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Patents, Venture Capital, and Software Start-ups

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Patents, venture capital, and software start-ups

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Abstract

This paper analyzes the relation between the patenting behavior of startup firms and the progress of those firms through the venture capital cycle. Linking data relating to venture capital financing of software startup firms with data concerning the patents obtained by those firms, we find significant and robust positive correlations between patenting and several variables measuring the firm's performance (including number of rounds, total investment, exit status, receipt of late stage financing, and longevity). The data also show that (1) only about one in four venture-backed software firms acquired even one patent during the period of the study; (2) patenting practices very considerably among the sub-sectors of the software industry; and (3) the relationship between patent metrics and firm performance depends less on the size of the patent portfolio than on the firm's receipt of at least one patent.

Keywords: Software; Patents; Venture capital; Start-ups; High-technology

1. Introduction

Throughout their relatively short histories, the software and venture capital industries have been intertwined. Formed in the mid-1960s, the software industry grew rapidly throughout the 1970s, and by the 1980s the United States had a large and well-developed software industry with more than one thousand firms.[1] Software firms enter and exit the industry with great frequency, and, evidenced by the size and frequency of investments, the venture capital model seems to work quite well for these firms.

The modern venture capital industry started modestly shortly after World War II. As recounted in Gompers and Lerner (2001), the industry struggled through a series of boom-and-bust cycles until the end of the 1970s. However, since about 1980, the modern model of syndicated limited partnerships investing funds largely derived from pension portfolios has transformed early-stage finance by increasing the availability of capital to young and risky firms. The potential for high growth rates and high operating margins attracts venture capitalists to firms touting highly innovative products, despite the absence of physical assets or operating histories necessary to obtain investment through traditional sources. Thus, the availability of venture capital likely has contributed both to the rapid pace of innovation and to the fragmented structure of the software industry.

As these industries have matured, the intellectual property protections available for software have shifted as well. From the mid-1960s when the Copyright Office formally decided to permit registration of computer programs through the late 1980s, copyright provided relatively strong protection for software. Early the next decade, a series of appellate decisions narrowed the scope of copyright for broader structural features

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[1] Campbell-Kelly (2003).

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of computer programs. However, major firms in the industry by that time had already begun turning to patent protection. Then, beginning in the 1980s and coming to fruition by the mid-1990s, judicial opinions and administrative actions began to adopt a more expansive approach to the breadth and strength of software patents.

As of late, patents have become particularly controversial in the software industry. The recent spread of patents and the cost and frequency of litigation have raised concerns, not only in the United States, but also in the European Union and Japan. This article bypasses many of the important public policy questions that those controversies entail, and instead focuses on the question whether patents are valuable to the firms that have them. If patents do not have a positive value for the firms that acquire them, then it is unlikely that the net effects of the patent system are positive. This question is surprisingly difficult to answer.

Patents might have private value to firms if they help firms attract financing or if they allow firms to exploit the value of internal research and development investments. There has been a good deal of empirical work, predominantly dealing with relatively large companies, examining the relation between patent counts and R&D.[2] Similarly, we have some empirical information about the role of patents in the software industry in particular. The most detailed published study of the industry is Graham and Mowery's 2003 book chapter. Their work compares patent grants in certain IPC classes with R&D expenditures for large packaged-software firms. They conclude that the propensity to patent (measured in patents per $100M R&D dollars) rose by about 50% (from about 2.0 to 3.0) from 1988 to 1996.

Those contributions aside, the literature addressing the role of patents in small firms or in small software firms is underdeveloped, primarily due to the paucity of data. There are, however, good reasons to consider the role of patenting in software startups. The lack of concentration in the industry, for one thing, suggests that smaller firms play a significant role. Moreover, some data suggest that small firms in our economy contribute disproportionately to R&D investment and innovative activity.[3] One possible explanation from the industrial organization literature is that property rights facilitate an industrial structure in which relatively small firms develop pieces of products assembled by larger firms (Arora and Merges, 2004; Gans et al., 2002).

Mann (2005a) reports qualitative empirical work (a series of interviews of venture capitalists, lenders, and executives at software startups and large software firms) suggesting that patents have a variety of potential positive effects, depending on the stage of firm's development. For firms in the pre-revenue stage, patents have little or no value; investors at this stage generally pointed to product market experience and management acumen as being more pertinent to initial investment decisions. For revenue-generating startups, patents seem to have positive value (in limited sectors). Investors commonly referred to the need to identify firms that will have sufficient market power to earn profits. Investors in those firms regard patent protection as a tool that might provide sustainable differentiation. Patents have ambiguous value for larger firms in that they facilitate cross licensing so that large firms can maintain a competitive equilibrium with other large established firms.

In this paper, we turn to a quantitative analysis of the first two stages of that framework: the role of patents for pre-revenue and later-stage startups. Specifically, by analyzing patent and financing data for a group of software startups, we can learn more about the significance of patents for those firms. Although many features of the data are ambiguous and suggest avenues for further inquiry, they do suggest that patents play a role of some importance in the development of firms seeking to enter the software industry, albeit one that depends substantially on the type of firm.

Specifically, the data suggest that:

- Patent acquisition (or application) at the time of initial investment is largely irrelevant to the firm's subsequent progress through the venture capital cycle, measured by any metric.
- Patent acquisition is significantly correlated with any of several variables that are indicators of the firm's progress through the venture capital cycle (including number of rounds, total investment, and longevity).
- The rates of patenting differ substantially from sector to sector within the industry, indicating that even among software firms there are differences in the use of patents.

Section 2 of the paper explains the data and the methods that we use to analyze it. Section 3 presents the empirical findings. Section 4 analyzes the implications of the empirical findings. Section 5 is a brief conclusion.

[2] For e.g. Blundell et al. (1999), Cincera (1997), Crepon and Duguet (1997a,b), Montalvo (1997).

[3] NSF statistics suggest that small firms contribute about 20% of all private R&D funding. NSF, Science and Engineering Indicators 2006, available at http://www.nsf.gov/statistics/seind06/c4/c4s1.htm. Audretsch (1995) illustrates that small firms have a disproportionate share of innovative activity given their level of formal R&D expenditures.

2. Data

This paper responds to the gap in the literature discussed above, by analyzing the relation between the patenting practices of software firms and their acquisition of venture financing and progress through the venture capital cycle. Given the relative lack of data on private firms and in an effort to test the hypotheses developed in Mann (2005a), we decided that a study of venture-backed software firms – for which there is at least some data – would be a good proxy for a study of new entrants in the industry. This limitation seems reasonable considering that most software firms that have risen to prominence in recent years have relied on venture capital financing at some point in their development cycle.[4] (Gompers and Lerner, 2001; Cusumano, 2004).

