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Essays on the Economic Value of Start-Ups' Patents

Dissertation in partial fulfillment of the requirements for the academic degree

of Doctor of Philosophy in Economics (XXII cycle).

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Contents

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Preface

This thesis focuses on the relationship between the intellectual property (IP) system and hi-technology ventures' financing activities. The last few decades have seen a tremendous growth in the creation of companies whose main tradable products are disembodied technologies. This trend was accompanied by an increase in the use of the IP system, with patent protection becoming available for subject matters such as software and business-methods, previously deemed unpatentable.

Knowledge-intensive firms face a number of problems associated with the fact that their assets are largely intangible and often use patents to help them mitigate these problems. Since knowledge is a non-rival good, entrepreneurs are faced with a dilemma, referred to by Arrow (1962) as the "paradox of disclosure". In order to signal the value of their technology to potential investors and acquirers, they are required to reveal technical details about their inventions. However, once this information is disclosed, the entrepreneurs risk not appropriating any returns from it. Therefore, having a clear title to at least some of their intangible assets might facilitate obtaining financing, at least from those willing to provide risk capital such as venture capitalists (VCs). In addition, patents can serve as a focusing device for the trading of expertise and know-how between commercial partners and between targets and acquirers.

This dissertation empirically estimates how the filing of patent applications and the receipt of legal patent protection impact startups' financial trajectory. It is based on an original dataset that combines data on pre-money valuations in sequential venture-capital funding rounds with patents and other characteristics of Israeli startup firms.

The first essay tests the following hypothesis: since the majority of US patent applications are eventually granted in some form (Quillen and Webster 2001; Graham and Harhoff 2006), once patents have been applied for at the USPTO, their subsequent grant should not have additional impact on firm evaluation by VCs, unless there is asymmetric information about the value of the patent that is disclosed at the moment of grant. Although most patent applications eventually get granted, the scope of patent protection, determined by the number of claims allowed, is only revealed at the time of grant. In the absence of market frictions, well-informed, forward-looking investors would base their valuations on the number of claims that are expected to be allowed and, on average, attribute similar values to pending and granted patents. However, in the presence of market frictions, startups' ability to provide an accurate quality signal to investors by disclosing complete information about their invention could be affected by their reluctance to disclose (yet unprotected) tacit knowledge and by prohibitive transaction and search costs which exist during patent pendency period. In such circumstances, patent grant, which mitigates uncertainty about the overall scope of patent protection, can spur additional information disclosure, reduce asymmetric information and adverse selection, and result in enhanced valuations. The problem of asymmetric information exists primarily for young firms or firms in their early rounds of financing because their technology is not yet embodied in a commercialized product and they lack an established track record as well as alternative mechanisms to protect their IP. My empirical analysis finds that the additional impact of granted patents on firms' valuations by VCs is positive and significant only for younger firms and during early financing rounds. It is small and insignificant for more mature start-ups. These findings confirm my hypotheses that patent grant can act as an information-producing device for less experienced firms.

This is an original paper in this literature for several reasons. First, it uses original data. Second, it is one of the first papers that studies how the patent office – and not just the patent holders or the VCs – can produce value by reducing potential asymmetric information. In this respect, the result that the additional value is only created for younger firms suggests an interesting value-enhancing policy for patent offices: accelerating patent examination for younger firms. Third, it exploits having multiple evaluations of the same firms to estimate fixed effects regressions, which control for unobserved firm heterogeneity. As a result, I can show estimates of monetary marginal values of patent applications and of the additional monetary value of grants for younger firms. There are practically no good monetary estimates of patents like these in the literature.

The second chapter of my dissertation examines the role of startups' patents in influencing their ability to reach an exit by acquisition. Over the last decade, acquisition has become the dominant exit strategy for Israeli technological ventures, who find it increasingly difficult to reach an IPO at the NASDAQ or to access later stage financing. Despite its importance, there has been little empirical research on the timing of acquisition decisions in this high technology environment and how it might be affected by the intellectual property (IP) system. The results of a survival analysis of data similar to those used in the first essay show that granted patents speed up the arrival of acquisition for younger firms, while pending patents have no influence on their acquisition hazard rate. The impact of granted patents is larger when the acquisition is a positive liquidity event, that is, one in which the acquisition amount exceeds the total amount previously invested in the company. These results confirm that for reasons of asymmetric information and adverse selection patent grants are important for younger firms also in the context of acquisitions and that they are therefore likely to assist in decreasing the time-to-market of new technologies. In the case of mature startups, which are considered less attractive for acquisition (Ransbotham and Mitra 2010), pending patents are more instrumental in speeding up an acquisition than granted ones. These results confirm recent findings by Ransbotham and Mitra (2010), which suggest that recent patents can mitigate the negative impact of age on the likelihood of acquisition by signaling the 'newness' of an older company's R&D, thus making it more akin to a younger firm.

The third chapter of my dissertation addresses the issue of software patents. The patenting of software has been a highly contentious issue ever since it became generally patentable in the U.S in the mid-1990s, following a series of court decisions. The value to society of software patents is debatable and evidence on the private value of patents to software companies remains largely inconclusive. This paper examines the value of software patents to software startup firms using data on VC-backed Israeli ventures. It finds that the propensity to patent in the software sector is significantly lower than in other sectors such as life-sciences, telecommunications and semiconductors. The overall number of patent applications filed by software startups does not have a significant effect on their valuations. At the same time, once I control for the companies' stock of software patents, identified using the IPC classification system (Graham and Mowery 2003), the association between these patents and firms' valuations is found to be positive and significant. In addition, filing software patent applications appears to be particularly beneficial for target companies in enhancing their acquisition amounts. Overall, my findings suggest that in the highly "thicketed" software market, where innovation is cumulative, applying for patent rights can assist entrepreneurs in demonstrating ownership over their intellectual property and in improving their bargaining positions vis-à-vis acquirers.

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Small Firms, Big Patents? Estimating Patent Value Using Data on Israeli Start-Ups' 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-ups' 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 could 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 the course of negotiations with investors and potentially induce additional information disclosure.

[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 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 7,000 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 1,381 patent applications, of which 671 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*:

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

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:

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

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 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-----

[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*.

4. Results and Discussion

The results of the multivariate regression analysis to test H1 appear in Table 3. I use a log-log 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 examination process is

[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.

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 log-log 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

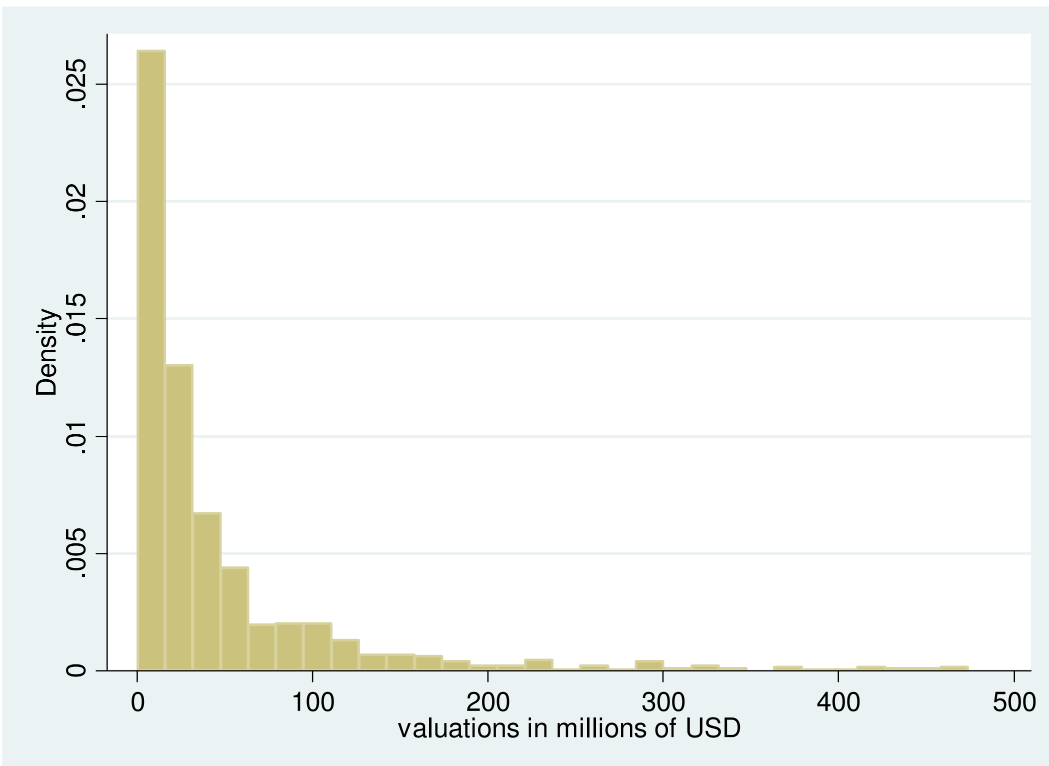
Independent Variables	Dependent Variable: Log Valuation
Log P. Applications*Pre-Revenue Stage	0.318**
	(0.12)
Log P. Applications*Revenue Stage	0.507***
	(0.13)
Log P. Granted*Pre-Revenue Stage	0.280*
	(0.15)
Log P. Granted*Revenue Stage	-0.0377
	(0.14)
R&D	1.020***
	(0.15)
Initial Revenues	1.022***
	(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



Targets' Patents and the Impact of Uncertain Intellectual Property Rights on Acquisitions

Gili Greenberg Alfonso Gambardella

ABSTRACT

Over the last decade, acquisition has become the dominant exit strategy for Israeli technological ventures. Despite its importance, there has been little empirical research on the timing of acquisition decisions in this high technology environment and on how it might be affected by the intellectual property (IP) system. If the market for technology is efficient, the timing of acquisition is independent of whether formal IPR have already been granted. In contrast, the need to disclose (yet unprotected) knowledge, asymmetric information or search costs may retard efficient technology transfer during the pre-patent period. This paper therefore compares the marginal impacts of targets' pending and granted patents on their likelihood of being acquired. Applying survival analysis methodology to study the patenting, financing and acquisitions of 317 Israeli startups we find a large and positive impact of patent grant on young firms' hazard of acquisition. For older firms, on the

other hand, it is the stock of pending patents which modestly affects this hazard rate. Our findings suggest that in the case of younger startups, uncertainty about patent scope, coupled with imperfections in the markets for technology, adversely affect the relationship between entrepreneurs and buyers. A more speedy examination process of these firms’ patent applications therefore could enhance their ability to experience a successful exit by acquisition.

