describe the empirical design and data, I report my main findings. In the final sections, I discuss the study results and conclusions.

2. Literature and Theory Development

2.1. Information asymmetries in the market for entrepreneurial finance

New ventures generally form to develop and commercialize entrepreneurial innovations. The markets for technology and entrepreneurial finance thus are inherently characterized by information asymmetries (Arora et al. 2001; Gans et al. 2008; Dushnitsky and Shaver 2009; Amit et al. 1998), because entrepreneurs possess more information about the value of their innovations (Shane and Cable 2002; Shane and Stuart 2002). Discerning the value and commercial promise of new technologies in the presence of asymmetric information is challenging for investors. The difficulty of distinguishing between high- and poor-quality projects can result in adverse selection, such that the market becomes crowded with low-quality projects (Akerlof 1970). Accordingly, potential investors tend to be wary of funding new entrepreneurial endeavors (Amit et al. 1998).

2.2. Information disclosure as a signaling mechanism

A natural market response to adverse selection is signaling (Spence 1973), such that the informed party provides some signal of its quality. The disclosure of technical details can provide an effective signaling mechanism (Bhattacharya and Ritter 1983; Anton and Yao 2002), but many entrepreneurs prefer not to disclose, because they fear the expropriation of their technical ideas by potential investors, especially corporations and VCs with proprietary interests in similar ventures. According to RedHerring magazine (1999), one of the questions most frequently asked by entrepreneurs is, “When I approach a venture capitalist, how can I protect my idea?” The magazine also cautions entrepreneurs to “pore through a VC firm’s website to determine if it has a similar investment,” because if the VCs’ existing portfolio contains companies that develop similar products, the entrepreneur should be on guard for potential

malfeasant behavior (Promod Haque of Norwest Venture Partners, quoted in Red Herring, 1999). Siegel et al. (1988) report that fears of their ideas being stolen remains an important obstacle for entrepreneurs to obtain investments—fears that are not unfounded. In 2005, Toshiba illegally transferred trade secrets from Lexar Media, a start-up in its corporate VC portfolio, to a rival start-up. The dispute resulted in a massive intellectual property award of almost $500 million in damages (Strasburg 2005). In 2002, the Israeli semiconductor start-up Saifun sued AMD and Fujitsu for wrongfully incorporating information about its flash memory technology, provided in confidence, into patent applications in the United States and other countries. The legal settlement obliged AMD and Fujitsu to acquire 5% of Saifun's equity, based on a pre-money valuation of half a billion dollars.

Dushnitsky and Shaver (2009) thus point to a paradox of corporate VC: Many profitable investment relationships never form because the corporation is not interested in investing unless entrepreneurs demonstrate their quality by disclosing details about their innovations. Disclosure, however, can be prohibitively costly for the entrepreneur, because the investor can exploit disclosed information and imitate the innovation, leaving the entrepreneur empty-handed.[1]

2.3. Patents as quality signals

Patents conform to Spence's (1973) conceptualization of a signal: They are costly to obtain and, through the government certification process, provide a mechanism for sorting by quality (Hsu and Ziedonis 2008). They also have intrinsic value in the form of property rights. Patent applications should provide protection against the misappropriation of ideas disclosed in

[1] In a recent article in *The Marker* (July 29, 2010), Israel's leading financial newspaper, interviews with Microsoft, Hewlett-Packard, EMC, and Cisco about start-ups' perceived risks of cooperating with large firms generally revealed that such fears are most common among younger entrepreneurs. One interviewee said that he tells entrepreneurs not to disclose details in their patent applications if they are reluctant to do so.

the course of negotiations with investors and potentially induce additional information disclosure.

The handful of studies that examine the relationship between patenting and VC financing indicate a positive and significant link. Hall and Ziedonis (2001) interview players in the high-tech sector, who cite patent applications as high on the list of questions asked by prospective VC investors. Haeussler et al. (2009) show that patent applications, especially those of high quality, speed the arrival of VC financing for British and German biotechnology start-ups. They also find that patent opposition increases the likelihood of financing, but ultimate grant decisions do not spur financing. Hsu (2004) finds that a lack of patents reduces a start-up's pre-money valuation by 17% to 20%. Cockburn and MacGarvie (2007) confirm that patent applications significantly raise the probability that a firm obtains initial funding. In their examination of software firms that received their first financing round during 1997, 1998 or 1999, Mann and Sager (2007) count patents granted before December 2004 and relate them to the total investment received before January 2005; they find that having patents relates significantly to the firm's progress in terms of the number of financing rounds, longevity, and total investment (the size of the patent portfolio does not seem to matter).

In T. Hall's (2006) interviews of 351 managers of technological start-ups that received their seed round funding between 1998 and 2001, he finds that approximately 30% of the companies in his sample had "useful" patents and another 10% had patents that were not considered useful. With a regression analysis, he also shows that the presence of patents does not significantly enhance valuation: Controlling for usefulness, the coefficient on patent possession is negative and significant in various specifications. Yet the usefulness of patents is robustly and positively related to valuation and the amount raised, especially for expansion-stage firms.

