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PATENTS, VENTURE CAPITAL, AND SOFTWARE START-UPS

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Abstract

This paper analyzes the relation between the patenting practices of startup firms and their ability to progress through the venture capital cycle. Linking data relating to venture capital financing of software and biotech startup firms with data concerning the patents obtained by those firms, we find significant and robust positive correlations between the existence of patents and several other variables measuring the firm's ability to progress (including number of rounds, total investment, and longevity). The data also show sectoral variations between the patenting practices in the software and biotech industries and within the software industry, supporting the claim that there are differences in the use of patents to appropriate the value of innovation. The data also suggest that it is the existence of patents—not the number of patents—that has significance. Finally, the data support the claim that patents are likely to have their greatest value for late-stage startups.

PATENTS, VENTURE CAPITAL, AND SOFTWARE START-UPS

I. INTRODUCTION

If there is any single industry in which patents are controversial it is the software industry, where the recent spread of patents, coupled with the risks those patents apparently pose to the open-source movement, has raised concerns both here and abroad. From a finance perspective, the most important question about those patents is whether they help attract funds to the industry. To answer that question, it is natural to look to the milieu of venture-backed startups. Although some of the major firms did not begin with venture financing, almost all of the software firms that have risen to prominence in recent years relied on venture capital financing at some point in their development cycle.[1] Accordingly, a study of venture-backed software firms is a good proxy for a study of new entrants in the industry. An understanding of the relation between patents and the financing and performance of those firms would go far toward illuminating the effects that patents have on the industry. To that end, this paper combines data about venture capital financing of software startups with data about the patents held by those firms.

Although the study is part of a large project related to the software industry, it serves two general objectives that extend beyond that industry. The first is to promote an understanding of the factors that drive investments by venture capitalists. Existing scholarship tells us much about how and why venture capitalists structure relations with

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[1] See Paul A. Gompers & Josh Lerner, The Money of Invention: How Venture Capital Creates New Wealth (2001); Michael A. Cusumano, The Business of Software (2004).

the portfolio companies in which they invest.[2] At its best, that literature has combined empirical data with organizational theory to illuminate the strategic interplay that drives that structure, and how that interplay affects the types of firms for which the venture capital investment model is most effective.[3] Most of that analysis, however, has been either anecdotal or at the macroeconomic level. Thus, there has not been a great deal of quantitative analysis at the firm level to illuminate exactly what characteristics of portfolio firms relate to successful investments.[4] To the extent the literature has worked at the level of the firm, it generally has looked at mature firms that rely primarily on internal R&D investment[5]; thus, it says relatively little about the relation between patents and external venture-capital investment. This paper advances that debate by providing a rare quantitative glimpse at the relation between patenting practices of portfolio firms and the ability of portfolio firms to survive and mature.

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[2] See, for example, Gompers & Lerner, *supra* note 1; Paul A. Gompers & Josh Lerner, The Venture Capital Cycle (2000).

[3] See Thomas Hellman and Manju Puri, The Interaction Between Product Market and Financing Strategy: The Role of Venture Capital, 13 Rev. Fin. Studies 959 (2000); David H. Hsu, What Do Entrepreneurs Pay for Venture Capital Affiliation?, 59 J. Fin. 1805 (2004); Cusumano, *supra* note 1.

[4] Several existing papers have analyzed datasets that include both data on patents and data on success. For example, Samuel Kortum & Josh Lerner, Assessing the Contribution of Venture Capital to Innovation, 31 RAND J. Econ. 674 (2000); Josh Lerner, Did Microsoft Deter Software Innovation? (unpublished 2001 manuscript); David H. Hsu, Venture Capitalists and Cooperative Start-up Commercialization Strategy (unpublished November 2004 manuscript). None of those papers, however, has taken the approach here, of looking for relations between patenting practices and the progress of the portfolio firm through the venture capital cycle.

[5] Ashish Arora, Marco Ceccagnoli & Wesley M. Cohen, *R&D and the Patent Premium* (Jan. 2003) (NBER Working Paper 9431); Bronwyn H. Hall, Adam Jaffe & Manuel Trajtenberg, Market Value and Patent Citations, 36 RAND J. ECON. 16 (2005).

The second objective is to examine the relation between patents and innovation. One prominent strain in the existing literature, focused directly on the software industry, has argued that the rapid proliferation of patents has caused a thicket or anticommons that stifles the formation of new firms and consequent innovation.[6] More broadly, a number of writers have expressed doubts about the value of patents in any industry characterized by complex cumulative innovation.[7] Even with the analysis of patent doctrine, fears about adverse consequences for innovation have led to a line of works arguing that software patents should be given a narrow scope.[8]

Conversely, a line of scholars building on the work of Suzanne Scotchmer have analyzed the tradeoff between increased IP protection for an early inventor and harms from increased costs to follow-on innovators.[9] The foundational insight of that literature

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[6] Lawrence Lessig, The Future of Ideas: The Fate of the Commons in a Connected World (2001); Carl Shapiro, Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting, in Innovation Policy and the Economy 121 (Adam Jaffe, Joshua Lerner & Scott Stern, eds., 2001).