The paper considers two different types of information about venture-backed software firms: information about their operations and information about their patents. This section of the paper discusses the methods of collecting data for that analysis. It proceeds in three steps: the selection of firms, the collection of performance data, and the collection of patenting data.

2.1. Selecting the firms

Our investment data were obtained from the VentureXpert database. VentureXpert is a proprietary database of Venture Economics, which is a division of Thomson Financial. Venture Economics receives quarterly reports on portfolio holdings from more than 1000 venture capital organizations and major institutional investors. The information includes several data points about the portfolio companies, including, among other things, a designation of the type of investment, name and location of the portfolio firm, date and amount of investment and the industry in which the firm competes.

We restricted the search to "venture-related" deals, which is defined as firms that received at least one venture stage investment from any kind of firm or one non-venture stage investment from a firm that traditionally focuses on venture capital. We also limited the search to United States investments. Because we wanted to analyze firms of similar ages and sizes, we restricted our search to firms that had received their first round of venture financing within a relatively narrow window of time.[5]

We also wanted to select a time recent enough that the experience of the firms and their patenting would be representative of current conditions in the industry. Because the legal significance of software patents changed during the early part of the 1990s, it was important to select a period that began some time well after 1995. At the same time, to allow sufficient time since first financing to have a fair sense of the outcome of the investments, it was important that the period not be too recent. Venture capital funds generally receive little or nothing on their investments until some cognizable liquidation event – bankruptcy, merger, IPO, or the like – that disposes of their investment at a single point several years after the investment. Because the value placed on the firm at that time is the main indicator of a successful investment—rather than cash flow during the intervening years (which is likely to be minimal or non-existent), a somewhat longer focus is appropriate. Thus, if we had selected a dataset of firms that received their initial funding after the market crash of 2001, too little time would have passed to provide any fair assessment of the results of the investments. We recognize that this means that our firms are situated within what might reasonably be called a "bubble" of investment practices that preceded the crash. But as we write it remains too soon to analyze the outcome of a substantial group of post-"bubble" investments.

Accordingly, we restricted the analysis to firms that received their first round of venture financing during 1997, 1998, or 1999. To limit the dataset to firms that actually were startups at that time, we included only firms whose first round was identified as seed, startup, early stage, first stage or other early (excluding firms whose first venture round was a late stage or expansion round, or an acquisition or debt round).

We defined the software industry broadly to include firms listed in the VentureXpert database (in the range 2700–2799) as well as firms listed in the Moneytree database (VEIC 1563, 2900, 2910, 2911, and 2990). The Venture Capital Yearbook reconciles the conflicting definitions of software firms. For purposes of this study, we have adopted the broadest definition, including all sectors that would be included in the industry under either the Moneytree definition or the VentureXpert definition. The selection criteria result in a dataset of 3,147 financing rounds in 877 firms.

[4] Prominent venture-backed companies include Intel, Microsoft, eBay and Google.

[5] If we extended the period during which the firms received funding, we could learn more about how the relationships we examine might have changed over time. But at the same time we would lose the analytical benefits of a dataset in which all of the firms began their life at substantially the same time. For the same reason, we have not performed year fixed effect regressions—the period over which we collected data is so short as to make that analysis seem superfluous.

For comparative purposes, we collected a parallel group of firms in the biotechnology industry (specifically, firms in the VEIC 4000 and 5500 series) that received their first round of venture financing during the same years. We selected biotechnology because it is both a sector of significant interest in the IP literature and because it is one of the largest sectors (other than software) of venture capital investment. That dataset includes 772 financing rounds in 212 firms. We report comparative results for those firms at relevant points in the paper below. As the literature would predict,[6] the results suggest that patents play a different role for biotech startups than they do for software startups.

2.2. Finance data

Our strategy was to determine whether we could find or reject a relation between patents, on the one hand, and some dependent variable indicative of the investment decision or the success of the investment. As suggested above, the underlying theory was that patents are related in some way to the decision to invest or to the ability of the firm to attract investment. We cannot of course obtain information on firms that never received venture financing, so we are not directly examining the question whether patents are important to the initial investment decision, a question as to which investors seem to have conflicting perspectives (Mann, 2005a). Rather, we are examining the question whether patents relate to subsequent investment decisions. Within the analytical framework developed in the prior work, that is an important distinction: the reasoning of Mann (2005a) suggests that patents should play at best an inconsistent role in the initial investment decision, but that their role should become increasingly important as firms advance through the venture financing cycle.

To investigate that problem, we collected several different pieces of information from VentureXpert. First, we collected details about the investment decisions, including the total amount of financing obtained by the firm, the dates of the financing rounds, and a designation of the stage of each financing round (starting with seed and startup, and ranging through other early stage, expansion, later stage, bridge financing, and open market financing). Second, we collected information about the performance of the investment, including a designation of the firm's status as defunct, acquired, existing, or public, as of January 2005. For public firms, we added the IPO date. For acquired firms, we included information on acquisition date and the value of the deal (if disclosed). Finally, to investigate the possibility that the role of patents might differ even within the software industry, we collected information about the state in which the company was located as well as a four-digit VentureXpert code designating the primary sector within the software industry in which each firm competed.

As it happens, the existing literature makes it clear that the VentureXpert database is incomplete (Kaplan et al., 2002). Both the VentureXpert and the competing VentureOne databases depend on voluntary contributions of information from venture capitalists. Their research suggests that both datasets have significant omissions. They do not suggest, however, any obvious reason to think that the omissions would lead to a selection bias relevant to our work. Cognizant of that problem, we collected from the VentureSource database parallel information about a similar set of firms. Specifically, we counted the number of rounds of financing that each of the firms obtained in the VentureSource database, and recorded the total investment in the firm and the status of the business as shown in the VentureSource database in August of 2003. Because that database is less complete and confirms the results from the VentureXpert analysis, we do not report that analysis here.

2.3. Patent data

Using Delphion, we collected information about the patents assigned to each firm in the dataset. For each firm, we collected the total number of patents, the date of the first patent application, and the date on which each patent was granted. The searches were run in January 2005, and were restricted to patents issued as of 31 December 2004. We used the company names and any alternate or former names shown in VentureXpert. This search methodology is underinclusive, because smaller firms tend to change names frequently. In addition, some firms receive patents by assignment. Where the firm names shown in Delphion and VentureXpert were similar but not identical, we made judgments based on city/state designations and technology area.