Perhaps firms with patents but not useful patents wasted their resources on technologies that did not help their prospects, resulting in lower valuations and less money raised.

In Hsu and Ziedonis's (2008) fixed-effects regression analysis of 813 financing rounds by 269 U.S. semiconductor firms, doubling a company's patent application stock was associated with a 28% increase in pre-money valuations, or $2.3 million per patent in 2008 prices. They also find that the signaling value of patents is greater in earlier financing rounds.

2.4. Uncertainty about property rights

The positive association between patents and firm value is unsurprising, though it also seems plausible that the precise impact of patents on valuations depends on their degree of noise as signals, the scope of IPR protection they provide, and their ability to induce information disclosures. These attributes of patents change as a function of their status as pending, granted, or litigated. Because only a small fraction of patents are ever litigated (Lanjouw and Schankerman 2001), I note the difference in value associated with granted versus pending patent applications.

Patent applications contain claims about the subject matter that the applicant regards as innovative and define the scope of the patent protection. During the application's examination process, the patent examiner may, and often does, reject claims on the basis of prior patents or publications not found in the preliminary search conducted by the applicant (see the U.S. Patent and Trademark Office [USPTO] Web site). The number of claims ultimately allowed is therefore likely to vary between patent applications and granted patents. Yet many analyses implicitly assume that once applied for, patents are granted and enforced. In reality, both the grant of IPR and investment decisions take place over time.

According to Gans et al. (2008), when a U.S. patent is licensed, that licensing takes place largely within a narrow time span around the date of the grant of the patent by the USPTO.

Controlling for several factors, they argue that this focus reflects reduced uncertainty and asymmetric information about the extent of the property right. On the date of the grant, both parties know which claims appear in the patent and whether it has been granted. Licensing occurs near the date of grant, because prior to that point, the applicant has no property right to sell. However, the trade may take place earlier, at an appropriate discount that accounts for the probability the patent will be granted or for the expected number of claims. Because this information is asymmetric, the buyer may ask for a premium in the form of a discount, which induces the supplier to prefer to conclude the deal after the grant.

Yet start-ups, which tend to be liquidity constrained, cannot await patent grants before seeking financing. In the absence of market frictions, uncertainty about patent scope would not influence investors' estimates of the value of patent applications, because each forward-looking investor would estimate a venture's value based on the expected IPR scope. However, in the presence of market frictions, patent grants should make a difference. Similar to a licensor–licensee relationship, entrepreneur–investor links are characterized by asymmetric information. Before they know the extent of their property rights, entrepreneurs may be reluctant to disclose complementary, unpatentable knowledge to potential investors, in particular Corporate Venture Capitalists (CVCs) and companies operating in the same field. That is, "While it may be difficult to predict the impact of unpatentable knowledge disclosure during the pre-grant period, start-up innovators may be able to tailor their disclosures to avoid expropriation in the event of bargaining breakdown once the scope of rights is clarified. For example, prior to patent grant, nondisclosure agreements with potential partners may be difficult (if not impossible) to write with any degree of precision or potential for enforcement; after a patent is granted, the costs and complexity of such contracts may decrease significantly" (Gans et al. 2008, p. 987).

Therefore, pending patent applications, compared with granted patents, entail several types of uncertainty. First, they are noisy signals about innovation quality, because they have not undergone examination to determine their novelty. Second, there are no property rights attached to them. Third, the scope of IPR protection that they provide is uncertain. These factors alone would not result in different valuations of pending and granted patents by investors, because VCs specialize in assigning values to new ventures and are often assisted by patent attorneys who can determine the merit of pending patent applications. But because the relationship between investors and entrepreneurs is characterized by asymmetric information, high-quality entrepreneurs with greater fears of expropriation likely restrict, more so than lower quality entrepreneurs, their disclosure of tacit information about their innovations before their patent is granted. Investors then cannot form correct expectations, resulting in adverse selection and lower overall valuations. Patent rights mitigate uncertainty about the scope of patent protection and should induce information disclosure by high-quality entrepreneurs that enables them to signal their quality; in turn, adverse selection declines, and overall valuations increase.

As Gans et al. (2008) show, patent grants should increase start-ups' ability to commercialize their technology, because they reduce information asymmetries and transaction costs in the markets for technology. This effect can reinforce the impact of patent grants on VCs' valuations, because demonstrated success in product commercialization is an important determinant for their assessments of new ventures.

In summary, patent grants matter to the extent that the mitigation of uncertainty about patent scope induces further information disclosure by entrepreneurs and reduces asymmetric information and adverse selection in the markets for technology and entrepreneurial finance. Therefore, I predict:

Hypothesis 1: In the presence of asymmetric information, granted patents have an additional positive impact on investors' estimates of start-ups' values compared with patent applications.