[7] John R. Barton, Reforming the Patent System, 287 SCIENCE 1933 (2000); Ann Bartow, Separating Marketing Innovation from Actual Invention: A Proposal for a New, Improved, Lighter, and Better-Tasting Form of Patent Protection, 4 J. SMALL & EMERGING BUS. L. 1 (2000); Don E. Kash & William Kingston, Patents in a World of Complex Technologies, 28 SCI. & PUB. POL'Y 11 (2001).

[8] Julie E. Cohen & Mark A. Lemley, Patent Scope and Innovation in the Software Industry, 89 Cal. L. Rev. 1 (2001); Dan L. Burk & Mark A. Lemley, Is Patent Law Technology-Specific, 17 Berkeley Tech. L.J. 1155 (2002); Dan L. Burk & Mark A. Lemley, Policy Levers in Patent Law, 89 Va. L. Rev. 1575 (2003); Dan L. Burk & Mark A. Lemley, Designing Optimal Software Patents, in Intellectual Property Rights in Frontier Industries (Robert W. Hahn ed. 2005).

[9] Suzanne Scotchmer, Standing on the Shoulders of Giants: Cumulative Research and the Patent Law, 5 J. Econ. Persp. 29 (1991); Jerry R. Green & Suzanne Scotchmer, On the Division of Profit in Sequential Innovation, 26 RAND J. Econ. 20 (1995); Pamela Samuelson & Suzanne Scotchmer, The Law and Economics of Reverse Engineering, 111 Yale L.J. 1575 (2002); Suzanne Scotchmer, Innovation and Incentives (2004).

has been that the effect of the IP system on optimal exploitation of a new discovery will depend on the ability of follow-on innovators to obtain access to the technology necessary for their work. Thus, that work suggests an empirical inquiry into the practical institutions that foster – or retard – access to existing technology in an industry.

This paper contributes to that debate by studying the role of patents in obtaining financing in an industry characterized by complex cumulative innovation.[10] We draw on the industrial organization literature suggesting that property rights can be effective in facilitating an industrial structure in which relatively small firms develop pieces of larger products assembled by larger firms.[11] Connecting that literature to the debate discussed above, one of us has argued in earlier interview-based qualitative work that patents in an industry of cumulative innovation can facilitate entry by new competitors.[12] That argument, of course, is in tension with theories of a patent thicket stifling new development in the industry.

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[10] The only published paper that previously has examined those patents directly is Stewart J. H. Graham and David C. Mowery, Intellectual Property Protection in the U.S. Software Industry, in Patents in the Knowledge-Based Economy 219 (Wesley M. Cohen & Stephen A. Merrill eds., 2003). Because their dataset is drawn primarily from CompuStat, there is little overlap between that paper and this one focused on venture-backed software firms. For a similar paper focused on semiconductor firms (albeit relatively large semiconductor firms), see Bronwyn H. Hall & Rosemarie Ham Ziedonis, The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979–1995, 32 Rand J. Econ. 101 (2001).

[11] Ashish Arora & Robert P. Merges, Specialized Supply Firms, Property Rights and Firm Boundaries, 13 Indus. & Corp. Change 451 (2004); Ashish Arora & Robert P. Merges, Property Rights, Firm Boundaries, and R&D Input (unpublished 2001 manuscript); Joshua S. Gans, David H. Hsu & Scott Stern, When Does Start-up Innovation Spur the Gale of Creative Destruction?, 33 RAND J. Econ. 571 (2002).

[12] Ronald J. Mann, Do Patents Facilitate Financing in the Software Industry?, 83 Texas L. Rev. 961 (2005).

More generally, the earlier work articulates a framework of patent value under which the value of patents to firms shifts as they develop through three stages: (I) little or no value for early-stage pre-revenue startups, (II) substantial positive value (in limited sectors) for revenue-generating startups trying to protect themselves against incumbents, and (III) more ambiguous value as fodder for cross-licensing to maintain a competitive equilibrium among 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 large group of software startups, we can discern a great deal about the significance of patents for those firms. Although many features of the data are ambiguous and suggest avenues for further inquiry, their broad outlines provide considerable support for the framework summarized above. Specifically, the data suggest that:

- The existence of patents (or patent applications) at the time of the initial investment seems to be largely irrelevant.
- There are significant and robust positive correlations between the existence of patents, on the one hand, and several variables measuring the firm's ability to progress (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 great differences in the use of patents to appropriate the value of innovation.