1. Introduction

In high technology industries, external acquisition of new technology plays a vital role in the product development process (Higgins and Rodriguez 2006). For the acquiring firms, it can fill gaps in product portfolios and reduce time to market. For target firms, an acquisition by a larger incumbent enables a focus on innovation and R&D while relying on the specialized assets of the acquirer for complementary downstream activities (Chan et al. 2007). In the case of Israeli startup firms, the greater difficulty in reaching an IPO at the NASDAQ (an increase in the annual revenue requirements from $50 to $100 million) and the limited availability of later stage financing have made acquisition the dominant exit strategy over the past decade[4]. In some cases, it is the hope of exiting wealthy which provides the incentive for entrepreneurs to set up new companies in the first place (Gans and Stern 2003).

The buying and selling of entrepreneurial firms is largely a trade in intangible assets which forms part of the markets for technology. Similar activities include the formation of joint ventures, R&D alliances, licensing deals and a variety of other outsourcing arrangements with universities, technology-based startups, and other established firms. The work of Arora et

[4] "Innovative Israel Failing to Grow High-Tech Start-Ups". The Wall Street Journal, August 26 2010.

al. (2001) has highlighted the positive role that intellectual property rights (IPR) have in fostering these activities and in developing the markets for technology. Additional studies, focused on entrepreneurial ventures, provide evidence that patenting can be particularly beneficial for these firms. Hsu and Ziedonis (2008) and Haussler et al. (2009), among others, show that patent applications provide quality signals to investors, increase pre-money valuations and speed the arrival of initial investment or IPO. Cockburn and MacGarvie (2009) find that holding patents may stimulate entry to the market by improving the bargaining position of entrants vis-à-vis incumbents and Gans et al. (2008) find that patent allowances significantly raise the hazard rate of achieving cooperative licensing agreements.

Yet, despite its importance as an exit strategy for young technological firms, there has been relatively little empirical research focused on the impact of patents on the timing and likelihood of acquisition. This paper adds to existing research by estimating the differential impacts of pending and granted patents on younger and older startup firms' probabilities of being acquired. Moreover, and unlike previous papers, it does not consider every acquisition to be a success. Rather, it makes a distinction between "good" and “bad” liquidity events (from the target’s investors’ point of view), by employing data on the return on investments made in VC-backed companies.

As developed more fully below, we predict that if the technology market is efficient, the timing of target acquisition is independent of whether it has obtained formal protection of its IP. In contrast, if the market has frictions, the granting of patent rights will make a difference to the probability of acquisition. Prior to being granted a patent, targets’ need to disclose complementary (yet unprotected) knowledge, asymmetric information, transaction and search costs may retard efficient technology transfer. This is particularly true in the case of younger firms who face greater uncertainty about the quality of their technology, are more liquidity constrained and lack alternative mechanisms to protect their IP. For them, holding granted patents, which reduces the uncertainty about the scope and extent of IP protection, is likely to be more important in speeding up acquisitions than for older firms. In addition, companies with better technologies risk a higher loss in case of expropriation, and are therefore more likely to restrict information disclosure prior to patent grant. Since better quality companies normally get acquired for an amount which exceeds the total amount previously invested in them, we expect that the impact of patent grant on the probability of experiencing a “good” acquisition will be larger.

To test our hypotheses we perform a survival analysis of panel data consisting of 981 financing rounds received by 317 Israeli technological startups between 1994 and 2010. The data contain information about the companies’ stock of patent applications, granted patents, venture financing, partnering, and exit histories.

Our results show that granted patents have a large and significant impact on the likelihood that younger firms (under the age of 7) will experience an acquisition and that this impact is larger when the acquisition generates a positive return on investment. Pending patents, on the other hand, have no explanatory power when it comes to younger firms’ acquisitions, but do have a small positive impact on the likelihood that older firms will experience such an exit event.

This study contributes to previous research on the association between startups’ patenting activities and financial performance and to the literature which discusses the role of IPR in mitigating imperfections in the markets for technology (Arora et al. 2001; Gans et al., 2008; Long 2002; Dushnitsky and Shaver 2004; Amit et al. 1998).

The paper proceeds as follows. In the next section we discuss relevant literature on acquisitions, market imperfections and signaling in the market for technology. Then, we develop and propose testable predictions about the role of patent grants in mitigating market frictions and spurring trade in technology. After we describe the empirical design and data, we report our main findings. In the final sections, we discuss the study results and conclusions.

2. Literature and Theory Development

New hi-technology ventures form to develop and commercialize entrepreneurial innovations. In general, there is a great deal of uncertainty about the quality of their technology, its possible applications and the existence and size of potential markets. Since the entrepreneurs themselves possess superior information about the value of their innovations (Shane and Cable 2002; Shane and Stuart 2002), the markets for technology are also inherently characterized by information asymmetries (Arora et al. 2001; Gans et al. 2008; Dushnitsky and Shaver 2009; Amit et al. 1998). Discerning the value and commercial promise of new technologies in the presence of uncertainty and asymmetric information is challenging for potential buyers.

Ransbotham and Mitra (2010) point to the dilemma faced by acquirers: "From the perspective of the buyer, the emergence of an early stage company begins an inherent conflict between risk and safety. Should organizations wait until more information is available about the target, its technology, its product, and the market so that a better valuation can be obtained? Or should the target be acquired early to gain quick access to key technologies, reduce integration problems and lower the cost of acquisition?"

The authors' general answer to this dilemma is that acquirers choose to acquire early in the face of uncertainty. They assert that flexible growth options and greater valuation uncertainty, associated with a younger venture, make it more attractive for acquisition. They also find that the probability of acquisition is higher for targets that have more patent citations and that the negative effect of age is partially mitigated if the target has recent patents.

Their analysis of the association between patents and acquisitions focuses on the important role that patents have in signaling the quality and 'newness' of the R&D undertaken by firms. Patents conform well to Spence's (1973) original conceptualization of a signal: they are costly to obtain and, through the government certification process, provide a mechanism by which the quality of innovative activities can be sorted. Previous studies (Hsu and Ziedonis 2008; Mann and Sager 2007) confirm that startups' patents can indeed act as quality signals to investors and raise pre-money valuations and investment amounts. Patents, however, have an additional role, which is the protection of the companies' IPR. This legal protection can be very instrumental to the commercialization of innovation and to the transfer of knowledge from the original inventor to a firm able to effectively develop that innovation for the market.

While applying for a patent is a signal that a company's technology is worth protecting, the scope of possible protection is only determined once a patent is granted. In the interim, uncertainty about ultimate patent scope coupled with market imperfections can influence the speed and efficiency of trade in technology.

A study by Gans et al. (2008) considers the impact of uncertain intellectual property rights on the timing of licensing by start-up technology entrepreneurs. The authors find that the grant of patent rights substantially increases (by 70%-80%) the hazard rate of achieving a licensing agreement. This result is attributed to the positive role that formal intellectual property rights have in mitigating market imperfections which can prevent an earlier efficient trade. They suggest that during the pre-grant period, innovators seeking commercialization partners may be subject to expropriation and are therefore likely to limit their disclosure of information. This exacerbates problems of asymmetric information and uncertainty and prevents potential partners from forming correct expectations about the value of a startup's technology. Under such circumstances, at least some startup firms will delay cooperative commercialization until the uncertainty about patent scope is mitigated. A second mechanism hypothesized to result in a dependency between patent grant and the timing of cooperation arises from the presence of search costs. If the innovator has to engage in costly research to locate the most suitable commercialization partner, the incentives to search may only be sufficient after a patent (with a broad scope) has already been granted (Hellmann 2007). A third mechanism arises from the ability of licensees to expropriate knowledge that is disclosed by licensors but is unprotected by IPR. Prior to patent grant, non-disclosure agreements (NDA) with potential partners may be difficult (if not impossible) to write with any degree of precision or potential enforcement. Patent grant can significantly decrease the costs and complexity of such contracts and spur participation in the market for ideas.

The relationship between a target and a potential acquirer is not dissimilar to that which exists between a licensor and a licensee. Here as well, uncertainty about the eventual scope of IPR protection can decrease the probability that an effective technology transfer will occur, in this case through acquisition. Fears of expropriation during patent pendency period can result in limited information disclosure on the part of a target firm to potential acquirers. As a result, its ability to credibly signal the quality of its innovation (relative to the distribution of quality types) is reduced, and its probability of experiencing a successful exit is decreased. This problem is exacerbated in the case of younger firms. Uncertainty and information asymmetries regarding the quality and promise of their nascent technologies are more severe. Since they normally do not yet have a commericalizable product, the risks of expropriation loom large, and at the same time, their ability to use alternative mechanisms to protect their IPR, such as the threat of reputational damage are limited. Together, these factors imply that younger firms are more likely to restrict information disclosure during the pre-patent period and that after patent grant their ability to provide accurate quality signals to potential acquirers will be significantly enhanced. Transaction and search costs are also likely to be more prohibitive for these firms, who are highly liquidity constrained. These costs can lead them to retard their search for and negotiations with potential acquirers until they are granted patent rights.

For all these reasons we predict that:

Hypothesis 1: In the presence of market frictions, granted patents have an additional positive impact, compared to pending patents, on younger firms' likelihood of being acquired.

Moreover, entrepreneurs who have better quality technologies have higher reservation prices for their companies and hence risk more by early disclosure and possible expropriation. Patent grant is therefore predicted to be particularly beneficial for them as it can greatly increase their ability to provide an accurate signal of their companies' superior quality and improve their bargaining position vis-à-vis potential acquirers. If we consider that better companies get acquired for a price which constitutes a positive return on the investment made in them, we expect the following:

H2: The impact of granted patents on younger firms' likelihood of being acquired is larger when the acquisition amount exceeds the total amount previously invested in the company.