Problems of asymmetric information and adverse selection are generally more acute for younger companies. Nascent firms suffer greater technical and demand uncertainties, which make evaluations by investors more difficult. The issue becomes even more serious to the extent that new firms possess new technologies, because innovators' ability to provide a credible quality signal to investors could enhance their start-ups' valuations. In the early stages of idea development though, the risks of expropriation are greatest, and entrepreneurs' ability to protect their IPR are at their weakest. Younger start-ups cannot rely on alternative mechanisms, such as greater bargaining power or the threat of reputational damage, which exists once the company is embedded in a larger social network, to protect their IPR. Therefore, prior to being granted a patent, younger start-ups' strategy likely consists of limited information disclosure, resulting in adverse selection—a major concern in the early stages, before the start-up has established a reputation or begun to commercialize its innovation (Gompers 1995).

The greater asymmetric information and adverse selection for younger start-ups, coupled with their limited capacity to protect their IPR by other means, implies that patent grants are particularly instrumental for these companies. By inducing more information disclosure, these grants also enhance younger start-ups' ability to provide an accurate quality signal to investors, which is critical for attracting more funds by firms without any performance track record. In combination, these arguments suggest the following:

Hypothesis 2: The additional value of granted patents is greater for younger or less experienced start-ups relative to their more mature counterparts.

Moreover, information asymmetry is a lesser problem for more mature start-ups. Having a proven track record and a commercialized product greatly reduces the threat of technology expropriation. Furthermore, as ventures develop, they can acquire alternative mechanisms to mitigate the threat of expropriation. For example, by being embedded in a larger social network (Coleman 1990), a firm can restrain opportunistic behaviors by others through the threat of reputational damage (Hsu and Ziedonis 2008). The disclosure of complementary tacit information also should not be prohibitively costly for mature start-ups, because investors are unlikely to exploit the information or imitate their innovations.

Therefore, I predict that mature start-ups are more likely to provide fairly complete information about their innovations during the early stages of the patent application process; in their case, the benefits of providing more accurate quality signals to investors outweigh the costs. Asymmetric information and adverse selection can be mitigated by patent applications, and patent grants, which spur no further information disclosures, should not make a difference to their valuations. Accordingly, I propose:

Hypothesis 3: In the case of more mature start-ups, granted patents have no additional value compared with patent applications.

3. Empirical Analysis

3.1. Data and methodology

The Israeli entrepreneurial community offers several advantages for the purposes of this study. Israel has experienced tremendous growth in technological entrepreneurship in the past two decades, with more companies on the technology-oriented NASDAQ stock exchange than any country other than the United States. It has attracted, per capita, more than twice as much venture capital investment as the United States and 30 times more than Europe (Senor and Singer

2009). This small, open economy consists of a fairly homogenous investment climate and an abundance of young start-ups that compete for financing. The new ventures' ability to secure resources largely depends on the professional capabilities of their founders and the quality of their difficult-to-value, intangible assets.

The Israel Venture Capital (IVC) online database contains information about approximately 6,000 Israeli technological start-ups, most of which were founded in the past 20 years. The information in the database has been disclosed by the companies or their investors on a voluntary basis and includes details about each company's technology, date of establishment, founders, investors, stage of development, number of financing rounds, total investment per round, exit status, eventual fate (i.e., ongoing, ceased to exist, had an initial public offering [IPO], merged, or was acquired), pre-money valuations, and acquisition amounts.

Of the companies listed in the IVC, 1,409 were backed by VCs. To obtain the panel data required for this study, I collected information about all companies that had at least two rounds of financing or a round of financing and an exit round prior to March 2010. Not all information was available for each company; therefore, I collected data about 369 companies in six technological sectors: semiconductors, communications, life sciences, cleantech, IT & enterprise software, and Internet. These heterogeneous sectors differ in their patenting behavior, so I separated them into two broad technological groups: software-based (Internet, communications software, IT & enterprise software) and non–software-based (semiconductors, communications infrastructure, life sciences, and cleantech). The option to apply for software patents is fairly recent, dating back only to the late 1990s. The software industry traditionally relied on copyright and trade secrets to protect its intellectual property, such that the sample software companies' propensity to patent was only 56%, compared with the much higher propensity to patent of 84%

in the non-software group. In my analysis, I found patents had no significant impact on VCs' valuations of software start-ups; this issue will be addressed in another comparative study. For this article, I focus solely on non-software companies.

The sample includes 188 Israeli technological companies established between 1987 and 2005, which underwent a total of 604 financing or exit rounds in the past 17 years. The sample firms collectively submitted 2,816 patent applications, of which 1,075 were granted prior to exit through an IPO or acquisition or a final VC financing round before March 2010.

The use of panel data in this setting is particularly important. Start-ups valuations often depend on unobserved characteristics related to founders' abilities and specific product attributes. These features likely correlate with the patents variable, and their omission could bias the results. By using panel data in a fixed-effects regression analysis, I control for time-invariant unobserved firm heterogeneity and provide more accurate estimates of the patents' impact on valuations.