Section II of the paper explains the data and the methods that we use to analyze it. Section III presents the results. Section IV analyzes the results. Section V is a brief conclusion.

II. 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 ability to obtain venture financing and progress through the venture capital cycle. The paper considers two different types of information about a particular set of 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 the firms, the collection of performance data, and the collection of patenting data.

A. Selecting the Firms

The firms were collected from the VentureXpert database. That database includes information collected by questionnaires addressed to members of the National Venture Capital Association. That association appears to include substantially all of the significant venture-capital investors in this country. The information includes details about the specific financing transactions in which each of the venture-capital firms has engaged. The information also includes several data points about the portfolio companies, including a designation of the industry in which each of the portfolio companies competes.

We limited 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. This makes sense given the dominant role that the United States plays in the software industry. Because the software markets in other countries are so much smaller, they tend to be heavily concentrated and

dominated by local "champions" heavily subsidized by local governments.[13] Thus, inclusion of investments in those countries in the dataset would be likely to detract from the clarity of the analysis on which this paper focuses. Moreover, because venture-capital markets in those countries are so different from this country – they appear to tolerate lower returns by more firms (as compared to the American model that demands higher returns, but accepts them from fewer firms) – patents might be less important there.

Because we wanted to avoid problems caused by having firms of widely varying ages and sizes, we decided to select firms that had received their first round of venture financing within a relatively narrow window of time.[14] 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 rules governing software patents changed significantly during the early part of the 1990's, it was important to select a period that began some time well after 1995. At the same time, in order 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

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[13] MARTIN CAMPBELL-KELLY, FROM AIRLINE RESERVATIONS TO SONIC THE HEDGEHOG: A HISTORY OF THE SOFTWARE INDUSTRY (2003).

[14] If we extended the period of time during which our 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 time period over which we collected data is so short as to make analysis of the separate years seem superfluous.

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 nonexistent), a somewhat longer focus is appropriate.[15] 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 the important legal changes in 1995-96, and the general youth of the industry make it impossible to analyze a substantial group of pre-"bubble" investments.

Accordingly, we decided to select 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. When run against those databases, the selection criteria identified 877 firms.

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[15] See Gompers & Lerner, *supra* note 1.

Finally, for comparative purposes, we collected a parallel group of all of the firms in biotechnology sectors (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 212 firms. We report comparative results for those firms at relevant points in the paper below.

B. Performance Data

The strategy of the project was to determine whether we could find or reject a relation between patents, on the one hand, and some dependent variable indicative of the performance of the firm. As suggested above, the underlying theory was that patents are related in some way to success of the 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.[16] Rather, we are examining the question whether patents relate to the progress of the firms in which venture capitalists choose to invest. Within the analytical framework developed in the prior work, that is an important distinction: the reasoning of the related paper 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 progress through the venture financing cycle.

[16] See Mann, *supra* note 12.

To investigate that problem, we collected several different pieces of information from the VentureXpert database. First, we collected details about the financing that the firm obtained, which included the total amount of financing obtained by the firm, the dates of the various financing rounds, and a designation of the stage of the financing (starting with seed and startup, and ranging through other early stage, expansion, later stage, bridge financing, and open market financing). Second, we collected 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.[17] 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

[17] Steven N. Kaplan, Berk A. Sensoy & Per Strömberg, How Well Do Venture Capital Databases Reflect Actual Investments (unpublished Sept. 2002 manuscript).

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 it in detail.

C. 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 of the patents was granted. The searches were run in January 2005, and were restricted to patents issued as of December 31, 2004. We searched using 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 analyze data about issued patents rather than patent applications. First, we are not able to obtain complete data about patent applications. 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 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.[18]

Second, because our main research interest is whether patents are associated with the successful development of a venture-backed firm, there is little to be gained by studying applications. Few would suggest, for example, that venture capitalists are motivated by the prospect of patent applications that will not ripen into issued patents. More generally, the main benefit of using applications is that it makes it easier to tie a particular innovation to a particular point in the life-cycle of the firm – the point at which the application was filed. So, for example, a study of R&D investment naturally would focus on the relation between R&D investments in a particular year and applications related to that research. In our case, however, we are looking at a specific point in the life cycle of our firms – their early progress through the venture capital cycle. Because all of our firms began operations at about the same time and are being examined the same number of years later, there is much more to be lost by looking at truncated data about applications than is to be gained.

Third, 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,

[18] We did run a series of regressions designed to test whether there was any significance to an application having been filed before the first financing. As discussed below, those regressions were inconclusive.

it seemed unlikely to produce valuable information to examine further details about the time at which the patents were obtained.