As far as older startup firms are concerned, Ransbotham and Mitra (2010) find that they are generally considered less attractive targets for acquisition for several reasons. First, as targets age, their technology becomes more mature and defined, and there is less flexibility for opportunistic evolution. Second, the markets for their technologies become more defined and competition becomes more entrenched, thereby reducing flexibility for the buyer. Third, older targets have already developed entrenched processes and practices which increase their structural inertia (Hannan and Freeman 1984). This reduces flexibility to develop them along unique paths, and reduces the opportunity for private valuations by potential buyers. The authors provide empirical evidence that the negative effect of age on a target's probability of being acquired is mitigated if the target has recent patents that indicate the presence of growth options and make an older target more akin to a younger company. It is therefore likely that for older startups, pending patents, which represent the "pipeline" of IP assets under development (Cockburn and MacGarvie 2009), will have a larger impact on the probability of being acquired than older, granted patents. This prediction is strengthened when we consider that the role of patent grant in mitigating uncertainty and asymmetric information is expected to become muted as firms age. Having a longer history of operations implies less uncertainty and more information availability on older firms' operations, management, technological feasibility and revenue potential, which enables a more precise valuation by buyers even before patents are granted.

In addition, having a proven track record and a commercialized product greatly reduces the threat of technology expropriation and as ventures develop, they can also 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). Therefore, we predict that mature startups 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 acquirers outweigh the costs. Accordingly, we propose:

H3: In the case of older firms, pending patent applications will have a greater impact on the hazard of acquisition than granted patents.

3. Empirical Analysis

3.1. Hazard analysis of the risk of acquisition

To identify factors that affect the risk that a potential target's final financing round is an acquisition, we employ a Cox proportional hazard model (Cox 1972). Our analysis employs data on Israeli VC-backed start-up firms taken from the Israel Venture Capital (IVC) database, which contains information about technological ventures, most of which were founded in the past 20 years. We focus on VC-backed firms so that we can control for their round-level valuations by investors and distinguish between a "good" and a "bad" acquisition according to whether the acquisition amount was greater or smaller than the total amount of investment previously received by the company. The sample includes 317 technological companies established between 1987 and 2005, who had a total of 981 rounds of financing, acquisition or IPO in the past 17 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. The financial data about the companies were matched with data on the companies' cumulative stocks of pending and granted patents at each given financing round, taken from the USPTO database. The sample companies collectively submitted 1585 patent applications, of which 732 were granted prior to exit or a final VC financing round before March 2010.

In the hazard model presented, the event being explained is the acquisition or merger of a target firm by a buyer. The model allows us to integrate information about potential targets in our data set that were part of the Israeli hi-tech industry but were not acquired, and to handle truncation errors caused by the end of the study period.

The Cox model is specified as a continuous-time hazard-rate function, incorporating a non parametric baseline hazard rate and a multiplicative term allowing the round-varying regressors to have a proportional impact relative to the baseline (Lancaster 1990). We let $h_{acquisition}$ equal the hazard rate of *acquisition/merger* which changes from zero to 1 (i.e. the instantaneous probability of failure at t, conditional on survival until t) and allow for stratification by industry[5]. We allow the coefficients on the number of

[5] Our results do not qualitatively change when we used a shared frailty model.

pending and granted patents to differ between younger and older firms and include time-varying firm level controls and year fixed effects. This yields the following hazard function:

$$\begin{aligned} & h_{acquisition}(t, \text{pending} \times \text{young}_{\text{it}}, \text{granted} \times \text{young}_{\text{it}}, \text{pending} \times \text{old}_{\text{it}}, \text{granted} \times \text{old}_{\text{it}}, \text{l}_{\text{i,}}\ \text{Z}_{\text{it}}) \\ & = h^{l_i}(t) \cdot \exp\{\ \beta_Z Z_{it} + \beta_{pend\_Y} \text{pending} \times \text{young}_{\text{it}} + \beta_{\text{grant\_Y}} \text{granted} \times \text{young}_{\text{it}} \\ & + \beta_{pend\_O} \text{pending} \times \text{old}_{\text{it}} + \beta_{grant\_O} \text{granted} \times \text{old}_{\text{it}}\ \} \qquad (1) \end{aligned}$$

where *i* subscripts each firm and *l* subscripts each industrial sector. The young and old dummies are equal to 1 or 0 according to whether a company is under or over a certain age threshold, varying between 6 and 9 years old. Z_{it} are firm specific round-varying control variables which are detailed in a later section. Using this framework, we can test H1 by determining whether $\beta_{\text{grant\_Y}} > \beta_{\text{pend\_Y}}$ in a regression analysis which estimates equation (1).

To test H2, we run the same regression but instead of the dependent variable being the hazard rate of experiencing an acquisition, the dependent variable is the hazard rate of experiencing a “good” acquisition, $h_{good\_acquisition}$. *Good Acquisition* is a dummy variable which equals 1 if the acquisition amount exceeds the total amount previously invested in the company and zero otherwise. To determine whether the acquisition made a positive return on investment we use data from the IVC database about round level investment amounts and supplement it with information from the local press. To test H2 we compare the magnitude of the coefficient $\beta_{\mathrm{grant\_Y}}$ in the regression where the dependent variable is $h_{acquisition}$ with that estimated in the regression where the dependent variable is $h_{good\_acquisition}$.

Finally, to test H3, we examine whether the coefficient on pending patents becomes larger than the coefficient on granted patents when firms' age increases.

3.2. Variables

The key dependent variable is the hazard rate of acquisition or merger, which is equal to 1 in rounds in which the company was acquired or merged and zero otherwise. The independent variables consist of several categories. The data about the companies' patent applications and granted patents were taken 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, we 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 we collected the patent data in 2010. The cumulative stock of *pending patent applications* is equal to the difference between the cumulative stock of *patent applications* and *granted patents*.

Financial data about the companies were taken from the IVC database. The *valuation* variable is pre-money valuation, which reflects the product of the share price before the funding round multiplied by the number of the outstanding shares of the firm. This estimate of the aggregate value of the firm provides a basis for calculating the equity stake for a given cash infusion by VCs. The coding of a set of round-type and company-stage dummies 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 *IPO Round* dummy indicates exit rounds in which the company had an IPO and *Post-IPO*

Round indicates either second or third public offerings or pipe financing. Four dummies reveal different stages of progress in product development: *Seed*, *R&D*, *Initial Revenues*, and *Revenue Growth*.

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.[6] Finally, we included year dummies for each year in which a financing round, an acquisition or an IPO took place. The baseline hazard rate was stratified

[6] 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*.

by the following industries: semiconductors, communications, IT & enterprise software, life sciences and internet.

In Table 1, we summarize information about the variables used in the round-level regressions, and in Table 2, we report the bivariate correlations.

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

4. Results and Discussion

The results of the Cox hazard regressions that test hypotheses 1 and 3 , according to which patent grants impact the likelihood of acquisition of younger firms while pending patents influence that of older firms, are presented in Table 3. In this table and in the next, we present the implied hazard ratios (which should be read relative to one) rather than the estimated coefficients because they make the estimated size effects more apparent. All estimates are based on robust standard errors, clustered by firm. The “failure” event in the Table 3 regressions is an acquisition or a merger and our specification uses the funding round as the unit of analysis. Pre-money valuation is the only explanatory variable specified in natural log because of its right-skewed distribution. Since this variable might be endogenous, we present the results of regressions in which it is included as a control variable as well as ones in which it is excluded.

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

The results in Table 3 show a positive and significant association between the granted patents of firms under the age of six or seven and the acquisition hazard rate. Each additional granted patent is associated with a significant (at the 1% level) increase of approximately 73% in the underlying hazard rate for firms under the age of six and with an approximate increase of 85% for firms under the age of seven. The pending patents of these young firms either have a small and marginally significant impact (at the 10% level) on the hazard rate or no significant impact at all.

As young firms age, the roles of pending and granted patents in influencing their likelihood of acquisition become reversed. The impact of pending patents becomes significant, albeit small, with each additional patent application filed by companies under the age of eight or nine increasing the hazard rate by about 8%. The impact of granted patents, on the other hand, becomes small and insignificant.

In the case of “older” startups, both pending and granted patents seem to have little or no impact on the likelihood of being acquired. Overall, the results presented in Table 3 support hypotheses 1 and 3. Patent grant seems to be highly important for increasing the likelihood of acquisition of young firms but unimportant in the case of mature companies. As young firms become older, it is their stock of pending patent applications, which represents their current R&D that has an impact on the acquisition hazard rate. This impact is relatively small however, because the overall uncertainty associated with target companies tends to decrease with age, and buyers are more likely to base their decision on other information such as the company’s track-record and the quality of its commercialized product.

A final interesting point to observe in Table 3 are the negative and significant impacts that reaching the *Initial Revenue* or *Revenue Growth* stages have on the hazard of acquisition, which they decrease by 50% or more. These results appear to support Mitra and Ransbotham (2010) assertion that more mature and developed companies are generally less attractive as acquisition targets.

In Table 4 we present a set of regressions in which the “failure” event is an acquisition or merger where the acquisition amount exceeds the total amount previously invested the company.

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

Similarly to the results presented in Table 3, granted patents have a positive impact on the likelihood of acquisition of young firms under the age of seven. In this case however, the size of the coefficients is almost twice as large as in the previous regression, with each granted patent increasing younger firms' hazard of acquisition by over 100%. These results support our second hypothesis which suggests that patent grant is particularly beneficial for firms with better technologies as it helps them to signal their superior quality and mitigate asymmetric information and adverse selection.

The significance of the coefficients on the other patent variables, for younger and older firms, depends on whether or not pre-money valuation is included as a regressor. The coefficient on the log of pre-money valuation is large and significant in these regressions, suggesting that companies which are more highly valued by their investors stand a better chance of experiencing a positive liquidity event. When the pre-money valuation variable is excluded, the coefficients on pending patents are generally small and significant for both young and older firms. In the case of older firms, the size of the impact that each pending patent has on the underlying hazard rate increases from 9% for firms over the age of six to 22% for firms over the age of nine. This seems to confirm the conjecture that for older companies, who become increasingly less attractive to buyers, having recent pending patents becomes more important for mitigating the negative impact of age. Finally, the granted patents of older firms appear to have a small negative impact between 6 and 10 percent on the hazard of experiencing a good acquisition. This, most likely, is due to the fact that older, granted patents might be correlated with outdated technologies or with other attributes of mature firms which make them less attractive for acquisition.