The main set of regressions serves to estimate the effect of companies' stocks of patent applications and granted patents on their valuations by VCs, across financing and exit rounds, when I hold the unobservable time-invariant effects constant through start-up fixed effects (γ_i). Thus, I estimate the following equation for firm *i* in funding round *t*:

$$\log(valuation)_{it} = \beta_0 + \gamma_i + \beta_1 \log(1+\text{patent applications})_{it} + \beta_2 \log(1+\text{patents granted})_{it} + \beta_3 (\text{age})_{it} + \beta_4 (\text{company stage})_{it} + \beta_5 (\text{round type})_{it} + \beta_6 \log(1+\text{prominent partners}) + \beta_7 (\text{funding year})_{it} + \varepsilon_{it} \quad (1)$$

Using this framework, I can test H1 by determining if $\beta_2 > 0$. For H2, I test whether $\beta_{2a} > \beta_{2b}$ in the following regression:

$$\log(valuation)_{it} = \beta_0 + \gamma_i + \beta_{1a}\log(1+\text{patent applications})_{it} \times Young + \beta_{1a}\log(1+\text{patent applications})_{it} \times Old + \beta_{2a}\log(1+\text{patents granted})_{it} \times Young + \beta_{2b}\log(1+\text{patents granted})_{it} \times Old + \beta_3(\text{age})_{it} + \beta_4(\text{company stage})_{it} + \beta_5(\text{round type})_{it} + \beta_6\log(1+\text{prominent partners}) + \beta_7(\text{funding year})_{it} + \varepsilon_{it} \quad (2)$$

Finally, for H3, which predicts that granted patents have no supplementary value for older firms, I estimate whether $\beta_{2b} = 0$ in Equation 2. By including patent applications and granted patents separately as explanatory variables in these regressions, I can control for firms' overall degree of innovativeness, as represented by their entire stock of patent applications, and correctly estimate the supplementary value created by granted patents.

3.2. Variables

The key dependent variable is pre-money valuation, which reflects the product of the share price before the funding round multiplied by the number of outstanding shares of firms. This estimate of the aggregate value of the firm provides a basis for calculating the equity stake for a given cash infusion by VCs. When the financing round investigated is an acquisition round, I use the acquisition amount. The valuation data come from the IVC database.

The independent variables consist of several categories. The data about companies was hand-matched with data about patent applications and grants from the USPTO online database, which contains information about all patents granted in the past 200 years and published patent applications since 2001. The USPTO grant rate is estimated to be approximately 90% (Quillen and Webster 2001), because the United States is unique in permitting patent applicants to refile continuation and continuation-in-part applications to claim the benefit of the filing date of the initial application, then restart the examination process. Quillen and Webster's (2001) analysis of the data for continuing applications to the USPTO during fiscal years 1993–1998, in conjunction with the USPTO Annual Report statistics for the same fiscal years, shows that the number of

utility, plant, and reissue (UPR) applications allowed in 1995–1998 equaled 95% of the number of original UPR applications filed in 1993–1996. Therefore, I assume there are not many missing patent application observations dated prior to 2001, because it is likely they were granted, in some scope, by the time I collected the patent data in 2010.

The coding of a set of round-type and company-stage dummies from the IVC database proceeded as follows: The *Early Financing Round* dummy equals 1 if a funding round is a seed, a first, or a second financing round. The *Acquisition/Merger Round* and *IPO Round* dummies indicated exit rounds in which the company was acquired or merged or had an IPO. Four dummies revealed different stages of progress in product development: *Seed*, *R&D*, *Initial Revenues*, and *Revenue Growth*. The company's age at the time of the financing round helps control for firm maturity.

To measure new ventures' affiliation with prominent third parties, I constructed the *prominent partner stock* variable, a cumulative count (up to the funding round) of commercially prominent alliance partners or corporate equity partners. Data about corporate equity partners also came from the IVC database. The information about the other types of alliances was gathered through an Internet search of press articles about the companies in the sample. For the purposes of this study, a strategic alliance is either an Original Manufacturer Agreement (OEM) or an R&D agreement to develop a product jointly. A partner is prominent if it operates in a similar sector as the start-up (determined by its North American industrial classification code, taken from the Gale Business & Company Resource Center database) and is among the top 50 world leaders in this sector in terms of annual revenues.[2] Finally, I included year dummies for

[2] In the case of semiconductors, information about leading manufacturers was cross-referenced with information from iSuppli Corporation and Gartner Dataquest Corp. In the case of medical device manufacturers, the data from Gale Business & Company Resource Center were cross-referenced with data from *Medical Product Outsourcing Magazine*.

each year in which a financing round took place. In Table 1, I summarize information about the variables used in the round-level regressions, and in Table 2, I report the bivariate correlations.

-----Insert Tables 1 and 2 about here-----

The distribution of valuations is very skewed, with a few high values and a large difference between the valuations' mean and median. In Figure 1, I plot the density function of valuations, excluding the highest 12 observations, which are greater $500 million.

-----Insert Figure 1 about here-----

4. Results and Discussion

The results of the multivariate regression analysis to test H1 appear in Table 3. I use a translog functional form, with both the dependent variable and continuous independent variables specified in natural logs, considering the right-skewed distributions associated with these variables. This specification uses the funding round as the unit of analysis and includes start-up fixed effects. Therefore, my approach reduces the risk that unobserved, time-invariant differences across firms, which likely correlate with the independent variables, bias the empirical results.