Finally, although we collected the data, we have not conducted any statistical analysis incorporating information about patent citations. Because the patenting practices of our firms are so highly skewed, and because our firms and their patents are so young – most of the patents are less than two years old – we doubt the value of such analysis.

III. RESULTS

The impetus for the research is to examine the relation between patenting and the firm's performance. The data, however, shed light on a number of related questions not previously examined in the literature. Accordingly, before we turn to that point, we provide descriptive data about patenting rates and information about differences in patenting by geography and sector.

A. Patenting Rates

The most startling feature of the data is the information about the firms' patenting practices. Despite concerns that patents are deterring innovation in the industry, 76% of the firms in the dataset (663 of 877) had not obtained a patent by January 1, 2005 when we finalized our data collection, between five and eight years after the dates on which each firm received its first round of venture financing. For comparative purposes, 56% (119/212) of the parallel biotech firms obtained patents by the end of the same period. Moreover, the 56% biotech figure probably understates the reliance of those firms on patented IP because of the likelihood that biotech startups are relying on in-licensed

patented technology from universities, a relatively uncommon scenario for venture-backed software firms.

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

FIGURE 1: NUMBER OF PATENTS PER FIRM

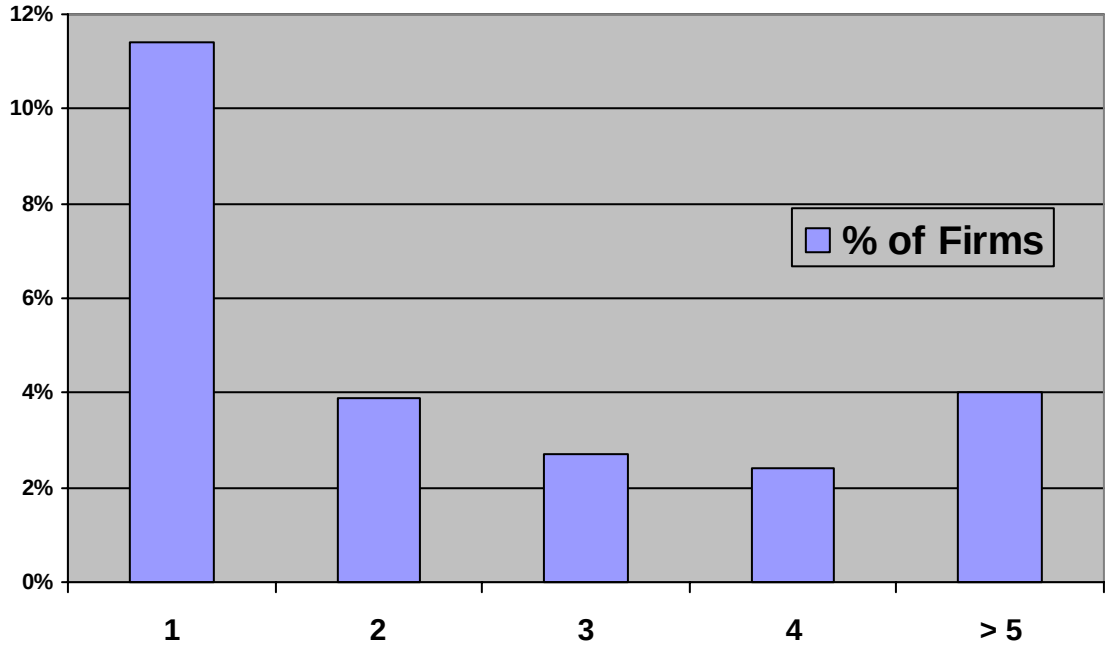


Table 1 presents a summary of the most important classes, headed by G06F [Electric Digital Data Processing], which included 384 (56%).