5. Conclusion

This study provides new evidence that granting patent rights can positively affect the likelihood of acquisition of early-stage startups. 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 markets for technology (e.g., Arrow 1962; Amit et al. 1998). Patent grants are significant only for young ventures, 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. IPR protection is also likely to reduce the costs of searching for and negotiating with potential buyers, which can be prohibitive for young, liquidity constrained ventures.

For older firms, obtaining formal protection of their IP is relatively less important. Since these companies are generally considered less attractive for acquisition and have other means to protect their IP, it is in their interest to disclose full information about their recent, ongoing R&D, to signal the quality and relevance of their technology.

Gans et al. (2008) find that patent grants are instrumental in shaping start-ups' licensing strategy. This study provides direct evidence that patent grants also influence start-ups' acquisitions.

The study's findings are important from a policy perspective. The long, variable grant lags that currently characterize the U.S. patenting system can adversely affect young start-ups' commercialization strategies and the time-to-market of new and innovative technologies. 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 commercialization. As a result, high-quality young firms would be able to attract buyers, which are often 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 additional information about the exact timing of patent grant relative to that of acquisition. 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 signaling value of patents 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 technology.

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Table 1. Summary Statistics and Variable Definitions

VARIABLE	DEFINITION	MEAN	STD. DEV
Pending patents	The difference between the cumulative stocks of patent applications and granted patents at the time of the funding round	2.09	4.37
Granted patents	Cumulative granted patent stock at the time of the funding round	1.19	4.66
Pre-money valutaion	VC pre-money valuation (share price*shares outstanding prior to venture round) of the focal round, deflated to 2008 prices	51.38	170.54
Late stage round	Dummy=1 if funding round is classified as 3rd round or above	0.21	0.41
Acquisition/merger round	Dummy=1 if the focal funding round involved an acquisition/merger	0.13	0.34
"Good" acquisition/merger round	Dummy=1 if the focal funding round involved an acquisition/merger where the acquisition amount exceeded total investment	0.08	0.27
IPO round	Dummy=1 if the venture achieved an initial public offering	0.04	0.20
Post-IPO round	Dummy=1 if the venture had subsequent public offerings of pipe financing	0.02	0.14
Seed stage	Dummy=1 if the venture is in its early days of product development and fund raising	0.12	0.32
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	0.50	0.50
Initial revenues stage	Dummy=1 if the venture has revenues which do not exceed $10 million dollars	0.26	0.44
Revenue growth stage	Dummy=1 if the venture has revenues which exceed $10 million dollars and a double digit yearly growth rate	0.13	0.33
Prominent partners	Cumulative count of commercially prominent strategic alliace or corporate equity partners at the time of the funding round	0.50	0.91
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	Pending Patents	Granted Patents	Seed Stage	R&D Stage	Initial Revenue Stage	Revenue Growth Stage	Early Financing Round	Late Financing Round	Acquisition/ Merger Round	Good Acquisition/ Merger Round	IPO Round	Post IPO Round	Prominent Partners
Valuation	1													
Pending Patents	0.1666*	1												
Granted Patents	0.1269*	0.5237*	1											
Seed Stage	-0.0961*	-0.1532*	-0.0925*	1										
R&D Stage	-0.0235	-0.1073*	-0.1487*	-0.3600*	1									
Initial Revenue Stage	-0.0324	0.0481	0.026	-0.2143*	-0.5869*	1								
Revenue Growth Stage	0.1695*	0.2441*	0.2768*	-0.1392*	-0.3812*	-0.2269*	1							
Early Financing Round	-0.2058*	-0.2910*	-0.2342*	0.3002*	0.3946*	-0.3491*	-0.4202*	1						
Late Financing Round	0.0173	0.2418*	0.0791*	-0.1881*	-0.1509*	0.2229*	0.1139*	-0.6265*	1					
Acquisition/Merger Round	0.1777*	0.0122	0.1173*	-0.1398*	-0.2675*	0.1880*	0.2876*	-0.4657*	-0.2000*	1				
Good Acquisition/Merger Round	0.2601*	0.0539	0.1224*	-0.1058*	-0.1988*	0.1130*	0.2505*	-0.3525*	-0.1514*	0.7568*	1			
IPO Round	0.1264*	0.1233*	0.1345*	-0.0776*	-0.1130*	0.0212	0.2154*	-0.2586*	-0.1111*	-0.0826*	-0.0625	1		
Post IPO Round	0.0587	0.1018*	0.1089*	-0.0536	-0.1328*	0.0894*	0.1327*	-0.1786*	-0.0767*	-0.057	-0.0432	-0.0317	1	
Prominent Partners	0.1750*	0.2660*	0.2150*	-0.1710*	-0.1237*	0.0591	0.2713*	-0.2956*	0.2030*	0.1353*	0.0938*	0.0958*	-0.0193	1

* Indicates statistical significance at the 5% level.

Table 3. Baseline Industry-Stratified Cox Hazards with Controls (Dependent Variable=Acquisition/Merger)

	cutoff age 6		cutoff age 7		cutoff age 8		cutoff age 9	
Pending Patents*Young	1.10	1.12*	1.03	1.04	1.07**	1.08***	1.06**	1.07***
	(0.08)	(0.08)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Granted Patents*Young	1.74***	1.73***	1.84***	1.88***	1.09	1.11	0.96	0.98
	(0.33)	(0.34)	(0.33)	(0.33)	(0.12)	(0.11)	(0.08)	(0.08)
Pending Patents*Old	1.03	1.05**	1.03	1.05	1.03	1.05	1.03	1.05
	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)	(0.04)	(0.07)	(0.07)
Granted Patents*Old	0.94	0.94	0.95	0.95	0.95	0.94	0.95	0.94
	(0.06)	(0.04)	(0.05)	(0.04)	(0.07)	(0.06)	(0.07)	(0.06)
Log Valuation	1.11		1.11		1.12		1.12	
	(0.08)		(0.08)		(0.08)		(0.08)	
R&D	0.81	0.89	0.79	0.87	0.96	1.06	1.03	1.15
	(0.26)	(0.29)	(0.00)	(0.00)	(0.30)	(0.33)	(0.00)	(0.35)
Initial Revenues	0.46***	0.46***	0.44**	0.44**	0.51***	0.51***	0.58	0.58**
	(0.12)	(0.10)	(0.16)	(0.15)	(0.13)	(0.12)	(0.20)	(0.12)
Revenue Growth	0.22	0.25	0.22***	0.25***	0.26	0.30	0.30***	0.35
	(0.00)	(0.00)	(0.07)	(0.08)	(0.00)	(0.00)	(0.09)	(0.00)
Prominent Partners	1.04	1.04	1.05	1.05	0.97	0.96	0.98	0.98
	(0.08)	(0.08)	(0.09)	(0.08)	(0.09)	(0.08)	(0.10)	(0.09)
Round Type Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hazard rate stratified by industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	981	981	981	981	981	981	981	981

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Baseline Industry-Stratified Cox Hazards with Controls (Dependent Variable=”Good” Acquisition/Merger)

	cutoff age 6		cutoff age 7		cutoff age 8		cutoff age 9	
Pending Patents*Young	0.98	1.14*	0.97	1.04	1.03	1.09***	1.02	1.09***
	(0.08)	(0.09)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)
Granted Patents*Young	2.43***	2.04***	2.42***	2.39***	1.13	1.13	0.95	1.01
	(0.51)	(0.42)	(0.63)	(0.54)	(0.20)	(0.18)	(0.12)	(0.11)
Pending Patents*Old	1.02	1.09***	1.03	1.16***	1.011	1.14***	1.07	1.22**
	(0.03)	(0.03)	(0.04)	(0.06)	(0.04)	(0.05)	(0.07)	(0.09)
Granted Patents*Old	0.96	0.94***	0.96	0.92***	0.97	0.93***	0.95	0.90***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Log Valuation	2.61***		2.54***		2.49***		2.45***	
	(0.51)		(0.48)		(0.44)		(0.43)	
R&D	0.15	0.61	0.15	0.46*	0.24***	0.75	0.30	0.77
	(0.00)	(0.27)	(0.00)	(0.21)	(0.11)	(0.30)	(0.00)	(0.30)
Initial Revenues	0.15***	0.32***	0.15***	0.25	0.22	0.36	0.27***	0.39***
	(0.08)	(0.09)	(0.08)	(0.00)	(0.00)	(0.00)	(0.13)	(0.10)
Revenue Growth	0.03***	0.26	0.03***	0.20***	0.06***	0.31***	0.08***	0.35
	(0.02)	(0.00)	(0.02)	(0.05)	(0.02)	(0.08)	(0.04)	0.00
Prominent Partners	0.91	0.97	0.90	0.93	0.82	0.85	0.85	0.86
	(0.11)	(0.10)	(0.12)	(0.11)	(0.12)	(0.11)	(0.12)	(0.12)
Round Type Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hazard rate stratified by industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	981	981	981	981	981	981	981	981

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The Value of Software Patents to Software Start-Up Firms

Gili Greenberg Alfonso Gambardella

ABSTRACT

The patenting of software has been a highly contentious issue ever since software became generally patentable in the U.S. in the mid-1990s, following a series of court decisions. The value to society of software patents is debatable and evidence on their value to software companies remains largely inconclusive. This paper examines whether patenting by software start-ups affects their valuations by investors and acquirers. To this aim, it employs new panel data on VC-backed Israeli ventures in a fixed-effects analysis which controls for firms' unobserved heterogeneity. We find that the overall number of patent applications filed by software start-ups does not have a significant effect on their valuations. At the same time, once we control for the companies' stock of software patents, identified using the IPC classification system, the association between these patents and firms' valuations is found to be positive and significant. In addition, filing software

patent applications appears to be particularly beneficial for target companies in enhancing their acquisition amounts. Overall, our findings suggest that in the highly “thicketed” software market, where innovation is cumulative, applying for patent rights can assist entrepreneurs in demonstrating ownership over their intellectual property and in improving their bargaining position vis-à-vis acquirers.