For a number of reasons, we primarily analyze data about issued patents rather than patent applications. Although we have collected all published patent applications for our study period, those data necessarily are incomplete. For much of the period governed by this dataset, there was no requirement that U.S. patent applications be published. Even for the period during which

[6] The existing literature centers on a debate over whether so many patents are issued as to create an "anticommons" that impedes startup formation. Compare Heller and Eisenberg (1998) (arguing that there is an anticommons) with Walsh et al. (2003) (arguing that there is not).

publication has become the norm, firms have the option to keep the application from being published, and it appears that many software firms (particularly smaller ones) routinely take advantage of that option. Thus, if we wished to study applications we could study at most a truncated set of applications matched to the patents that ultimately were issued.[7]

Moreover, except for a series of regressions based on whether firms had applications or patents before their first financing, all of our patenting variables examine a firm's patent portfolio as of the close of our data collection. Because our data is so highly skewed, and because we found no significance to the existence of pre-financing patents, it seemed unlikely to produce valuable information to examine further details about the time at which the patents were obtained.

Finally, although we collected citation data, we have not conducted any statistical analysis of how citation-weighted patents relate to the investment and performance metrics. Because the patenting practices of the firms are so highly skewed, and because the firms and their patents are so young – most of the patents are less than 2 years old – we are the skeptical of the value of such analysis.

3. Results

The purpose of the research is to examine the relation between patenting and venture capital investment and performance data. The data shed light on a number of related questions not previously examined in the literature. Accordingly, before we turn to that point, we provide descriptive information about patenting rates and differences in patenting by location and sector.

3.1. Patent rates and characteristics

The most surprising finding is that, despite policy debates about the pervasive impact of software patenting, most venture-backed software firms did not acquire any patents during the period of the study. About nine percent of the firms (75/877) had obtained a patent before their first financing. The number of firms with patents grew to about 24% (214/877) by 1 January 2005, between 5 and 8 years after the firms received their first rounds of venture financing. For comparative purposes, about 23% (49/212) of the parallel biotech firms had obtained a patent before their first financing and more than half (56% or 119 of 212) had obtained patents by the end of the study period. The biotech percentage probably understates the reliance of those firms on patented IP, because biotech startups are more likely to rely on in-licensed patented technology from universities.

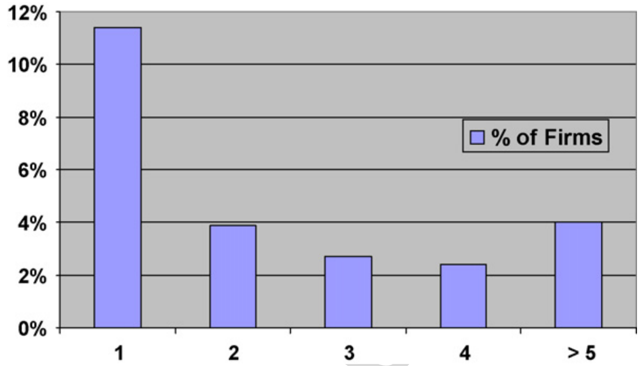

Fig. 1. Number of patents per firm. For clarity of presentation, the figure omits the 663 firms (76% of the total) that had no patents.

The 877 software firms have a combined 624 patents, for an average of 0.71 patents per firm. Among the firms that had patents, there was an average of 2.92 patents per firm. Fig. 1 illustrates the distribution by number of patents among the firms in the dataset that had patents.

The characteristics of the patents are diverse. International Patent Class (IPC) G06F [Electric Digital Data Processing] accounts for 384 (or 56%) of the patents in the dataset.[8] Table 1 shows the distribution of IPCs to patents in the dataset. No U.S. patent class accounted for more than 12% of the patents in the dataset.

The patents have an average of 27 claims; the average number of domestic references is just over 22 per patent, with this number steadily increasing over time from about 18 in 1999 to over 28 by 2003. Finally, the number of times that subsequent patents cite the patent in question (referred to as forward citations) as of January 2005 is just over five per patent.[9]

For comparative purposes, in the parallel biotechnology database, the 212 firms had 1161 patents, for an average of 5.48 patents per firm. Among the firms that had patents, there was an average of 9.76 patents per firm. Thus, the biotechnology industry not only has more

[7] We supplemented the applications data to include all of the applications filed through 2004 that had been published as of August 2006. Using that data, we ran a series of regressions designed to test whether there was any significance to filing an application before first financing. Those regressions were inconclusive.

[8] Compare Graham and Mowery (2003), which reports the IPCs of patents assigned to the largest firms in the software industry.

[9] We do not analyze the patents based on the number of references, citations, or claims, because the data is so highly skewed. One of us is undertaking that type of analysis in a related paper with a much larger dataset of software patents issued to a larger group of firms over a longer period.

Table 1
International patent class

Ipc	Type of invention	Number of patents	% of all patents
G06F	Electrical digital data processing	371	59.5
A61B	Medical diagnosis	24	3.8
H04L	Transmission of digital information	23	3.7
G06K	Recognition and presentation of data	23	3.7
G06T	Image data processing	20	3.2
H04B	Transmission of electronic communication	15	2.4
G01S	Radio direction-finding	14	2.2
H04M	Telephonic communication	13	2.1
H04N	Pictorial communication	12	1.9
G09G	Control of indicating devices to present information	9	1.4
G10L	Speech recognition	9	1.4
H04Q	Communication switches	9	1.4
Other	{33 other classes}	82	13.1
Total	–	624	100

patents but also has a significantly larger share of firms with larger patent portfolios. For example, only 2% of software firms had more than 4 patents, and less than 1% of software firms had more than 10 patents; 19% of biotechnology firms had more than 4 patents and 6% had more than 10 patents.

3.2. *The effect of location and industry group*

We analyzed information about the state in which the firms were located and the specific sector of the industry to see whether those variables correlated with the existence or number of patents. Generally, the data indicate no correlation with location, but a significant correlation related to industry sub-sector. The latter finding is consistent with the premise (discussed in Mann, 2005a) that firms in different sub-sectors of the software industry have different abilities to appropriate the value of an invention with a patent.

3.2.1. *Location*

We tested the role of location by looking for possible relations between the state in which the firm is located and several alternative dependent patenting variables: the number of patents, the existence of patents, the existence of multiple patents, and the issuance of patents before the first round.[10] The latter three are categorical dependent variables coded 1 (yes) and 0 (no); the number of patents is numeric. Location is a categorical independent variable, broken up into a number of 0–1 indicator variables for the domiciliary states of the firms.

To test the effect of location on number of patents, we used analysis of variance. To test the effect of location on the existence of patents and multiple patent indicators, we used a χ^2-test for independence. Table 2 shows the results. In general, there is no correlation between location and any of the patent variables.

For comparative purposes (and to test whether we should place any weight on the lack of correlation), we conducted a similar analysis of the biotech firms. The biotech data, by contrast, suggest that location has considerable significance, at least in relation to the first three patent variables identified above. One possible explanation is the connection between patenting and university affiliations in the biotech industry, so that location is relevant to patenting practices (Lowe and Ziedonis, 2006).