TABLE 1: CLASSES OF SOFTWARE PATENTS

IPC CLASS	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%

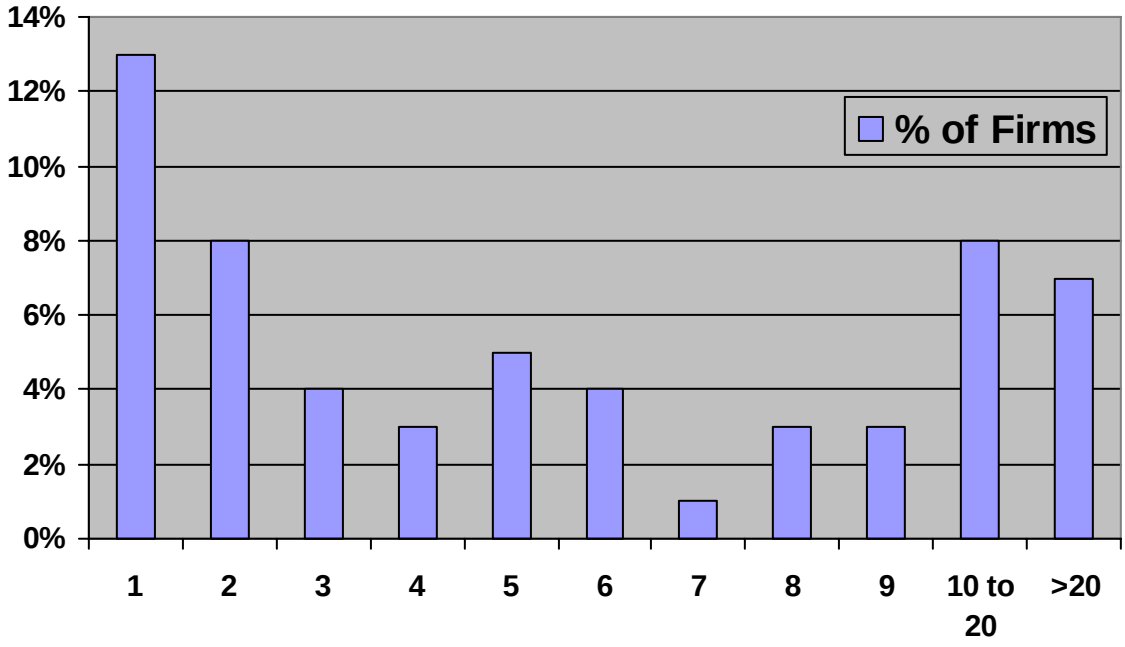
The average number of domestic references was just over 22 per patent, with this number steadily increasing over time from about 14 in 1999 to over 28 by 2003. Finally, the number of forward citations of the patents (as of January 2005) is just over five per patent.[19]

For comparison purposes, the parallel biotechnology database included 1161 patents for the 212 firms, 5.48 patents per firm. Among the firms that had patents, there

[19] We do not analyze the patents based on the number of references, citations, or claims. Because our data is so highly skewed (so few firms have patents), the regressions below indicate that our results are less conclusive when we analyze the number of patents (rather than simply the existence of patents). We expect that the results would be even less robust if we analyzed specific data about the patents. One of us is undertaking that type of analysis in a related paper with a much larger dataset of software patents issued to a much larger group of firms over a longer period of time.

was an average of 9.76 patents per firm. Figure 2 illustrates the distribution by number of patents among the biotech firms in the dataset that had patents. We note that the higher rate of patenting in biotech firms cannot be attributed to greater vulnerability of software startups. As we report below, about 7% of firms failed in each of the two datasets.

FIGURE 2: NUMBER OF PATENTS PER FIRM (BIOTECH)



As that figure demonstrates, the biotechnology industry not only has more patents but also has a significantly larger share of firms with larger patent portfolios. For example, only 2% of software firms had more than four patents, while less than 1% of all software firms had more than ten patents; 19% of biotechnology firms had more than four patents and 6% had more than ten patents.

B. The Effect of Location and Industry Group

We analyzed information about the location of the firm 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 geographic correlation, but a strongly significant correlation related to industry sector. The latter correlation is consistent with the notion (discussed in detail in Mann 2005) that the sectors of the software industry have varying abilities to appropriate the value of an invention by a patent.

1. Location.--We tested the role of location by looking for possible relations between location 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. We also have run parallel analyses throughout this paper on data we have collected on applications for patents made before first financing. That information is less reliable because for the most part those applications would never become public unless they resulted in an issued patent. In any event, the results are similar to the (generally inconclusive) analyses that we report for our data on patents issued before first financing.

For the number of patents analysis, we used an analysis of variance. For the existence of patents and of multiple patents – binary dependent variables – we also performed a Chi-square table analysis. As Table 2 displays, the results generally indicate that for software firms there is no cognizable correlation between location and any of those metrics of patenting. The biotech data, by contrast, suggest considerable significance of location in post-financing patent variables, but no significance in pre-financing patenting. At first, it seems odd that the biotech data would suggest that

location matters and that sector does not, while the software data would indicate that location does not matter and that sector does. The most obvious potential explanation is that the biotech sector is more homogenous than the software sector (so that there is no significant relation between patenting practices and the intra-industry sector designations), but that at the same time there is some tie between patenting and university affiliations, so that location is relevant to patenting practices.[20]