-----Insert Table 3 about here-----

The results show a positive and significant association between patent applications and valuations. In the first regression, the doubling of patent application stock is associated with a 45% increase in valuation. Considering the highly skewed distribution of the valuations, I use this coefficient to estimate the monetary impact of a single patent application on the median, rather than the mean, valuation, using the moments of the log-normal distribution. It is equal to $3.2 million.

The coefficients of the control variables are as expected. The coefficients for the *R&D*, *Initial Revenues*, and *Revenue Growth* stages are positive and significant compared with the omitted category, that is, the *Seed* stage. The valuations assigned to start-ups during the *Early Financing Rounds* are lower than those in *Late Financing Rounds* (omitted category), whereas those at the time of the *IPO* are higher. The coefficient for *Acquisition/Merger Round* is not significant, as expected, because an *IPO* is clearly a positive liquidity event, whereas an acquisition or a merger might indicate either success or failure. Alliances or investments by prominent corporate entities have positive and significant impacts on valuations. For granted patents, the results show that, after controlling for patent applications, granted patents do not add to valuations, which indicates no support for H1.

In Table 4, I present the results of four regressions designed to test H2 and H3, according to which granted patents are more important to younger firms and less important to mature start-ups. The dummies *Young* and *Old* indicate firms below and above a certain age threshold. I used different age thresholds, starting with six years and ending with nine years. The average grant lag in the sample is 3.5 years, so there are very few observations of companies younger than six years with any granted patents.

-----Insert Table 4 about here-----

The results in Table 4 show that for younger firms, granted patents play an important role in attracting finance, beyond that of total patent applications, but this role becomes muted as companies mature. The coefficient for the log of patent application stock is positive and significant for all companies in the sample, but the coefficient for granted patent stock is positive and significant only for young companies that have been operational for less than six or seven years. In contrast, this value is small and not significantly different from 0 for older firms. The

coefficients equal the estimated elasticities of valuations with respect to patents, so the value associated with a single patent for a certain group of companies depends on the average number of patents per company in that group. The higher coefficients on patent applications in the older group, compared with the younger group, do not indicate a higher impact per application, because more mature companies have more patent applications than their younger counterparts.

In Table 5, I convert estimated elasticities that are significantly different from 0 into the percentage and monetary impacts of a single patent application or granted patent on the median valuation in each group of companies.

-----Insert Table 5 about here-----

The results highlight several findings. First, the additional value associated with granted patents is substantial for younger companies, but it diminishes with age. Second, in general, there are decreasing marginal returns to patenting as firms age. Third and in support of H3, mature start-ups appear to disclose information about their innovations early in the patent application process, such that the entire signaling value of their patents is embodied in their applications. For younger start-ups though, the signaling value is split between the applications and granted patents, and the part attributed to granted patents is greater for the youngest firms and diminishes as firms age.

These empirical results also appear consistent with hypotheses that do not assume asymmetric information between entrepreneurs and investors. That is, assuming only symmetric uncertainty about the quality of the innovation while the patent is pending that gets mitigated at the time of grant, I would obtain similar results, as long as there is greater uncertainty about the patent applications of less mature companies.

When evaluating projects during the pregrant period, investors could make both Type I and Type II errors. Thus there is a probability, between 0 and 1, that investors fail to provide

adequate financial support to a good project and provide excessive financial support to a bad project. After the patent is granted, additional information about the quality of the project gets revealed, which decreases the probabilities of committing both Type I and Type II errors. The greater the decrease in these probabilities, the greater the value created by the patent grant. In the case of younger companies, which possess more novel and unproven technologies and lack an established track record, investors run a higher risk of committing both types of errors before patents are granted. Therefore, the grant should make more of a difference, as predicted in H2. However, if in the case of older companies, investors have enough information during the pregrant period to determine their preferred level of support for projects, the information revealed by the patent grant does not minimize the risks of committing errors any further, so the patent grant should not make a difference, as predicted in H3. In summary, the difference in the value of granted versus pending patents is greater for younger firms than for older ones, because the probability of committing Type I or Type II errors declines more for younger firms than for older ones at the moment of the grant. This effect reflects that investors have less experience working with younger firms, so at the margin, grants are more informative for them.

Although this explanation is consistent with the empirical results, I assert that there is more support for the asymmetric information hypothesis. First, asymmetric information in the market for entrepreneurial finance has been widely discussed (Sahlman 1990; MacIntosh 1994; Amit et al. 1998, Dushnitsky and Shaver 2009, Hsu and Ziedonis 2008). Second, the risk of misappropriation, or at least this *perceived* risk, appears evident, particularly when investors are CVCs or corporations. In the case of younger firms, grants not only spur information disclosures to existing investors but also encourage entrepreneurs to approach additional sources of investment. The more investors they approach, the larger is the probability of that they can

obtain investments and higher valuations. In contrast, the symmetric information case requires some assumptions about VCs' decision-making processes, which are difficult to verify. Nonetheless, it is possible that these results are driven by both types of information uncertainty.

The empirical findings might also risk being attributed to an attrition bias, such that firms that fail to gain a patent with a wide scope drop out of the sample before they reach the later financing rounds. In such circumstances, the comparison would be between "good" companies with granted patents and "bad" companies with pending ones. However, in the study sample, only 8 of the 188 firms ceased to exist before they reached a later or an exit round, and therefore, attrition bias does not seem to constitute an important problem for this study.