1. Introduction

The patenting of software has been a highly contentious issue ever since software became generally patentable in the U.S. in the mid-1990s, following a series of court rulings. Recently, the patentability of business methods came into question in the U.S. Supreme Court's Bilski v. Kappos[7] case and despite the court's ruling (in June 2010) in favor of these patents, questions of patentable subject matter for software patents remain left open. Proponents of software patenting claim that it fosters innovation through the disclosure of information and by allowing software components to be used by others (Cohen and Lemley 2001). Those who oppose it argue that software patents stifle innovation and entrepreneurship (Bessen and Hunt 2007; Bessen and Maskin 2009) and have a negative effect on the open source model of innovation (Kasdan 1999; Barton 2000; Hunt 2001; Bakels and Hugenholtz 2002; Lunney 2001; Dreyfuss 2000, 2001; Meurer 2002). Cockburn and MacGarvie (2009) find that since software patents are often of low quality, they increase uncertainty in the market and lead investors to postpone their investment decisions. Moreover, they show that greater

[7] Bernard L. Bilski and Rand A. Warsaw v. David J. Kappos, Under Secretary of Commerce for Intellectual Property and Director, Patent and Trademark Office, 130 S. Ct. 3218 (2010)

patent thickets are likely to prevent new companies from entering the market altogether.

At the same time, since the software sector is characterized by low tangible assets and high intangible assets, it seems plausible that intellectual property rights would be highly important for software companies in order to secure funding for investment (Hall and MacGarvie 2010).

To test the latter hypothesis in the context of the market for entrepreneurial finance, this paper examines whether patenting by software start-up companies has an impact on their valuation by investors and acquirers. If software patents do not have a positive value for the firms that hold them, then it is unlikely that the net effects of the patent system are positive (Mann and Sager 2007).

Fifteen year long panel data on Israeli firms' sequential financing rounds, before, during and after the dot.com bubble of the early 2000s, are employed in a fixed-effects analysis of the association between patents and firm valuation. Separate estimates for the impacts on valuations of the company's entire patent portfolio and its particular stock of software patents are provided.

Our data show that the propensity to patent in the software sector is much lower than in other sectors, such as life-sciences, telecommunications and semiconductors. In addition, and contrary to other sectors, we find that the simple number of patents filed by software companies has no significant impact on their value at any stage of the financing cycle. On the other hand, we do find that their stock of software patents, likely to be related to their core technologies, has a large and positive impact on valuations. In addition, software patents appear to be most instrumental in enhancing target firms' acquisition amounts, suggesting that holding such patents can assist s in their negotiations with potential acquirers.

This study makes several contributions to the literature. First, it provides new empirical evidence on the relationship between software start-ups' patenting and financing activities using data on the Israeli economy, where software entrepreneurship has been a key driver of recent growth. Second, the use of pre-money valuations or acquisition amounts as dependent variables in the analysis enables a quantitative assessment of the impact of patent portfolios on firms' entire value and not just on the amounts of investment that they received or on the time elapsed before a first financing or an exit event. Third, the use of fixed-effects regression analysis controls for firms' unobserved heterogeneity, which is often correlated with the valuation variable, and results in more accurate estimates. Finally, this study moves beyond the simple analysis of patent counts, by claiming that investors and acquirers consider the technological focus on core technological competences of the IPR possessed by target companies in their selection process.

The rest of the paper is organized as follows. First, we briefly summarize the evolution of software patenting over the last two decades. Then, we discuss the existing literature which addresses the relationship between patenting and firm performance, particularly in the software industry. Third, we describe the data and methodology used in the empirical analysis. We then turn to present and discuss the results of different regression analyses. In the final section, we outline the main conclusions to be drawn from the empirical analysis and the implications for future research.

2. The Patenting of Software

When software first emerged as a field in the 1970s, it did not fit easily into existing patent categories at the U.S. Patent and Trademark Office (USPTO). Software can be viewed as an input rather than an end product and cannot function on its own, but instead has to interact with hardware components. Being different from other emerging technologies, it was initially foreclosed from patenting altogether because it was viewed as an algorithm, akin to a natural law or mathematical function and thus statutorily excluded from patenting. A series of U.S. court cases began to open the doors to patenting software innovations in the 1980s[8]. In 1981 the Supreme Court's ruling in Diamond v. Diehr[9] allowed the patenting of software tied to physical or mechanical processes. This standard was substantially unchanged until the mid 1990s. In 1994 and 1995 the Court of Appeals for the Federal Circuit (CAFC) handed down a number of decisions that affected the scope of software patents. In response to the confusion created by the court's determination that much of software was patentable, the USPTO proposed new guidelines for software patentability, published in March 1996. The guidelines allowed inventors to patent any software embodied in physical media. They also stated that inventions that were to be considered non-statutory included data compilations or structures independent of physical elements, encoded information representing creative or artistic expression, and processes that do "nothing more than manipulate abstract ideas or concepts"[10].

[8] For a more detailed account of the history of software patenting, see the introductory chapter in Robert W. Hahn (ed.), *Intellectual Property Rights in Frontier Industries: Software and Biotechnology*, Washington, D.C.: AEI-Brookings Press, 2005

[9] Diamond, Commissioner of Patents and Trademarks v. Diehr et al,.450 U.S. 175 (1981)

[10] USPTO guidelines quoted in Huttner and Strobert (1995).

A second important expansion of patentability took place in 1998 when Judge Rich issued the famous opinion in State Street Bank and Trust v Signature Financial Group.[11] The Signature patent at issue was a "pure" number-crunching type of application, which implemented financial accounting functions. The Federal Circuit court decision stated clearly that Section 101 of the Patent Act (the section that deals with subject matter for patentability) is unambiguous - "any" means ALL, and it is improper to read limitations into 101 not intended by Congress. Therefore, mathematical algorithms are non-statutory only when "disembodied" and thus lacking a useful application. The court went on to make sure that the decision was precedent-setting by stating that with regard to the business method exception, "We take this opportunity to lay this ill-conceived exception to rest." This decision was followed by an increase in applications for "business method" patents, most of which are arguably also software patents, because they describe the implementation of a business method on a computer or the internet (Hall and MacGarvie 2010).

[11] State Street Bank and Trust Co., Inc. v. Signature Financial Group, Inc., 149 F.3d 1368 (Fed. Cir. 1998). See Lerner (2002) for a fuller discussion of this case.

The most recent landmark case concerning the patenting of business methods is re Bilski[12], initially argued before the Federal Circuit court on October 1, 2007. The applicants in this case appealed the rejection of their patent application for a method of hedging risks in commodities trading. Their application was first rejected by the patent examiner and later by the Board of Patent Appeals and Interferences (BPAI), who concluded that the applicants' claims did not involve any patent-eligible transformation and that they only claimed an abstract idea ineligible for patent protection. The Board also held that the process as claimed did not produce a "useful, concrete and tangible result," and for this reason as well was not drawn to patent-eligible subject matter. In its decision, issued on October 30, 2008, the Federal Circuit court affirmed the rejection of the patent claims and reiterated the machine-or-transformation test as the applicable test for patent-eligible subject matter. It also stated that the test in State Street Bank and Trust v. Signature Financial Group should no longer be relied upon.

On June 28, 2010 the Supreme Court issued an opinion on appeal that affirmed the judgment of the CAFC, but revised many aspects of their decision. Most importantly, in their decision, the Supreme Court rejected the

[12] In re Bernard L. Bilski and Rand A. Warsaw, 545 F.3d 943, 88 U.S.P.Q.2d 1385 (Fed. Cir. 2008)

machine-or-transformation test as the sole test of process patent eligibility based on an interpretation of the language of Section 101. “The court is certainly not shutting the door on business method patents, as some thought it might,” said Josh Lerner of the Harvard Business School to the New-York Times[13] and added that: “This preserves a fair amount of ambiguity”. The Harvard Law Review commented that “The Court made a wise policy decision not to risk foreclosing property rights in Information Age inventions such as lifesaving medical diagnostic techniques or technologies that happen to facilitate business. However, by relying too heavily on the novelty and non-obviousness requirements of the [Patent] Act while failing to provide any meaningful guidance as to what constitutes an “abstract idea”, *Bilski* left behind very little of the patent-eligibility requirement as a threshold inquiry. The outcome may be an increase in litigation over non-technological business method patents that threaten to stifle entrepreneurship”. [14]

The question whether patents, particularly those in software and business methods, stifle or foster entrepreneurship, is an important one and has sparked a lively academic debate. In the next section we review the main findings and controversies which surround these issues.

[13] New-York Times. “ Bilski Ruling: The Patent Wars Untouched”. 28 June, 2010.
[14] 124 Harv. L. Rev. 370 (2010)

3. Literature Review

Several strands of literature are relevant to this study. The first is the literature which highlights the positive role of patents and other formal IP rights in supporting a "market for technology," which provides an avenue for new entrants to realize value from innovation by licensing or selling themselves to incumbents (Arora et al. 2001; Gans and Stern 2003; Gans et al. 2008).

The second is the literature which examines the relationship between start-ups' patenting and financing activities. 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 Venture Capital (VC) investors. Haussler 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. Hsu (2004) finds that a lack of patents reduces a start-up's pre-money valuation by 17% to 20%. 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. Using regression analysis, he 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. He concludes that firms with patents but not useful patents might have 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. They also find that the signaling value of patents is greater in earlier financing rounds. Munari and Toschi's (2007) examination of a sample of nanotechnology start-ups finds that the simple number of patents applied for by the company before the first investment round does not have a significant impact on the amount of financing obtained, controlling for its age, stage of development, location and the degree of market diversification. On the other hand, the start-up's stock of patents belonging to the nanotechnology class, representing its core technological competencies, has a positive and significant effect on VC financing. They show that it is the type of patents owned by the start-up that matters in the financing decision, in particular for what concerns their technological content, not just their simple number. Patent applications that were actually in the nanotechnology class increase the financing amount received at the initial round by 15%.

Finally, the most relevant for our study is the literature on software patents, which has so far yielded mixed results. Despite some debate about what constitutes a software patent, there is general agreement that the last two decades have seen a tremendous increase in the number of such patents issued in the U.S. (Hall and MacGarvie 2010; Bessen and Hunt 2007; Cockburn and MacGarvie 2009).