TABLE 2: LOCATION AND PATENTING

DEPENDENT VARIABLE	EXPLANATORY POWER (%)	P-VALUE (ANALYSIS OF VARIANCE)	P-VALUE (CHI-SQUARE)
Total Patents	1.8552	0.4367	n/a
Total Patents (Biotech)	5.5749	**0.0179***	n/a
Patents/No Patents	2.3721	0.1858	0.1862
Patents/No Patents (Biotech)	9.4786	**0.0004*****	**0.0005*****
Multiple Patents/Not	2.1296	0.2865	0.2858
Multiple Patents/ Not (Biotech)	15.1152	**<0.0001****	**<0.0001****
Patent Before Round 1	2.5626	.1276	.1285
Patent Before Round 1 (Biotech)	1.0320	0.7068	0.7012

2. Industry Group.--We also tested the possibility that patenting practices might differ substantially within the different sectors of the industry. We grouped the firms by three-digit codes from the VentureXpert data, putting small groups in an "other"

[20] See Robert A. Lowe & Arvids A. Ziedonis, Start-ups, Established Firms, and the Commercialization of University Inventions (unpublished 2004 manuscript) (describing important differences between the patenting practices of startups associated with UC and MIT).

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 much more homogenous than the software industry.

TABLE 3: INDUSTRY GROUP AND PATENTING

DEPENDENT VARIABLE	EXPLANATORY POWER (%)	P-VALUE (ANALYSIS OF VARIANCE)	P-VALUE (CHI-SQUARE)
Total Patents	2.1633	**0.0146***	n/a
Total Patents (Biotech)	0.9189	.8607	n/a
Patents/No Patents	2.2190	**.0122***	**.0126***
Patents/No Patents (Biotech)	0.5565	.9488	.9468
Multiple Patents/Not	2.1885	**.0135***	**.0139***
Multiple/Not (Biotech)	0.8007	.8929	.8892
Patent Before Round 1	1.9101	**0.0323***	**0.0328***
Patent Before Round 1 (Biotech)	4.6989	0.0756	0.0763

Accordingly, there is good reason to think that patenting practices differ significantly among the various industry groups in the software industry. Interestingly, parallel analysis of the biotech sectors suggests no significant relation to the sector in which the firms operate. 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.

C. The Relation Between Patenting and Firm Performance

The hardest aspect of our inquiry is the relation between patenting and the performance of the firms. The first problem is identifying a quantitative variable that directly indicates that the firm has successfully progressed through the venture capital cycle. Ultimately, we settled on five separate indicators: 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 January 1, 2005, whether the firm attained a late financing stage; and the longevity of the firm's existence. As Tables 4 and 5 show with simple cross-tabulations, firms with and without patents have cognizably different levels of performance on each of those metrics.

TABLE 4: CROSS-TABULATION OF PERFORMANCE DATA FOR FIRMS WITH AND WITHOUT PATENTS

	FIRMS W/ PATENTS	FIRMS W/O PATENTS
Financing Rounds		
Median	4	3
Mean	4.126	3.415
S.D.	2.100	2.028
Total Investment		
Median	$26.33M	$14.80M
Mean	$35.60M	$24.95M
S.D.	$33.90M	$30.33M
Exit Status		
Defunct/Liquidated	4%	8%
Existing	54%	63%
Acquired	30%	26%
Public/Merger	13%	3%
Late-Stage Financing	27%	37%
Longevity (Days)		
Median	2052	1971
Mean	1938	1759
S.D.	734	840
N	214	663

TABLE 5: CROSS-TABULATION OF PERFORMANCE DATA FOR BIOTECH FIRMS WITH AND WITHOUT PATENTS

	FIRMS W/PATENTS	FIRMS W/O PATENTS
Financing Rounds		
Median	4	2
Mean	4.336	2.753
S.D.	2.096	2.083
Total Investment		
Median	$31.75M	$5.200M
Mean	$40.27M	$24.89M
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)		
Median	2294	2295
Mean	2073	2043
S.D.	755	812
N	119	93

The more challenging analytical problem is the issue of endogeneity – does causation run from the performance variable to the patenting variable or does it run from the patenting variable to the performance variable. Neither those simple cross-tabulations nor the statistical analysis that we report below prove that the patents cause the firms to succeed (or that success caused the firms to obtain the patents). We attempted to resolve the endogeneity problem with simultaneous equations, but were unable to obtain any definitive results, largely because we have no truly exogenous information for our set of small privately-traded firms.

Thus, at most our findings suggest that the factors that allow firms to obtain patents – the potential for patented technology and the ability to obtain it – are related to the factors that cause venture-backed software firms to survive and progress. Because the results are relatively stable across a wide variety of scenarios – differing variables for patenting and differing proxies for success – the results seem to be relatively robust.

Ultimately, we concluded that the nature of any causative relationship is not particularly important. For example, it might be that the possession of patentable technology, even before patenting, *causes* the firm to succeed. Conversely, it might be that the ability of the firm to progress to a more mature stage gives the firm the breathing room that it needs to obtain patents.[21] Even in that case, a consistent decision to obtain patents (reflected in a strong correlation between progress and patenting) suggests either persistently irrational behavior or a consistent judgment that patents are useful as the firm matures.[22] Given the policy controversy about software patents discussed above, those findings make a substantial contribution to our knowledge.