3.2.2. *Industry group*

We also tested the possibility that patenting practices might differ among the sub-sectors of the industry. For

Table 2
Location and patenting

Dependent variable	*P*-Value
Software	
Total patents	0.437
Patents/no patents (0–1)	0.186
Multiple patents/not (0–1)	0.286
Patent before round 1 (0–1)	0.128
Biotech	
Total patents	0.0179
Patents/no patents (0–1)	<0.001
Multiple patents/not (0–1)	<0.0001
Patent before round 1 (0–1)	0.707

[10] We also ran parallel analyses on patent applications filed before first financing. That information is less reliable because applications often do not become public unless they result in an issued patent. In any event, the results are similar to the analyses that we report patents issued before first financing.

Table 3
Industry group and patenting

Dependent variable	*P*-Value
Software	
Total patents	0.015
Patents/no patents (0–1)	0.012
Multiple patents/not (0–1)	0.014
Patent before round 1 (0–1)	0.032
Biotech	
Total patents	0.86
Patents/no patents (0–1)	0.95
Multiple patents/not (0–1)	0.89
Patent before round 1 (0–1)	0.076

this purpose, we grouped the firms by three-digit codes from the VentureXpert data, putting small groups in an "other" category. Again, we used indicators of patenting intensity as the dependent variable. As Table 3 displays, those results suggest a substantial relation between industry group and the metrics of patenting that we examine. The absence of such a relation in the biotech industry suggests that the biotech industry is for this purpose more homogenous than the software industry.

Those results suggest a number of things relevant to the role of patenting in the industry, the most obvious of which is that the appropriability of innovation through patenting is likely to differ markedly based upon the type of software development in which the firm is engaging. To explore the precise nature of the relationship, we interacted the patenting variables with the various industry group variables, but none of those regressions indicated any significant relationships and we do not report them here.

3.3. The relation between patenting and firm performance

The more difficult part of our inquiry is to consider the relation between patenting and various investment and performance metrics. We selected five separate metrics: the number of rounds of financing that the firm obtained, the total amount of financing that the firm obtained, the status of the firm as of 1 January 2005, whether the firm attained a late financing stage; and the longevity of the firm. The subsequent sections provide detailed analyses of the relations between those variables and patenting practices, but Tables 4 and 5 provide simple cross-tabulations for both industries, showing each of those metrics for firms with and without patents.

A more challenging problem is the difficulty of disentangling the possible causal relations among our variables. Neither the simple cross-tabulations nor the statistical analysis that we report below can distinguish between the possibility that patents facilitate progress through the investment cycle and the possibility that progress through the investment cycle facilitates the firm's ability to acquire patents. We attempted to resolve this problem with simultaneous equations, but were unable to obtain any definitive results, largely because we have no truly exogenous information for these small private firms.

Our research hypotheses suggest an ambiguous link between patenting and investment progress. On the one

Table 4
Cross-tabulation of performance data for firms with and without patents

	Firms with patents	Firms without patents
Financing rounds	4 (4.126)	3 (3.415)
S.D.	2.100	2.028
Total investment	$26M ($36M)	$15M ($25M)
S.D.	$34M	$30M
Exit status		
Defunct/liquidated	4%	8%
Existing	54%	63%
Acquired	30%	26%
Public/merger	13%	3%
Late-stage financing	27%	37%
Longevity (days)	2052 (1938)	1971 (1759)
S.D.	734	840
N	214	663

For financing rounds, total investment, and longevity, the table reports median values with means in parentheses.

Table 5
Cross-tabulation of performance data for biotech firms with and without patents

	Firms with patents	Firms without patents
Financing rounds	4 (4.336)	2 (2.753)
S.D.	2.096	2.083
Total investment	$32M ($40M)	$5M ($25M)
S.D.	$37.85M	$66.33M
Exit status		
Defunct	7%	6%
Existing	57%	75%
Acquired	14%	13%
Merger/public	22%	5%
Late-stage financing	30%	13%
Longevity (days)	2294 (2073)	2295 (2043)
S.D.	755	812
N	119	93

For financing rounds, total investment, and longevity, the table reports median values with means in parentheses.

hand, venture financing contributes to the ability of startup firms to apply for patents in several ways; the venture capitalist facilitates patenting both by providing funds and by providing management expertise to assist the portfolio firm in the development process. On the other hand, the interviews reported in Mann (2005a) suggest that patents (or the prospect of patents) often can be useful in obtaining funding. Most obviously, patents can solve one of the most difficult problems for a startup: convincing the venture capitalist that the startup can sustainably differentiate itself from its competitors. Similarly, as the firm advances through the venture capital cycle, patents often are useful to protect the firm against larger incumbent firms that might try to drive the startup from the market. Many investors also value patents because of information they convey about the operational competence of the firm's management. On rare occasions, patents might generate licensing revenues, but that is quite uncommon for software startups and rarely, if ever, the ex ante aim of a venture capital investment.

A related issue is the likelihood that the factors that cause or permit a firm to obtain a patent (e.g., organizational competence, valuable technology, etc.) will be closely related to the factors that allow it to succeed. For example, the patent serves as a proxy for both the innovation and the legal protection. We cannot untangle whether the patent or the technology that it covers best explains the results that we report. In the absence of a natural experiment to compare firms that do or do not obtain patent protection upon identical technologies, it is difficult to resolve those problems definitively. Our hypothesis, based on the interviews in Mann (2005a), is that technology explains a great deal of the variation in the outcome of venture capital investments but that patents (and other IP, broadly defined) play a role of considerable importance.

Subject to those caveats, our findings suggest that the factors that make it possible for firms to obtain patents and motivate them to obtain patents relate to the factors that allow venture-backed software firms to progress through the venture capital cycle. The results are stable across a variety of performance metrics. We emphasize that the results we report below have a low explanatory power. That does not surprise us, however, given the numerous reasons (detailed in Mann, 2005a) that venture-backed firms might perform well or poorly that have nothing to do with patents. It is important to take account of the low explanatory power in trying to understand what the data suggest about the real world of investment decision making and venture-backed firm performance.

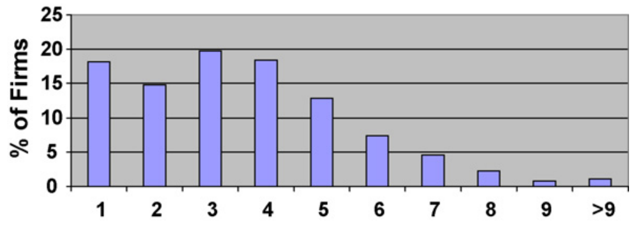

Fig. 2. Rounds of financing.