Negative effects of this trend have been found in several studies. Bessen and Hunt (2007) find that software patents substitute for R&D at the firm level and are associated with lower R&D intensity in the group of U.S.-owned public firms. This result occurs primarily in industries known for strategic patenting and is difficult to reconcile with the traditional incentive theory of patents. Bessen and Maskin (2007) argue that when discoveries are “sequential”, as is the case in software, society, and even the inventors themselves can benefit from competition and imitation. They suggest that limiting patent breadth and using copyright protection for software programs will achieve a better balance between preventing imitation and allowing developers to make similar, but potentially valuable complementary contributions. Noel and Schankerman (2006) study the impact of strategic patenting by technology rivals on the R&D spending, patenting and market value of firms in the computer software industry. They claim that patenting creates a thicket of fragmented property rights that impedes R&D activity by constraining the ability of firms to operate without extensive licensing of complementary technologies. Using panel data on public software firms in the U.S. during 1980-99, they highlight the following findings: First, greater patenting activity by technology rivals significantly reduces the firms' market value, patenting and R&D. They interpret this finding as indicating the importance of bargaining power in resolving patent disputes. Second, they find that higher concentration (less fragmentation) of patent rights- which corresponds to lower transaction costs - is associated with higher market value, but lower R&D and patenting activity. Hall and MacGarvie (2010) investigate the value creation or destruction associated with the introduction of broader software patenting in the U.S. in 1995 using panel data of publicly traded firms in the ICT sector. They evaluate several definitions of "software" patents that are based on keyword searches and patent classification systems and examine the relationship between patents, software patents and the market value of firms in different sectors. When measuring the stock market's reaction to legal decisions expanding the patentability of software, they find some evidence that the expansion of software patentability was initially negative for firms in the software industry. However, in the post-1995 period they find that a software firm with software patents was valued at a premium of 48% over similar firms without software patents - a finding which confirms that the financial markets perceived software patents to be valuable for software firms after 1995 but not before. From examining the relationship between Tobin's Q and firms' patent and citation stock they conclude that while patents for highly cited inventions were clearly positively correlated with market value overall, filing additional patents that do not increase the total stock of citations is negatively associated with market value. This suggests that while the marginal software patent filed may not be associated with much increase in market value, the decision of whether or not to patent at all seems to have been an important one.

There is limited evidence on the relationship between software patents and start-up companies' performance. Cockburn and MacGarvie (2009) use data on the financing of entrants into software markets between 1990 and

2004 to examine the impact of greater patent thickets on new software companies' interactions with the capital markets. They hypothesize that a higher level of uncertainty over the threat of litigation or other future patent-related costs, which characterizes software patents (Bessen and Meurer 2008), increase the value of delaying investments. This is because investors await information such as court rulings that clarify the scope of relevant patents, or the results of "field testing" licensing and enforcement strategies, before they make their investment decisions. The results show that start-up software companies operating in markets characterized by denser patent thickets see their initial acquisition of VC funding delayed relative to firms in markets less affected by patents after the mid 1990s. The impact of patent thickets on the ability of firms to "exit" from the start-up phase via an IPO or acquisition is more ambiguous, however, there is evidence that the negative effect of thickets intensified following changes in patentability and that this effect was felt disproportionately by firms without patents of their own. The authors consistently find a positive correlation between the firm's own patent holdings and "success" in financing transactions. Firms with patents are more likely to obtain initial funding or experience a liquidity event and it is the application for a patent rather than its grant that seem to matter more. The authors attribute this result to the increased ability of patent-holding start-ups to use them in cross-licensing negotiations, to defend themselves against litigation, or more generally to obtain better terms in any licensing negotiation. Overall, patents may act to reduce the transaction costs associated with operating in a “thicketed” market.

Mann and Sager (2007) analyze the relation between the patenting behavior of software start-ups firms and the progress of those firms through the venture capital cycle. In order to analyze firms of similar ages and sizes, they restrict their search to firms that had received their first round of venture financing during 1997, 1998, or 1999 and examine the history of their investment performance up to January 2005. Unlike Cockburn and MacGarvie (2009) and Haussler et al. (2009), they find that patent acquisition (or application) at the pre-financing stage is largely irrelevant to the firm’s subsequent progress through the venture capital cycle. On the other hand, they do find support for their hypothesis that the value of patents for software start-ups first becomes significant as they reach the stage at which they begin to generate revenues.

Overall, they show that software start-ups’ patents are significantly correlated with longevity, number of financing rounds and total investment.

They conclude that even if patent accumulations by mature industry incumbents might have potential deleterious effects for those companies, they can still support young firms in their efforts to compete and help forestall movement toward greater concentration in the market. In addition, there is the possibility that patents facilitate the intra-industry technology transfers upon which innovation depends in a realm of cumulative innovation.

4. Empirical Analysis

4.1. Data

4.1.1. Financial data

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). Software has been an important locus of innovation for this economy, and one where entrepreneurial ventures have played a particularly important role in driving technological change. For instance, according to the Israel Venture Capital (IVC) database, out of 7700 start-ups which were established in Israel over the past 20 years, 54% can be classified as software companies.

The companies in the database belong to six broad technological sectors: semiconductors, communications, life sciences, cleantech, IT & enterprise software, and internet. For the purpose of this study, we classified all the companies belonging to the IT & enterprise software and internet sectors as software companies. In addition, companies in the following sub-sectors of the communications sector: mobile applications, telecom applications and wireless applications and the sub-sector healthcare IT of life-sciences were also classified as software companies, following a careful examination of their technology description provided by the IVC.

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, we collected information about all the software companies that had at least two rounds of financing or a round of financing and an exit round prior to July 2009. For comparison purposes, similar data were collected on companies whose technology was not software-based. Data about pre-money valuations or acquisition values was not available for all companies; therefore, data about 372 companies – 163 software companies and 309 non-software companies was collected. The observations for non-software companies date from the period 1993 to 2009 and those for software companies – from 1994 to 2009.

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, we control for time-invariant unobserved firm heterogeneity and provide more accurate estimates of the patents' impact on valuations.

4.1.2. Patent data

The financial data on companies was matched with data about patent applications and granted patents 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, we 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 we collected the patent data in 2009.

It is important to note that all the patents applications filed by the software companies in the sample date from 1996 or later, that is, after the expansion in the patentability of software.

Statistics on the patenting behavior of the companies in the different sectors are presented in Table 1.

----- Insert Table 1 about here -----

The last two columns of the table show the general propensity to patent of companies in different sectors during the sample period. The propensity to patent is, as expected, very high in life-sciences, semiconductors and cleantech, and lowest in internet. It is recognized that software companies have traditionally tended to patent less for several reasons. First, software could be protected by copyright. Second, when filing for a patent, one has to disclose and publish one's technology. Software codes are fairly easy to copy and make slight changes to and as a result, difficult to defend in litigation. Finally, as stated in Hall (2009): “a large part of the software sector, especially firms producing package software for niche markets, still relies on copyright plus trade secrecy due their inexpensive cost when compared to patents”.

Despite the relatively low propensity to patent in this sector compared to others, existing research reveals a dramatic increase in the propensity to patent software over the last two decades. Some argue that this trend indicates that holding patents on software has become both easier and more valuable to firms (Bessen and Hunt 2003). The propensity to patent by the software companies in our sample, 49%, is much higher than the 24% mentioned in Mann and Sager (2007) and the 33% mentioned in Hall and MacGarvie (2010), and might be attributed to the fact that our sample is more recent. On the other hand, while the mean number of patent applications by software companies in Mann and Sager's (2007) sample is three, it is only 1.6 in our sample. This could actually support the authors' assertion that it is the existence of patents that is much more important to a firm's success than the number of patents that it has.

The statistics in Table 1 present a simple count of all the patents assigned to our sample of companies and do not consider whether not they can be classified as "software" patents. Since much of the recent academic and judicial polemic revolves around software and business method patents, it is important to identify which of these patents fall into these categories. This identification is not an easy task since the definition of a software patent is rather unclear (Layne-Farrar 2005) and therefore several definitions exist in the literature. Most definitions are based on keyword searches (Bessen and Hunt 2003) or patent classification systems (Graham and Mowery 2003, Graham and Mowery 2005, Hall and MacGarvie 2010).

In this paper we identify software patents according to the definition employed by Graham and Mowery (2003) (henceforth GM), which identifies as software patents those that belong to one (or more) of eleven International Patent Classification (IPC) class/subclass/groups.[15] Our reason for choosing the GM definition of software patents is that it is found by Layne-Farrar (2005) to do well on Type II error; that is, there is only a 5% chance that it will identify a patent as a software patent when it is not.

Graham and Mowery (2003) settle on their particular choice of IPC classes after reviewing patents granted between 1984 and 1995 and assigned to the six largest U.S. producers of personal computer software (based on calendar 1995 revenues)[16]. While the authors recognize that IPCs do "not map precisely to the universe of software patenting," they contend that their patent classes provide workable, longitudinal coverage of the software industry.

[15] These classes are G06F: 3,5,7,9,11,12, 13, 15; G06K: 9, 15; H04L:9.
[16] The firms are Microsoft, Adobe, Novell, Autodesk, Intuit and Symantec.

Since the IPC system does not have a special class for business method patents, they are excluded from the GM definition. To account for them in our sample, we add the patents that belong to the USPTO class 705 - the class in which business methods are patented - to the software patents count.

The software patenting statistics for our sample of software companies are presented in Table 2.

----- Insert Table 2 about here -----

Overall, patent applications in the GM classes account for 55% of the 255 applications filed by our sample of software companies and once the 18 applications in USPTO class 705 are added, the percent of software applications out of total applications rises to 62%. Graham and Mowery (2003) report that the IPC classes included in their definition of software patents accounted for 57% of the 600 some patents assigned to the 100 largest packaged software firms by 1995 – a percent which is very similar to ours.

4.2. Estimation

4.2.1. Methodology

The first set of regressions serves to estimate the effect of companies' general stock of patent applications or granted patents on their valuations by VCs, across financing and exit rounds, holding the unobservable time-invariant effects constant through start-up fixed effects (γ_i). Thus, the following equation for firm *i* in funding round *t* is estimated separately for firms in the software and non-software industries:

$$\log(valuation)_{it} = \beta_0 + \gamma_i + \delta_t + \beta_1 \log(1+\text{patents})_{\text{it}} + \beta_2(\text{age})_{\text{it}} + \beta_3(\text{company stage})_{\text{it}} + \beta_4(\text{round type})_{\text{it}} + \beta_5 \log(1+\text{prominent partners})_{\text{it}} + \varepsilon_{it} \quad (1)$$

The second set of regressions estimates the particular impact of software patent applications on software companies' valuations by estimating the following equation for software companies:

$$\log(valuation)_{it} = \beta_0 + \gamma_i + \delta_t + \beta_1 \log(1+\text{patent applications})_{\text{it}} + \beta_2 \log(1+\text{software patent applications})_{\text{it}} + \beta_3(\text{age})_{\text{it}} + \beta_4(\text{company stage})_{\text{it}} + \beta_5(\text{round type})_{\text{it}} + \beta_6 \log(1+\text{prominent partners})_{\text{it}} + \varepsilon_{it} \quad (2)$$

4.2.2. 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, we use the acquisition amount. The valuation data come from the IVC database. The key dependent variables are the cumulative stocks of patent applications and granted patents, taken from the USPTO database.