To be sure, the results we report below generally have a low explanatory power, which is consistent with the fact that there are many other reasons that venture-backed firms might succeed or fail 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.

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[21] *See* Mann, *supra* note 12.

[22] Mann, *supra* note 12, argues that the patents will be of increasing value as the firm matures, which supports the idea that the behavior is irrational.

1. Rounds of Financing.--Both VentureXpert and VentureOne include data about particular rounds of financing. Because each round of financing reflects a separate determination by venture capitalists that the prospects of the firm at the time warrant continued investment, the total number of rounds of financing obtained by the firm presents a reasonable proxy for the success of the firm. There is the obvious problem that we do not have a dataset of firms that obtained zero rounds of financing, so the best we can do is test the total number of rounds, among firms that obtained at least one round. 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 success in this context.[23]

The primary difficulty in examining that question is that the datasets on the number of rounds of financing are incomplete, in the sense that the two datasets include information about different financing rounds.[24] Conversations with representatives of VentureOne 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 of financing. That explanation is not consistent with the data analyzed below, which in fact indicate a slightly *higher* number of financing rounds in the VentureOne database than in the VentureXpert database (3.3

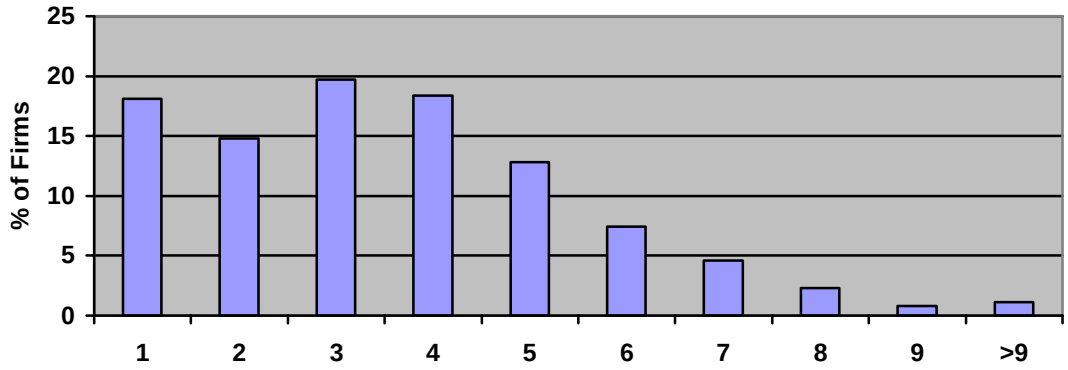
[23] Gompers & Lerner, *supra* note 1.

[24] Kaplan et al., *supra* note 17, provides some empirical evidence of the differences between the two competing datasets.

per firm versus 3.1 per firm, comparing for the matching time 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 our analytical results are quite similar, whichever measure is used, we believe that there is little reason to worry that the omissions reflect a selection bias that is likely to undermine our results.

We examined the relation between financing rounds and patenting by three tests. First, we tested the relation between patenting and the number of rounds of financing shown in the VentureXpert database. Second, we tested the relation between patenting and the number of rounds of financing shown in the VentureOne database. Because they are generally similar to the VentureXpert results, we do not report the VentureOne results here in detail. 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; Figure 3 illustrates the distribution of rounds of financing in detail.

FIGURE 3: ROUNDS OF FINANCING



For comparative purposes, Figure 4 displays the distribution of financing rounds for the biotech firms, which have a much less linear progression including noted peaks at one round and 4-5 rounds.

FIGURE 4: ROUNDS OF FINANCING (BIOTECH)