3.3.1. *Rounds of financing*

Both VentureXpert and VentureOne include data about financing rounds. Because the structure of venture capital financing gives venture capitalists a realistic opportunity to terminate firms after each round, and makes each additional round a substantial indicator of progress, the number of rounds is a good proxy for performance (Gompers and Lerner, 2001). We do not have a dataset of firms that failed to obtain even one round; thus, we necessarily are testing the total number of rounds among firms that obtained at least one round.

Unfortunately, it is clear that the data on financing rounds are incomplete, in the sense that the two datasets include information about different financing rounds.[11] VentureOne representatives suggested that a portion of the difference might be attributable to different protocols for what constitutes a financing round. Specifically, VentureXpert might report as separate financing rounds a series of closely connected disbursements that VentureOne might treat as separate tranches of a single round. That explanation is not consistent with the data we collected, which in fact indicate a slightly *higher* number of financing rounds in the VentureOne database than in the VentureXpert database (3.3 per firm versus 3.1 per firm, comparing for the matching periods). In any event, it is clear that the discrepancies are much more pervasive (as shown by examination of the dates and stages of the particular rounds). Thus, it is clear that both databases fail to include a substantial number of financing rounds. Nevertheless, because the databases produced similar results, we are less concerned that a selection bias might undermine our results.[12]

We start with some descriptive information about VentureXpert's data on financing. More than 80% of the firms received a second round. The number of rounds ranged from one to fourteen; Fig. 2 illustrates the distri-

[11] Kaplan et al. (2002) provides empirical evidence of the differences between the two competing datasets.

[12] We examined the relation between patenting and financing rounds using both the VentureXpert and VentureOne databases. Because they are similar to the VentureXpert results, we do not report the VentureOne results here in detail.

Table 6
Patenting and rounds of financing

Independent variable	*P*-value (regr.)	Expl. power (regr.) (%)	Coeff. (rounds/unit)
Number of patents	<0.0001	1.89	0.144
Patents/no patents (0–1)	<0.0001	2.19	0.71
Multiple patents (0–1)	0.0008	1.28	0.69
Patent issued before round 1 (0–1)	0.76	0.0102	n/a

The dependent variable is the number of rounds of financing.

Table 7
Patenting and total investment

Independent variable	*P*-Value (regr.)	Expl. power (regr.) (%)	Coeff. ($M/unit)
Number of patents (0–1)	<0.0001	2.95	2.745
Patents/no patents (0–1)	<0.0001	2.10	10.7
Multiple patents (0–1)	<0.0001	1.95	13.1
Patent issued before round 1 (0–1)	0.2276	1.166	n/a

The dependent variable is the total investment in the firm.

bution of financing rounds in detail. The firms in the dataset had an average of 11 different investors and received a total of $24 billion (or an average of $27.5 million per firm).

Table 6 reports the statistical analysis. As it shows, the data indicate a relationship between number of financing rounds and number of patents significant at the 1% level, for the other postfinancing variables at beyond the 0.01% level, but no significant relation for the prefinancing metric. To get a sense of the significance of the relationship, the coefficients suggest that each additional patent relates to 0.144 rounds, and that having at least one patent relates to 0.71 additional rounds. Parallel analysis of the biotech data (not reported here) indicated relationships of similar significance. Parallel analysis of the VentureOne data (not reported here) indicated a relationship significant at the 5% level for the patents/no patents variable, but no significant relationship for the number of patents or multiple patents metrics.

3.3.2. Total amount of financing

The second performance variable is the total amount of financing that the firm eventually obtains. This variable is somewhat different in its meaning from number of rounds of financing, because the total amount of investments probably relates more directly to the firm's overall performance, where the number of rounds might have a closer relation to the success of the venture capitalist's investment in the firm. Still, as Table 7 indicates, the results are similar to the results reported above for number of rounds. The coefficients suggest that an increase of one in the total number of patents is related with an increase of $2.7M in total investment, so that firms with patents receive about $10.7M more in total investment than those without.

3.3.3. Exit status of the firm

Another indicator of firm performance is the ability of the firm to exit the venture capital cycle successfully. Thus, a firm that has failed between the time of its first financing and the data collection for this project can be treated as a less successful investment than a firm that continues to operate at this time. This is a difficult metric because it is harder to quantify "success" than it is to quantify the amount of financing. For purposes of analysis, we aggregated the VentureXpert data into four categories: defunct (including liquidated and bankrupt firms), existing, acquired, and public (including mergers and those in registration). As Fig. 3 shows, more than half of the firms remained in private hands and thus had not exited, 10% of the firms had been acquired, 5% had gone public, and only 7% are shown as having failed. Interestingly enough, about three times the share of biotech firms had gone public (15%) as software firms (5%).

The analysis of exit status (summarized in Table 8) parallels the prior analyses. Again, the analysis suggests significant relations between exit status and all of the

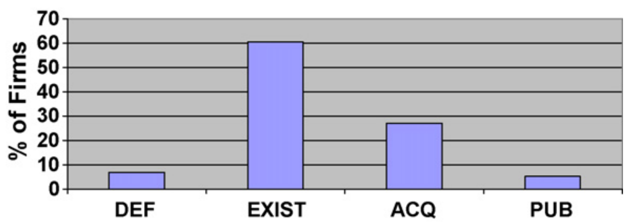

Fig. 3. Exit status.

Table 8
Patenting and exit status

Patenting variable	*P*-Value	Explanatory power (%)
Total patents	<0.0001	3.75
Patents/not (0–1)	<0.0001	3.84
Multiple patents (0–1)	<0.0001	3.11
Patent issued before round 1 (0–1)	0.016*	1.18

The analysis is a MANOVA, for the dependent variable, exit status, is a multi-valued categorical variable. In effect, the MANOVA converts exit status into a series of 0–1 indicator variables – one for each type of exit status – and then finds the linear combination of the indicators that correlates best with the independent variable. The regression of that linear combination on the independent variable yields the *P*-value and explanatory power reported above.

post-financing patent variables. The biotech data (not reported here) indicate similar relations. Perhaps the most interesting finding not evident from the table is that in both industries most of the significance for the post-financing patenting variables comes from differences in the share of firms with patents that went public compared to the share of firms without patents that went public.

3.3.4. Late-stage financing

The next metric of firm performance that we investigated was the ability of the firm to obtain late-stage financing. The VentureXpert database includes a categorization of the type of financing represented by each round of financing. The Venture Capital Yearbook includes a description of those categories that divides them into early, expansion, and late stage financing. Generally, early stage financing supports product development, market research, and the development of a business plan. Expansion financing involves working capital for a firm that has begun to produce and ship products. Later stage financing primarily involves firms with positive cash flow and a stabilized growth rate. Fig. 4 shows how the latest stage of financing that each firm obtained falls within that categorization.