Another potential drawback to the preceding analysis entails endogeneity, such that higher valuations and investments may result in more patent applications and grants. However, endogeneity is unlikely to constitute a serious problem. Each patent application, particularly for the industries included in this sample, results from a lengthy R&D process that precedes the patent application by a few years. Therefore, a contemporaneous impact of valuations on the cumulative stock of patent applications can be excluded. It remains possible that previous valuations influence patent applications, which in turn affect present valuations. An Arellano-Bond estimation, with lagged valuation as an additional explanatory variable, shows though that the coefficient of patent applications remains positive and significant in this specification as well, such that the impact of patent applications on valuations appears supplementary to that of lagged valuation.[3] Regarding the different impacts of pending and granted patents, the USPTO's

[3] The Arellano-Bond estimation requires at least three observations per firm, so the sample size declined to 228 observations of 121 firms. The coefficient of patent applications remained positive and significant, but the coefficient of granted patents was not significant for any subgroup of firms. Lagged valuation and some of the control variables also were not significant in this specification, which might be related to the small sample size.

examination process is independent of the assignee's identity, and therefore, companies with greater resources cannot influence the length of the examination process or the grant decision.

5. Robustness Checks

To test the predictions of H2 and H3, I estimated two additional regressions. In the first (see Table 6), I used the interaction terms of the logs of applications and granted patents with dummies that indicated *Early Round* or *Late/Exit Rounds* of financing. In the second regression (see Table 7), I used the interaction terms between the logs of patent applications and granted patents and dummies indicating the companies' *Pre-Revenue Stage* (i.e., *Seed* or *R&D*) and *Revenue Stage* (i.e., *Initial Revenues* or *Revenue Growth*). Firms in early financing rounds or in the pre-commercialization stage of their product development should exhibit greater reluctance to disclose information to potential investors during the pre-grant period. Similar to younger companies, I expect patent grants to have a considerable impact on the valuations of these firms.

-----Insert Tables 6 and 7 about here-----

In Table 8, I provide the transformation of the regression coefficients to monetary and percentage impacts of patents on valuations for the different groups.

-----Insert Tables 8 about here-----

The results of these two regressions confirm my predictions that granted patents have an additional impact for firms in their pre-commercialization stage and in early financing rounds. The overall value of patents as signals to investors decreases as firms reach the commercialization stage or late/exit rounds, similar to the distinction between young and old firms. The results also show, in a more pronounced fashion, that the patents' value is skewed toward granted patents during the early stages, whereas in later stages, it is entirely captured by patent applications.

For further robustness checks, I regressed the log of valuations on a set of dummy variables that indicated different numbers of applications and granted patents (instead of the logs of cumulative applications or granted patents stocks), interacted with young/old, early/late-exit rounds, and pre-revenue/revenue stage dummies. The control variables were the same as those in the translog specification. The results of the dummies' regression confirmed that granted patents offered supplementary value only for younger companies, during early rounds, and in pre-commercialization stages. Furthermore, the value associated with patents, in the case of younger firms, can be attributed mostly to granted patents, whereas in the case of older firms, the entire value was associated with patent applications.

6. Conclusion

This study provides new evidence that granting patents can positively affect investors' perceptions of firm value for early-stage start-ups. This finding is consistent with the view that the mitigation of uncertainty about the scope of IPR protection enhances information disclosure by entrepreneurs and reduces asymmetric information and adverse selection in the market for entrepreneurial finance (e.g., Arrow 1962; Amit et al. 1998). Patent grants are significant only for young ventures and during early financing rounds, in support of the conjecture that formal IPR is more important to firms that lack other mechanisms to prevent the expropriation of their ideas, such as reputation, bargaining power, or network effects. These mechanisms become more available to firms as they mature and establish proven track records. Gans et al. (2008) find that patent grants are instrumental in shaping start-ups' commercialization strategy. This study provides the first direct evidence that patent grants also influence start-ups' ability to obtain financing from external resource providers.

Although asymmetric information and adverse selection have been discussed in prior literature and supported in certain real-life cases, they are not strict prerequisites for obtaining the empirical results presented herein. As previously mentioned, reducing symmetric uncertainty about the quality of innovations, which occurs at the time of grant, could yield the same results, with certain assumptions.

This study's findings are important from a policy perspective. The long, variable grant lags that currently characterize the U.S. patenting system adversely affect young start-ups' financial trajectory and result in suboptimal allocations of funds by investors. The dedication of additional examiners' time to review younger companies' applications could reduce these grant lags and mitigate the market imperfections that decrease early-stage investments. As a result, high-quality young firms would be able to attract additional investments, crucial for their product development. From a societal point of view, this shift would lead to efficiency gains and an increase in the overall value created by patent-granting institutions.