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, we 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.[17] Finally, we included year dummies for each year in which a financing round took place. In Table 3, we summarize information about the variables used in the round-level regressions, and in Tables 4 and 5 we report the bivariate correlations for the variables in the software and non-software sectors.

----- Insert Tables 3, 4 and 5 about here -----

5. Results and Discussion

The results of the multivariate regression analysis of equation (1) appear in Table 6. Once we remove observations with missing control variables we end up with a sample of 129 software companies, who received 376 funding rounds, and 188 non-software companies, who received 604 funding rounds during the sample period. We use a log-log functional form,

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[17] 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*.

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. This approach reduces the risk that unobserved, time-invariant differences across firms, which likely correlate with the independent variables, bias the empirical results.

-----Insert Table 6 about here-----

The results show a positive and significant association between either patent applications or granted patents and valuations for non-software companies. In the first regression, the doubling of patent application stock is associated with a 45% increase in these firms' valuations and a doubling of their granted patents stock (which is smaller) is associated with a 22% increase.

Interestingly, in the case of software companies, neither patent applications nor granted patents have any significant impact on these companies' valuations.

The coefficients on the control variables for both sectors are as expected. The coefficients for the *R&D*, *Initial Revenues*, and *Revenue Growth* stages are positive and significant compared with the omitted category, which 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. Alliances or investments by prominent corporate entities have positive and significant impacts on valuations.

The only significant difference between the two sectors relates to the coefficient on *Acquisition/Merger Round*. In the case of non-software companies, this coefficient is not different from zero, supporting the hypothesis that an acquisition or a merger is a liquidity event which might indicate either success or failure (Hsu and Ziedonis 2008). In the case of software companies, on the other hand, this coefficient in positive and significant, suggesting that for software companies an acquisition or merger is a positive liquidity event. This result probably reflects the fact that exit by acquisition is a more common strategy for successful Israeli software companies and that the costs incurred by software entrepreneurs and investors prior to the liquidity event are lower than in other sectors, rendering the profit made at the time of exit - higher.

To test whether patents might have a significant impact on the financing of software start-ups in different revenue stages or financing rounds, we ran two additional regressions. In the first regression, the patent variable was interacted with the *Round Type* variable and in the second regression it was interacted with the *Company Stage* variable, where *Seed* and *R&D* were defined as *Pre-Revenue* stages and *Initial Revenues* and *Revenue Growth* – as the *Revenue* stages. We present the results of these regressions in Table 7.

-----Insert Table 7 about here-----

The patent variable used in these regressions is the cumulative stock of patent applications. Using the cumulative stock of granted patents renders the coefficients on the patent variables smaller, but the qualitative results remain unchanged: patents are found to have no significant impact on software companies' valuations at any stage of their financing or revenue-generating cycles.

We next turn to the empirical estimation of equation (2), which examines the association between software patent applications and software companies' valuations. From here onwards we focus on patent applications rather than grants because of the relatively short product life-cycle of software and the contemporaneous observability by outsiders. The results of this estimation are presented in Table 8.

----- Insert Table 8 about here -----

The results reveal an interesting finding. While the overall cumulative stock of patent applications has no significant association with software companies' valuations, the coefficient on their stock of *software patent applications* is positive and significant. This result suggests that the technological content of the start-up's patent portfolio is important. Patents differ not only in their potential economic value, but also in terms of fit with the core technological capabilities of the company, which are considered a source of long-term competitive advantage for the firm (Prahalad and Hamel, 1990). Munari and Toschi (2007) find that in a sample of nanotechnology start-ups, companies with a higher number of patents related to their core technological capabilities tend to receive a higher amount of VC funding. At the same time, the simple number of patents applied for by the companies is found to have no significant impact on the amount of financing. Our results suggest similar findings for the software industry.

We performed two additional regressions which included interaction terms between the software patents variable and the financing rounds and revenue stages variables. These results are presented in Table 9.

----- Insert Table 9 about here -----

Unlike the results in Mann and Sager (2007) which find that the value of patents for software start-ups first becomes significant as they begin to generate revenues, we find a large and positive impact of software patent applications on firm value also for firms in their seed or R&D stages. Statistically, the coefficients on the interaction terms of software patents with pre-revenue and revenue stage dummies are not different. It is possible that the difference between our results and those of Mann and Sager (2007) stems from the fact that their analysis uses the total count of patents rather than the count of software patents.[18]

The results of the second regression in Table 9 indicate that software patents are particularly valuable for start-ups at the time of their exit by acquisition. Cockburn and MacGarvie (2009) find that having patents increases the likelihood of software start-up firms to experience an exit event. They also assert that holding patents increases their ability to use them in cross-licensing negotiations, to defend themselves against litigation or more generally, to obtain better terms in any licensing negotiation. Our results support the conjecture that patents may also assist in negotiations

[18] Their sample includes a total 45 Class/Sub-Class combinations, among which are the three Class/Sub-Class combinations included in the GM definition of "software patents". Therefore, at most, only 67% of the patents in their sample would conform to the "software" definition. Furthermore, since the three Class/Sub-Class combinations probably include groups that are not included in the GM definition, this percent is likely to be much lower.

with potential acquirers and in obtaining better acquisition values. Considering the fact that the asset being sold by a software target company is intangible, being able to demonstrate propriety claims to it is critical. Software is typically cumulative and composed of various components which may come from a number of different sources, so that the combination and recombination of inputs is an essential part of its creation. It is therefore extremely important for acquiring companies to be certain of the nature and scope of the proprietary rights attached to their acquisition. Overall, our results support Cockburn and MacGarvie's (2009) general conclusion that patents may act to reduce the transaction costs associated with operating in a "thicketed" market.

Our results are also in line with the role attributed to IPR in promoting markets for technology. The work of Arora and Merges (2004) provides strong theoretical basis for the understanding that the availability of patents will facilitate the entry of smaller firms contributing technology to products assembled by larger firms. If the optimal structure for complex cumulative innovation is a structure in which a relatively large group of small firms develops components that are integrated into products or used in the delivery of services provided by larger firms, then the ability of patents to foster that structure is an important benefit.

Considering the small average number of patents per firm in the software sector, we performed the regressions presented in Tables 8 and 9 using a dummy for whether the company in question had ANY software or general patents, instead of the previous log-log specification. The results of these regressions are presented in Tables 10 and 11.

-----Insert Tables 10 and 11 about there-----

In all the regressions, we find that the coefficients on the different patent and software patent variables are very similar to those of the log-log regressions. These results are in line with Mann and Sager's (2007) findings that it is the fact of having patents or not rather than the number of patents that matters for companies' financing. They also support Hall and MacGarvie's (2009) assertion about public software firms: "while the marginal software patent filed may not be associated with much increase in market value, the decision of whether or not to patent at all seems to have been an important one."

6. Conclusion

The main goal of this paper has been to examine the relationship between the patenting and financing activities of software start-up firms. On the one hand, considering the intangible nature of their product, one would assume that property rights would enhance software start-ups' ability to interact with external resource providers. On the other hand, the relatively low quality of software patents and the uncertainty in litigation which surrounds them might render them a noisy and perhaps worthless signal to investors and acquirers.

Our analysis of a new dataset on the financing and patenting activities of Israeli software start-up firms during the past 15 years reveals that, unlike the case in other sectors, the overall number of patents held by software start-ups does not influence their value. At the same time, we do find strong evidence that software patents, which are, presumably, more reflective of these companies' core technologies, have a large and positive impact on valuations, although it is the fact of having any software patents at all which is more important than their number . In addition, our results suggest that holding software patents is particularly beneficial for start-up firms at the stage in which they become targets for acquisitions and might assist them in their negotiations with potential acquirers.

We cannot estimate the overall impact that software patents have had on societal welfare nor can we resolve the debate of whether these patents foster or stifle innovation and entrepreneurship. Our results do provide however, new evidence to the effect that for software start-up firms operating in the post-1995 “thicketed” markets, holding software patents is an advantage.

Further research could assess the impact of software patents on non-software start-ups to provide a more complete picture of the impact of these patents on start-up companies in general. In addition, employing supplementary data on VCs’ specialization fields could help in assessing whether software patents are more highly valued by VCs specializing in investments in this area. Finally, the business and technological focus of the acquiring firms could be assessed by examining these companies’ patent portfolios and matching them with those of the acquired firms. This information could help assess the IP strategy behind the acquisition of targets with patents in particular technological classes.