Assuming that a firm that develops far enough to obtain late-stage financing is a better investment than a firm that does not ever develop to that stage, we analyzed

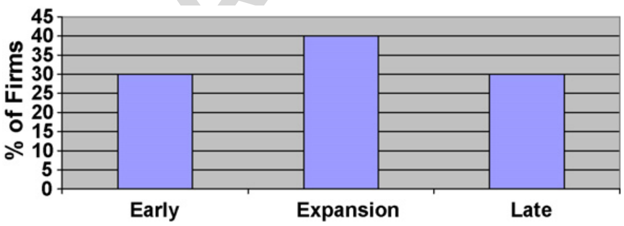

Fig. 4. Latest stage of financing.

Table 9
Patenting and late-stage financing

Patenting variable	*P*-Value	Explanatory power (%)
Total patents	<0.0001	2.40
Patents/not (0–1)	<0.0001	2.70
Multiple patents (0–1)	0.0009	1.63
Patent issued before round 1 (0–1)	0.26	0.32

As in Table 8, the analysis is a MANOVA, for the dependent variable, late-stage financing, is a multi-valued categorical variable.

the relation between that data and the various patenting metrics. We also used an adjusted metric, which removed treatment of "bridge" financing as late-stage financing. That metric relied on our view that bridge financing should not count as evidence of a firm's success. In each case, we perform a MANOVA, supplemented with a χ^2-test for independence (not shown). Both metrics produced similar results, indicating significant relations between the latest stage of financing obtained and the post-financing patenting variables. Table 9 summarizes the results for the adjusted metric. In this case, the analysis suggests that the significance comes from the early-stage category: the effects of patents are plainest in differentiating between firms that move on to the expansion stage and those that do not. This provides some support for the hypothesis that the value of patents for software startups first becomes significant as they reach the stage at which they begin to generate revenues.

3.3.5. Longevity and patenting

The last variable that we examined was longevity. In some contexts, longevity alone might not be characterized as success. Consider a public firm, for example, with earnings growth and a return on investment that are both lower than those for other firms in the same industry. In the context of a venture-backed firm, however, longevity alone is a reasonable indicator of success, because it generally suggests that the firm is making sufficient progress to avoid being liquidated by its venture capital investors.[13]

Unfortunately, longevity is not an easy variable to analyze directly because it is difficult to measure either the beginning or end of these firms. For the beginning point, we can use the date of the first venture capital financing as a reasonable proxy that at least measures a similar point in the life cycle of each firm. The end point is much more difficult, given the lack of data for when the firm fails. Ultimately, we decided to assign a number

[13] For details on that process, see Mann (2005b).

Table 10
Patenting and longevity

Independent variable	*P*-Value (regr.)	Expl. power (regr.) (%)	Coeff. (days/unit)
Number of patents	0.0013	1.1834	45
Patents/no patents (0–1)	0.0054	0.8830	179
Multiple patents (0–1)	0.0190	0.6275	193
Patent issued before round 1 (0–1)	0.2431	0.1557	n/a

The dependent variable is the days of longevity, as defined in the text.

of days to the various VentureXpert status categories, as indicated below, resting on the assumption that no firm is likely to fail within 6 months of getting financing. Although the numbers will not be perfect, we thought that they would put firms in a plausible series based on longevity:

- *Existing*: months from first financing to 1 January 2005.
- *Unknown or defunct*: months from first financing to 6 months after last financing.
- *Acquired*: months from first financing to the later of last financing or acquisition date.
- *IPO*: months from first financing to 1 January 2005. This assumes that all IPO firms were alive as of 1 January 2005, which might be wrong, but it is a better assumption than assuming that all IPO firms died on their IPO date.

Using that classification system, we used the patenting variables as independent variables and longevity (in days) as the dependent variable. The findings show correlations with strong significance, summarized in Table 10. The coefficients suggest that an increase of one in the total number of patents is related to an increase of 45 days in firm longevity, and that firms with patents survive 179 days longer than firms without patents. We do not report biotech data that found no significant correlations based on longevity.

An obvious concern with the results reported thus far is the possibility that the relationships between patenting and firm performance are attributable entirely to longevity: firms simply get more patents as times goes by, without regard to any other indicators of success. To investigate that question, we conducted a series of analyses to control for longevity.

Those analyses suggest that longevity alone does not explain the findings that we discuss above. Specifically, they indicate that each of the three post-financing patenting variables (number of patents, having a patent, and having multiple patents) is significantly related to number of rounds, total investment, and late-stage financing, even controlling for longevity. Conversely, when we control for longevity, having a patent before first financing is not significantly related to any of the performance variables. The analysis of status (not reported here) is consistent with that result, though less definitive, largely because of the interaction of the large number of different values for longevity and the relatively small number of firms in some of the exit status categories.

3.4. Controlling for industry group

The previous sections reported strongly significant relations between patenting and industry group and between patenting and each of the five variables we use as proxies for progress of the portfolio firm. It is therefore possible that industry group could explain the relationships between patenting and the various performance proxies. Accordingly, we undertook to control for industry group in the analysis of those five variables. In each case, the proxies for success retained their significance.

The analysis for rounds, total investment, and longevity was relatively straightforward, because those are numerical variables. We used a two-way analysis of variance with both industry group and patent status as independent variables and the various performance proxies as dependent variables. Table 11 summarizes the results of that analysis.

The analysis for the remaining variables (late stage financing and exit status) is more challenging, because they are categorical variables. Because of the number of industry groups, the firm counts in many of the cells are quite sparse when the data are separated into industry groups for the various financing and status categories. One possibility would be to combine some of the smaller industry groups into larger ones. We have resisted that approach, both because of the likelihood that any combination would be indefensibly subjective, and because we wished to attempt to locate the particular sectors in which significant differences appear.

Recognizing those difficulties, our approach has been to run a χ^2 analysis for each separate industry group, for both of the categorical variables, identifying the par-

Table 11
Patents and rounds, total investment, longevity (controlling for industry group)

Independent variable	*P*-Value (regr.)	Expl. power (regr.)	Coeff. (rounds/unit)
Rounds			
Number of patents	<0.0001	4.02	0.14
Patents/no patents (0–1)	<0.0001	4.41	0.73
Multiple patents (0–1)	0.0008	3.44	0.70
Patent issued before round 1 (0–1)	0.9021	2.16	n/a
Independent variable	***P*-Value (regr.)**	**Expl. power (regr.)**	**Coeff. ($M/unit)**
Total investment			
Number of patents	<0.0001	4.28	2.7
Patents/no patents (0–1)	<0.0001	3.48	10.6
Multiple patents (0–1)	<0.0001	3.34	13.0
Patent issued before round 1 (0–1)	0.23	1.62	n/a
Independent variable	***P*-Value (regr.)**	**Expl. power (regr.)**	**Coeff. (days/unit)**
Longevity			
Number of patents	0.0013	2.28	45
Patents/no patents (0–1)	0.0048	2.02	183
Multiple patents (0–1)	0.021	1.72	191
Patent issued before round 1 (0–1)	0.24	1.27	n/a

The dependent variable is the number of rounds of financing.