Further research could assess the impact of patent grants in more detail using a difference-in-differences analysis of firms' valuations as their pending patents get granted over time. Additional data from other patent-granting institutions, such as the European Patent Office with its lower grant rates, might be used to estimate whether the added value created by patent grants relates to the institution's perceived level of selectivity. Finally, research about firms' combined patenting and information disclosure strategies might support conjectures about whether patent grants are instrumental for reducing asymmetric information and adverse selection in the market for entrepreneurial finance.

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Table 1. Summary Statistics and Variable Definitions

VARIABLE	DEFINITION	MEAN	STD. DEV
Pre-money valutaion	VC pre-money valuation (share price*shares outstanding prior to venture round) of the focal round	58.7	209.6
Patent Applications	Cumulative patent application stock at the time of the funding round	4.52	9.6
Patents Granted	Cumulative patent stock at the time of the funding round	1.7	5.8
Start-up age at time of VC round	Age of the start-up in year at the timE of the VC funding round	5	3.7
Early stage round	Dummy=1 if funding round is classified as Seed, 1st of 2nd round	0.58	0.49
Late stage round	Dummy=1 if funding round is classified as 3rd round or above	0.23	0.42
Acquisition/merger round	Dummy=1 if the focal funding round involved an acquisition/merger	0.11	0.31
IPO round	Dummy=1 if the venture achieved an initial public offering	0.08	0.27
Seed stage	Dummy=1 if the venture is in its early days of product development and fund raising	0.11	0.31
R&D stage	Dummy=1 if the venture is discovering new knowledge and applying it to create new and improved products that fill market needs	0.52	0.50
Initial revenues stage	Dummy=1 if the venture has revenues which do not exceed $10 million dollars	0.24	0.43
Revenue growth stage	Dummy=1 if the venture has revenues which exceed $10 million dollars and a double digit yearly growth rate	0.13	0.34
Prominent Partners	Cumulative count of commercially prominent strategic alliace or corporate equity partners at the time of the financing round	0.57	1.00
Funding year controls	A dummy=1 for each of the years when the financing round occurred between 1993 and 2010		

Table 2. Bivariate Correlations

	Valuation	Patent Applications	Patents Granted	Seed Stage	R&D Stage	Initial Revenue Stage	Revenue Growth Stage	Early Financing Round	Late Financing Round	Acquisition/Merger Round	IPO Round	Prominent Partners	Age
Valuation	1												
Patent Applications	0.1643*	1											
Patents Granted	0.1238*	0.8920*	1										
Seed Stage	-0.0866*	-0.1556*	-0.1054*	1									
R&D Stage	-0.0075	-0.1744*	-0.1861*	-0.3561*	1								
Initial Revenue Stage	-0.036	0.0368	0.0232	-0.1984*	-0.5892*	1							
Revenue Growth Stage	0.1369*	0.3543*	0.3434*	-0.1340*	-0.3978*	-0.2216*	1						
Early Financing Round	-0.1881*	-0.3314*	-0.2641*	0.3028*	0.3671*	-0.3161*	-0.4127*	1					
Late Financing Round	0.0008	0.1890*	0.0800*	-0.1896*	-0.1249*	0.2213*	0.0788	-0.6262*	1				
Acquisition/Merger Round	0.1777*	0.0958*	0.1531*	-0.1230*	-0.2085*	0.1356*	0.2507*	-0.4062*	-0.1945*	1			
IPO Round	0.1424*	0.1916*	0.1678*	-0.1015*	-0.2036*	0.0161	0.3584*	-0.3351*	-0.1604*	-0.1041*	1		
Prominent Partners	0.1861*	0.2914*	0.2323*	-0.1767*	-0.1139*	0.0413	0.2765*	-0.3097*	0.1985*	0.1438*	0.0659	1	
Age	0.0681	0.3490*	0.3872*	-0.3892*	-0.2870*	0.2983*	0.4001*	-0.6050*	0.2833*	0.3248*	0.2548*	0.1894*	1

* Indicates statistical significance at the 5% level.

Table 3. Valuation Fixed-Effects Ordinary Least Squares Regression

Independent Variables	Dependent Variable: Log Valuation
Log Patent Applications	0.468***
	(0.10)
Log Patents Granted	0.134
	(0.10)
R&D	1.017***
	(0.14)
Initial Revenues	1.106***
	(0.21)
Revenue Growth	1.026***
	(0.27)
Early Round	-0.356**
	(0.14)
Acquision/Merger Round	0.119
	(0.16)
IPO Round	0.691***
	(0.20)
Log Prominent Partner	0.494***
	(0.16)
Age	-0.0798
	(0.14)
Year Dummies	Yes
Constant	1.820**
	(0.91)
Observations	604
R-squared	0.44
Number of id	188

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Valuation Fixed-Effects Ordinary Least Squares Regression