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Table 1: patenting statistics – software and non-software companies

	no. of companies	mean applications per company	% of companies with at least one application (before last observation)
IT& Entreprise Software	101	1.7	51%
Communications Software	37	1.6	51%
Internet	25	1.0	40%
Software Technologies	***163***	***1.6***	***49%***
Life sciences	83	7.0	88%
Semiconductors	41	10.5	85%
Communications	81	4.5	68%
Cleantech	4	4.5	100%
Non-Software Technolgies	***209***	***6.7***	***80%***

Table 2: software patenting statistics – software companies

	no. of companies	mean software applications per company	% of companies with at least one application (before last observation)
IT& Entreprise Software	101	1.1	42%
Communications Software	37	0.7	27%
Internet	25	0.7	28%
Software Technologies	***163***	***1.0***	***36%***

Table 3. Summary Statistics and Variable Definitions

VARIABLE	DEFINITION	Non-Software		Software	
		MEAN	S.D	MEAN	S.D
Pre-money valutaion	VC pre-money valuation (share price*shares outstanding prior to venture round) of the focal round, deflated to 2008 prices	58.1	98.1	46	78.9
Patent Applications	Cumulative patent application stock at the time of the funding round	4.52	9.6	1.1	2.7
Patent Grants	Cumulative patent stock at the time of the funding round	1.7	5.8	0.27	0.95
Software Patent Applications	Cumulative patent application stock at the time of the funding round			0.6	1.7
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	4.16	3.62
Early stage round	Dummy=1 if funding round is classified as Seed, 1st of 2nd round	0.58	0.49	0.63	0.48
Late stage round	Dummy=1 if funding round is classified as 3rd round or above	0.23	0.42	0.18	0.38
Acquisition/merger round	Dummy=1 if the focal funding round involved an acquisition/merger	0.11	0.31	0.17	0.37
IPO round	Dummy=1 if the venture achieved an initial public offering	0.08	0.27	0.023	0.15
Seed stage	Dummy=1 if the venture is in its early days of product development and fund raising	0.11	0.31	0.13	0.34
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	0.5	0.46	0.5
Initial revenues stage	Dummy=1 if the venture has revenues which do not exceed $10 million dollars	0.24	0.43	0.27	0.45
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	0.14	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	0.39	0.74
Funding year controls	A dummy=1 for each of the years when the financing round occurred between 1995 and 2009				

Table 4. Bivariate Correlations – Software Companies

	Valuation	Patent Applications	Patents Granted	Software Patent Applications	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	0.0654	1												
Patents Granted	0.023	0.4817*	1											
Software Patent Applications	0.0891	0.9162*	0.3994*	1										
Seed Stage	-0.1894*	-0.1457*	-0.1281*	-0.1244*	1									
R&D Stage	-0.1313*	-0.2157*	-0.2012*	-0.1907*	-0.3631*	1								
Initial Revenue Stage	-0.0111	0.1673*	0.2101*	0.1322*	-0.2394*	-0.5801*	1							
Revenue Growth Stage	0.4059*	0.2476*	0.1499*	0.2355*	-0.1463*	-0.3546*	-0.2337*	1						
Early Financing Round	-0.3811*	-0.2812*	-0.2936*	-0.2489*	0.2931*	0.4666*	-0.4214*	-0.4324*	1					
Late Financing Round	0.1096*	0.1841*	0.1091*	0.1649*	-0.1819*	-0.2054*	0.2347*	0.1776*	-0.6206*	1				
Acquisition/Merger Round	0.3151*	0.1804*	0.2615*	0.1643*	-0.1653*	-0.3564*	0.2627*	0.3507*	-0.5641*	-0.2007*	1			
IPO Round	0.1928*	-0.011	0.0434	-0.0273	-0.0606	-0.0772	0.0588	0.0986	-0.2068*	-0.0736	-0.0669	1		
Prominent Partners	0.1260*	0.1442*	0.0767	0.1745*	-0.1599*	-0.1675*	0.1090*	0.2680*	-0.2590*	0.2103*	0.1535*	-0.0585	1	
Age	0.2476*	0.2181*	0.3377*	0.1877*	-0.3759*	-0.3520*	0.3186*	0.4828*	-0.5675*	0.2395*	0.3879*	0.2539*	0.1720*	1

* Indicates statistical significance at the 5% level.

Table 5. Bivariate Correlations – Non-Software Companies

	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 6. Valuation Fixed-Effects Ordinary Least Squares Regression

Independent Variables	Dependent Variable: Log Valuation			
	Non-Software		Software	
Log Patent Applications	0.483***		0.117	
	(0.10)		(0.15)	
Log Patents Granted		0.224**		0.0457
		(0.10)		(0.22)
R&D	0.982***	1.121***	1.090***	1.111***
	(0.14)	(0.15)	(0.17)	(0.17)
Initial Revenues	1.080***	1.261***	1.228***	1.251***
	(0.21)	(0.21)	(0.25)	(0.25)
Revenue Growth	1.030***	1.259***	1.735***	1.773***
	(0.28)	(0.28)	(0.34)	(0.34)
Early Round	-0.339**	-0.417***	-0.557***	-0.577***
	(0.14)	(0.14)	(0.19)	(0.19)
Acquision/Merger Round	0.106	0.0146	0.430**	0.403**
	(0.17)	(0.17)	(0.21)	(0.20)
IPO Round	0.756***	0.684***	0.752*	0.715*
	(0.20)	(0.21)	(0.42)	(0.42)
Log Prominent Partners	0.512***	0.670***	0.594***	0.612***
	(0.16)	(0.16)	(0.20)	(0.20)
Age	-0.0625	-0.0296	-0.173	-0.169
	(0.14)	(0.15)	(0.19)	(0.19)
Year Dummies	Yes	Yes	Yes	Yes
Constant	1.412	1.449	-0.73	-0.721
	(0.92)	(0.95)	(2.34)	(2.37)
Observations	604	604	376	376
R-squared	0.47	0.44	0.51	0.51
Number of id	188	188	129	129
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table 7. Software Sector: Valuation Fixed-Effects OLS Regression

Independent Variables	Dependent Variable: Log Valuation	
Log Applications*Pre-Revenue Stage	0.259	
	(0.21)	
Log Applications*Revenue Stage	0.0631	
	(0.16)	
Log Applications*Early Round		0.189
		(0.20)
Log Applications*Late Round		-0.015
		(0.19)
Log Applications*Acquisition/Merger Round		0.26
		(0.20)
Log Applications*IPO Round		-0.22
		(0.81)
R&D	1.069***	1.083***
	(0.17)	(0.17)
Initial Revenues	1.297***	1.239***
	(0.26)	(0.25)
Revenue Growth	1.816***	1.753***
	(0.35)	(0.34)
Early Round	-0.547***	-0.672***
	(0.19)	(0.22)
Acquisition/Merger Round	0.431**	0.211
	(0.21)	(0.28)
IPO Round	0.767*	0.884
	(0.42)	(0.64)
Log Prominent Partners	0.580***	0.563***
	(0.20)	(0.21)
Age	-0.192	-0.181
	(0.19)	(0.19)
Year Dummies	Yes	Yes
Constant	-0.453	-0.703
	(2.36)	(2.36)
Observations	376	376
R-squared	0.512	0.514
Number of id	129	129

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

Table 8. Software Sector: Valuation Fixed-Effects OLS Regression

Independent Variables	Dependent Variable: Log Valuation
Log Patent Applications	-0.323
	(0.23)
Log Software Patent Applications	0.713**
	(0.29)
R&D	1.075***
	(0.17)
Initial Revenues	1.159***
	(0.25)
Revenue Growth	1.577***
	(0.34)
Early Round	-0.551***
	(0.19)
Acquision/Merger Round	0.439**
	(0.20)
IPO Round	0.712*
	(0.42)
Log Prominent Partners	0.556***
	(0.20)
Age	-0.114
	(0.19)
Year Dummies	Yes
Constant	-1.055
	(2.32)
Observations	376
R-squared	0.523
Number of id	129

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

Table 9. Software Sector: Valuation Fixed-Effects OLS Regression

Independent Variables	Dependent Variable: Log Valuation	
Log Applications	-0.328	-0.211
	(0.23)	(0.22)
Log Soft.Applications*Pre-Revenue Stage	0.875**	
	(0.38)	
Log Soft.Applications*Revenue Stage	0.689**	
	(0.29)	
Log Soft.Applications*Early Round		0.524
		(0.34)
Log Soft.Applications*Late Round		0.29
		(0.32)
Log Soft.Applications*Acquisition/Merger Round		0.823***
		(0.30)
Log Soft.Applications*IPO Round		1.128
		(0.91)
R&D	1.059***	1.095***
	(0.17)	(0.17)
Initial Revenues	1.197***	1.241***
	(0.26)	(0.25)
Revenue Growth	1.626***	1.666***
	(0.35)	(0.34)
Early Round	-0.536***	-0.659***
	(0.19)	(0.21)
Acquisition/Merger Round	0.443**	0.12
	(0.20)	(0.25)
IPO Round	0.713*	0.427
	(0.42)	(0.51)
Log Prominent Partners	0.555***	0.555***
	(0.20)	(0.20)
Age	-0.121	-0.131
	(0.19)	(0.19)
Year Dummies	Yes	Yes
Constant	-1.019	-0.573
	(2.32)	(2.32)
Observations	376	376
R-squared	0.524	0.53
Number of id	129	129
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Table 10. Software Sector: Valuation Fixed-Effects OLS Regression

Independent Variables	Dependent Variable: Log Valuation
D. Patent Applications	-0.308
	-0.255
D. Software Patent Applications	0.738***
	-0.276
R&D	1.073***
	-0.168
Initial Revenues	1.136***
	-0.249
Revenue Growth	1.586***
	-0.338
Early Round	-0.563***
	-0.188
Acquisition/Merger Round	0.453**
	-0.201
IPO Round	0.774*
	-0.417
Log Prominent Partners	0.604***
	-0.2
Age	-0.16
	-0.186
Year Dummies	Yes
Constant	-1.152
	-2.316
Observations	376
Number of id	129
R-squared	0.526

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

Table 11. Software Sector: Valuation Fixed-Effects OLS Regression

Independent Variables	Dependent Variable: Log Valuation	
D. Applications	-0.299	-0.195
	(0.26)	(0.25)
D. Soft.Applications*Pre-Revenue Stage	0.689**	
	(0.34)	
D. Soft.Applications*Revenue Stage	0.755***	
	(0.29)	
D. Soft.Applications*Early Round		0.515
		(0.32)
D. Soft.Applications*Late Round		0.27
		(0.33)
D. Soft.Applications*Acquisition/Merger Round		1.095***
		(0.32)
D. Soft.Applications*IPO Round		0.906
		(0.88)
R&D	1.077***	1.082***
	(0.17)	(0.17)
Initial Revenues	1.123***	1.195***
	(0.26)	(0.25)
Revenue Growth	1.571***	1.634***
	(0.34)	(0.34)
Early Round	-0.564***	-0.677***
	(0.19)	(0.21)
Acquisition/Merger Round	0.454**	0.019
	(0.20)	(0.26)
IPO Round	0.779*	0.513
	(0.42)	(0.51)
Log Prominent Partners	0.605***	0.572***
	(0.20)	(0.20)
Age	-0.155	-0.135
	(0.19)	(0.19)
Year Dummies	Yes	Yes
Constant	-1.213	-1.542
	(2.33)	(2.32)
Observations	376	376
R-squared	0.526	0.537
Number of id	129	129

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