Table 12
Patents and exit status, financing stage (controlling for industry group)

Independent variable	CMH *P*-value	Significant sectors	Source of significance
Financing stage			
Patents/no patents (0–1)	<0.0001	(Applications)***	Stage zero
Multiple patents (0–1)	0.0008	(Applications)*	Stage zero
		Internet**	Stage one
Patent issued before round 1 (0–1)	0.21	n/a	
Final status			
Patents/no patents (0–1)	<0.0001	Comm/Networking*	(Defunct)
		(Applications)***	Public
		Internet**	Public
Multiple patents (0–1)	<0.0001	Systems*	Public
		Comm/Networking*	Public
		(Applications)*	Public
		Internet*	Public
Patent issued before round 1 (0–1)	0.0133	Comm/Networking*	Acquisition

CMH: Cochrane–Mantel–Haentzel χ^2-test. Parentheses in Table 12 indicate sectors and statuses with substantially lower than expected levels of the applicable patenting variable. Generally, the applications sector and defunct status have abnormally low patenting rates and the other identified sectors (Internet, Systems, Comm/Networking) and the public status have abnormally high patenting rates.

ticular groups in which there appear to be significant relations. We then calculate an overall assessment for the significance of the relation, controlling for industry group (a Cochran–Mantel–Haenszel test).[14] Although that form of analysis can produce considerable ambiguity in situations in which the Cochran–Mantel–Haenszel test indicates a relation that is not apparent in any particular category, or in cases in which individual categories indicate relations but the Cochran–Mantel–Haenszel test does not, those problems do not afflict our data. For all of the relations that we test here, either both tests indicated a significant relation (the result for all of the post-financing patenting variables) or neither test did (the result for the pre-financing patenting variable). Table 12 summarizes the results of that analysis.

[14] For detailed explanation of that test, see Agresti (2002).

4. Analysis

The data presented in Section 3 are limited in a number of ways. For one thing, the dataset includes a narrow slice of the software industry: young firms that received their first round of venture financing during a relatively short period preceding the market crash in 2001. As explained in Mann 2005a, patents play a very different role in mature firms. Moreover, there is good reason to believe that the commercialization strategies of startup firms that are not venture-backed might differ significantly (Hsu, 2004; Hsu, 2006). Thus, for example, patents might be less important for firms that are not venture-backed because those firms are less likely to pursue cooperative commercialization strategies. Finally, we are unable to disentangle causation issues with this dataset; thus, despite the relationships between firm performance and patenting, we are left with the possibilities that funding might facilitate patenting or that the potential for patenting might be a precursor of the success that justifies continued funding.

We also emphasize that our data do not address the ultimate welfare question, whether patents provide a social benefit to the industry as a whole. Our data do suggest that patents are valuable for the firms that elect to obtain them, but this data does not exclude the possibility (frequently discussed in the existing literature) that the transaction costs those patents impose on third parties exceed the value they provide to the firms that obtain them.

Subject to those qualifications, we believe that our data illuminate several issues about the role of patents in the development of successful firms in the software industry.

4.1. Patenting rates

The most obvious point is that the rate of patenting – even in this subset of venture-backed firms – is quite low: only 24% of the 877 software firms had patents. The patenting rate for the software industry is much lower than the comparable rate for biotech firms, even though biotech firms are more likely than software firms to rely on patented technology licensed from third parties. The low patenting rate cannot be explained by the fact that we are examining firms at an early stage of their life cycle. A dataset that one of us has collected in related research indicates that patents were held by only 30% of the 1100 firms that have at any time in the last 5 years been in the Software 500 (an index of the nation's largest software firms). Thus, it appears that most software firms that obtain patents already have acquired some patents at this early stage.

The heterogeneity of the software industry contributes to an understanding of the data. As the interviews discussed in Mann (2005a) explain, the industry includes many sectors in which patents have considerable importance and many sectors in which patents have little value. Indeed, the data show a significant correlation between patent acquisition and the sector in which the firm operates. Although the idiosyncratic sector designations in our dataset make it difficult to test the intuition statistically, the distinction between products firms and services firms (Cusumano, 2004) seems to be of great importance.[15] In sectors dominated by products firms, patents might be useful to prevent competitors from developing products that offer similar functionality. By contrast, in sectors dominated by services firms, distinguished by the care and responsiveness of their employees, patents often would have relatively little value.

Given our focus on the role of patenting, it is notable that the great majority of venture-backed software firms are closer to the product end of the product/service continuum. It would be an exaggeration to say that there are *no* venture-backed software services firms: there certainly are quite a few (as Cusumano discusses). We do believe, however, that the products firms, which are the firms for which patents tend to be more useful, are much more common in our dataset. Only 48 of our 877 firms (5%) were listed with a primary industry code indicating that their primary business was in a software services sector (VEIC sectors 2760–2769). Thus, in this dataset, the variation in patenting is for the most part a variation in the usefulness of patents to different types of products firms.

Roughly speaking, we can speculate that the data reflect a distinction between sales to individuals and business users on the one hand (products that manage data, customer relationships, employees, and the like) and sales to designers/developers of software (development and graphics tools, server software, firmware, security, etc.), on the other. Generally, our intuition is that patents matter more in the latter group of sectors, where the innovation is in the design and functionality, rather than execution. If this analysis is correct, it would explain, for example, the results in Table 12 that indicate a persistently and significantly low level of patenting for the applications sector, which would fall within the first

[15] One of us is testing that hypothesis with a dataset of patents held by the 500 largest software firms.

group discussed above. Of course, IP still may be important in the first group of sectors, but copyright law may provide adequate protection for those products, particularly in areas where the visual aspects of the interface are important to product differentiation (Mann, 2005a).

Similarly, there may be a distinction based on the nature of the customers: firms that rely on a long-term contract with a large customer may depend less on IP, while those that use a large set of short-term contracts with smaller consumers or vendors might worry more about efforts to appropriate the functionality and compete against the original designer. It is difficult to generalize on this subject because the appropriability of patents in the industry is so weak that firms leverage their technology through countless other mechanisms such as strategic partnerships, distribution channels, and the like (Mann, 2005a).