Independent Variable	Dependent Variable: Log Valuation			
	cutoff age 6	cutoff age 7	cutoff age 8	cutoff age 9
Log Patent Applications*Young	0.425***	0.426***	0.450***	0.441***
	(0.11)	(0.11)	(0.10)	(0.10)
Log Patents Granted*Young	0.308**	0.255**	0.161	0.159
	(0.15)	(0.13)	(0.12)	(0.11)
Log Patent Applications*Old	0.498***	0.561***	0.553***	0.763***
	(0.14)	(0.17)	(0.19)	(0.23)
Log Patents Granted*Old	0.071	-0.00161	0.0128	-0.221
	(0.16)	(0.20)	(0.23)	(0.28)
R&D	1.025***	1.034***	1.030***	1.041***
	(0.15)	(0.15)	(0.15)	(0.15)
Initial Revenues	1.106***	1.121***	1.120***	1.127***
	(0.21)	(0.21)	(0.21)	(0.21)
Revenue Growth	1.061***	1.058***	1.053***	1.074***
	(0.28)	(0.28)	(0.28)	(0.28)
Early Round	-0.353**	-0.355**	-0.364***	-0.364***
	(0.14)	(0.14)	(0.14)	(0.14)
Acquision/Merger Round	0.109	0.112	0.109	0.11
	(0.17)	(0.17)	(0.17)	(0.16)
IPO Round	0.709***	0.698***	0.715***	0.700***
	(0.20)	(0.20)	(0.20)	(0.20)
Log Prominent Partner	0.522***	0.516***	0.502***	0.495***
	(0.16)	(0.16)	(0.16)	(0.16)
Age	-0.0964	-0.0908	-0.0832	-0.0816
	(0.15)	(0.15)	(0.15)	(0.15)
Year Dummies	Yes	Yes	Yes	Yes
Constant	1.362	1.42	1.431	1.443
	(0.92)	(0.92)	(0.92)	(0.92)
Observations	604	604	604	604
Number of id	188	188	188	188
R-squared	0.472	0.472	0.469	0.471

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5. Estimated Impact of Patents on Old and Young Companies

	coeff on applications	coeff on granted	median applications	median granted	median valuation (in 2008 prices)	value of application as percent of valuation	value of granted as percent of valuation	value per application (millions USD)	value per granted (millions USD)
young under 6	0.43	0.31	2.3	1.2	22.4	19%	26%	4.2	5.8
young under 7	0.43	0.26	2.4	1.3	23.4	18%	20%	4.1	4.8
young under 8	0.45	not sig	2.5	1.3	20.4	18%	-	3.6	-
young under 9	0.44	not sig	2.7	1.4	21.0	17%	-	3.5	-
old over 6	0.50	not sig	5.7	3.3	36.6	9%	-	3.2	-
old over 7	0.56	not sig	6.3	3.8	37.2	9%	-	3.3	-
old over 8	0.55	not sig	6.9	4.2	35.0	8%	-	2.8	-
old over 9	0.76	not sig	7.5	4.7	34.0	10%	-	3.5	-

Table 6. Valuation Fixed-Effects Ordinary Least Squares Regression

Independent Variables	Dependent Variable: Log Valuation
Log P. Applications*Early Round	0.244*
	(0.14)
Log P. Applications*Late/Exit Round	0.581***
	(0.12)
Log P. Granted*Early Round	0.369**
	(0.16)
Log P. Granted*Late/Exit Round	-0.0668
	(0.13)
R&D	1.069***
	(0.15)
Initial Revenues	1.151***
	(0.21)
Revenue Growth	1.100***
	(0.27)
Early Round	-0.132
	(0.19)
Acquision/Merger Round	0.164
	(0.17)
IPO Round	0.732***
	(0.20)
Log Prominent Partner	0.525***
	(0.16)
Age	-0.0661
	(0.14)
Year Dummies	Yes
Constant	1.177
	(0.93)
Observations	604
Number of id	188
R-squared	0.477
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1	

Table 7. Valuation Fixed-Effects Ordinary Least Squares Regression

Independent Variables	Dependent Variable: Log Valuation
Log P. Applications*Pre-Revenue Stage	0.318**
	(0.12)
Log P. Applications*Revenue Stage	0.507***
	(0.13)
Log P. Granted*Pre-Revenue Stage	0.280*
	(0.15)
Log P. Granted*Revenue Stage	-0.0377
	(0.14)
R&D	1.020***
	(0.15)
Initial Revenues	1.022***
	(0.24)
Revenue Growth	0.975***
	(0.32)
Early Round	-0.339**
	(0.14)
Acquision/Merger Round	0.114
	(0.17)
IPO Round	0.753***
	(0.20)
Log Prominent Partner	0.522***
	(0.16)
Age	-0.067
	(0.15)
Year Dummies	
Constant	1.322
	(0.93)
Observations	604
Number of id	188
R-squared	0.467

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8. Estimated Impact of Patents in Different Rounds and Commercialization Stages

	coeff on applications	coeff on granted	median applications	median granted	median valuation (in 2008 prices)	value of application as percent of valuation	value of granted as percent of valuation	value per application (millions USD)	value per granted (millions USD)
early round	0.24	0.37	2.0	1.2	17.3	12%	30%	2.1	5.2
pre-revenue stage	0.32	0.28	5.3	1.3	21.0	6%	22%	1.3	4.6
late/late-exit round	0.58	not sig	5.3	2.5	45.7	11%	-	5.0	-
revenue stage	0.51	not sig	4.9	2.5	38.3	10%	-	3.9	-

Figure 1. Valuations Density Function