Another notable point is the relatively small number of patents held by the firms that do acquire patents: an average of three in the software industry compared to an average of almost 10 in the biotech industry. One way to understand the data is that the existence of patents is much more important to a firm's success than the number of patents that it has, and that the number of patents depends on the nature of the technology. We draw some tentative support for that point from the consistency with which our data illustrated that the performance variables had a more significant relation to the patent/no patent variable than to the number-of-patents variable. That perspective is at least in tension with the notion that substantial benefits come directly from possession of large patent portfolios. Rather, it suggests, the number of patents that a firm obtains is more likely to be a function of the nature of the innovations of the firm. That might be particularly true for smaller firms still at the venture-backed stage. If those firms are not likely to be sued, and cannot yet exploit their patents (see Mann, 2005a), there is some reason to think that large patent portfolios will have relatively little value for those firms.

4.2. Patents and performance

The most important question for us is the one at the heart of the paper: the relation between patents and the progress of firms through the venture capital cycle. As reported above, there are strongly significant correlations between variables of patenting, on the one hand, and various proxies for strong performance: rounds of financing, total investment, exit status, reaching a late stage of financing, and longevity. In our view, these variables collectively include most of the characteristics that would count as "success" for a venture-backed firm: typically an entrepreneurial startup struggling to survive long enough to bring its product to market.

One important qualification relates to the question whether venture capitalists are acting rationally in their apparent attention to patenting practices in their investment decisions. As discussed above, we can see why venture capitalists would tend to prefer the kinds of firms for which patents would be valuable: products firms are likely to be characterized by high margins and easy scalability. The fact that more of those firms have patents does not necessarily say anything about the distinctive management acumen of the particular firm. Rather, it might simply indicate that *all* well-managed firms get the appropriate number of patents for their technology and that the appropriate number depends substantially on the nature of the firm's business model. Still, the data about successful exit strongly suggest that reliance on firms with a patenting model would be rational: Table 4 indicates that 13% of the firms with patents went public by 2005, while only 3% of those without patents did (22% and 5%, respectively of the biotech firms).

4.3. Patenting and development stage

The last major point is the timing question: when firms get patents. Patents are likely to have their greatest value for firms at the later stage of our dataset: when they have started to generate revenues (that patents might protect), but before they have obtained the market identification that might decrease the need for them to rely on patents to support their market share (Mann, 2005a). The data that we present here support that understanding of the dynamic value of patents in two different ways. First, the data suggest that there is little significance to having a patent before first financing.[16] Specifically, there was no indication that the existence of patents or applications before first financing had a positive impact on most of the performance variables. The only relation was with exit status, and that one was (by comparison to the other relations apparent in our data) not strongly significant.

Second, most of the firms that obtain patents do so at a relatively early stage after the first venture-backed financing. On that point, recall that 24% of this population of very young firms already has patents in an industry in which less than one-third of the most sub-

[16] Mann (2005a) explains that many investors place little or no weight on the existence of patents in their initial investment decision. That finding also is consistent with the data reported in Hsu (2004) (analyzing a dataset of venture-backed and SBIC startups in various industries and finding no relation between pre-funding patents and various measures of firm performance).

stantial mature firms have patents. That finding suggests that firms in this industry take steps to protect their IP early in their life cycle, long before the patents are likely to be useful for offensive purposes.

We note one additional possibility suggested by the data, that portfolio firms obtain the patents not because they increase the value of the firm to its investors, but because they protect the contributions of the firm from expropriation by the investors. The idea here is that by giving the portfolio firm a cognizable property right in its technology, the patents increase the value of the firm by decreasing the costs of moral hazard and hold-up in the relations between the entrepreneurs and their investors. Shane (2002) proposes a similar mechanism to explain patterns in licensing of patents assigned to MIT.

5. Conclusion

The question of whether patents actually foster innovation is an intractable one that cannot easily be resolved by empirical evidence, primarily because it is impossible to provide comparable datasets in which the same opportunities for innovation are available to firms with and without the incentives and constraints provided by a system of intellectual property. To be sure, historical data on such questions strongly suggest that intellectual property has a significant effect on the direction of innovation (Moser, 2005). Even that work, however, cannot say anything about the net effect on innovation.

Thus, the goals of this paper are more modest, to investigate for one particular industry the quantitative relation between patenting, receipt of early stage venture financing, and progression through the venture capital cycle. Although our data are ambiguous in some respects, they do provide considerable information about the role of patents in software startups. Most obviously, the irrelevance of pre-financing patents is consistent with the argument that for the great majority of venture-backed startups the possibility of patenting is quite low on the list of investment criteria. More broadly, the correlations between patenting and performance proxies are consistent with the view that the ability of firms to use patents to appropriate the value of innovation is at once crucially important for some firms and at the same time markedly different from firm to firm, even within the industry. Generally, those correlations suggest that the decision to patent is a routine one, not a strategic one, and that startup firms for which patents are useful will obtain patents in due course, if the firm survives long enough for the patents to become valuable. Many firms, for which patents are not useful, will never obtain patents, without regard to their initial financing arrangements and subsequent performance: 42% of the venture-backed firms that went public in our dataset do not yet have patents.

Finally, the analysis has implications for more recent developments in patent scholarship that focus on the potentially deleterious effects of the patent accumulations by mature industry incumbents. Even if those accumulations are deleterious to many of those firms, the analysis here suggests two important countervailing effects. The first is the possibility that patents support young firms in their efforts to compete, thus helping to stabilize the relatively decentralized structure of the industry and forestall movement toward greater concentration and the market power that goes with it. Even if we cannot disentangle the causal relation between patents and successful investments, the fact that patents are correlated so robustly with successful investments suggests that a software venture-investment cycle without patents would be different from the one we have now.

The second is the possibility that patents facilitate the intra-industry technology transfers upon which innovation depends in a realm of cumulative innovation. The work of Ashish Arora in particular has provided a strong theoretical basis for that understanding, rooted in the notion that the availability of patents will facilitate the entry of smaller firms contributing technology to products assembled by larger firms (Arora and Merges, 2004). 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.

In the end, the point of this paper is that a serious debate about the propriety of patents in the software industry must account not only for the possibility that patents might impose substantial costs, but also for the possibility that they provide substantial benefits. Our paper contributes to the existing literature by providing a quantitative link between patenting behavior and firm success. Our work provides substantial evidence that patenting, at least in this industry, is an important part of a well-organized operation, rather than a random or happenstance occurrence. Further, the paper is important simply for shedding light on the operations of patents in an industry in which they are highly controversial. Although we cannot answer the ultimate welfare question – would the industry be better without patents than it is with patents – we do shed a great deal of light on the reasons why so many firms do – and do not – choose to expend the time and resources necessary to obtain patents to protect their innovative work.

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