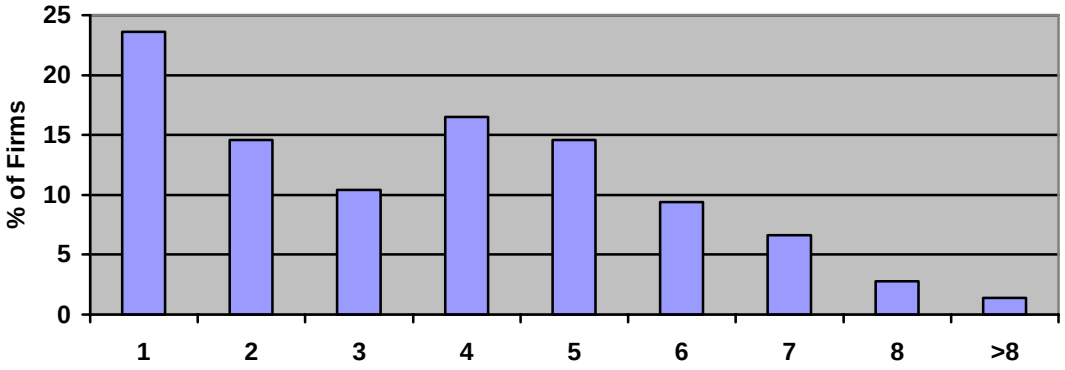


Table 6 reports the analysis of that data. As it indicates, the data indicate a relationship for the number of patents at the 1% level, for the other postfinancing variables at beyond the 0.01% level, and no relation for the prefinancing metric. The coefficients suggest, for example, that each additional patent relates to 0.144 rounds, and that having patents at all relates to 0.71 additional rounds. Parallel analysis of the VentureOne data 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.

TABLE 6: PATENTING AND ROUNDS OF FINANCING

INDEPENDENT VARIABLE	EXPL. POWER (ANOVA) (%)	P-VALUE (ANOVA)	P-VALUE (REGR.)	EXPL. POWER (REGR.)	COEFF. (Rounds /Unit)
Number of Patents	3.6097	**0.0067****	**<0.0001*****	1.8892	0.144
Number of Patents (Biotech)	27.9103	**0.0002*****	**0.0273***	2.2986	0.028
Patents/No Patents	n/a	n/a	**<0.0001*****	2.1865	0.71
Patents/No Patents (Biotech)	n/a	n/a	**<0.0001*****	12.4804	1.58
Multiple Patents	n/a	n/a	**0.0008*****	1.2792	0.69
Multiple Patents (Biotech)	n/a	n/a	**<0.0001*****	9.7525	1.40
Patent Issued Before Round 1	n/a	n/a	0.7648	0.0102	n/a
Patent Issued Before Round 1 (Biotech)	n/a	n/a	0.5815	0.1449	n/a

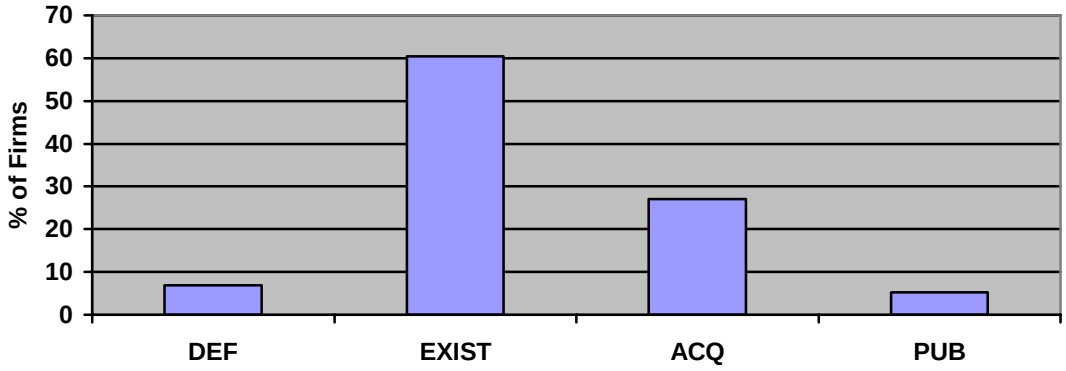
2. Total Amount of Financing.--A second possible indicator of the success of the investment is the total amount of financing that the firm eventually obtains. The intuition here is that better investments produce a greater total amount of financing than worse investments. We analyzed that question with four separate independent patenting variables: number of patents, existence of patents, having multiple patents, having a patent before round 1, and having a patent controlling for industry. As Table 7 indicates, the results are generally parallel 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.

TABLE 7: PATENTING AND TOTAL INVESTMENT

INDEPENDENT VARIABLE	EXPL. POWER (ANOVA) (%)	P-VALUE (ANOVA)	P-VALUE (REGR.)	EXPL. POWER (REGR.)	COEFF. ($M/ Unit)
Number of Patents	4.2217	**0.0011****	**<0.0001*****	2.9454	2.746
Number of Patents (Biotech)	15.9024	0.2469	**0.0036****	3.9537	0.871
Patents/No Patents	n/a	n/a	**<0.0001*****	2.1039	10.650
Patents/No Patents (Biotech)	n/a	n/a	**0.0346***	2.1075	15.383
Multiple Patents	n/a	n/a	**<0.0001*****	1.9488	13.091
Multiple Patents (Biotech)	n/a	n/a	**0.0013****	4.8038	23.253
Patent Issued Before Round 1	n/a	n/a	0.2276	.1663	n/a
Patent Issued Before Round 1 (Biotech)	n/a	n/a	0.7533	.0472	n/a

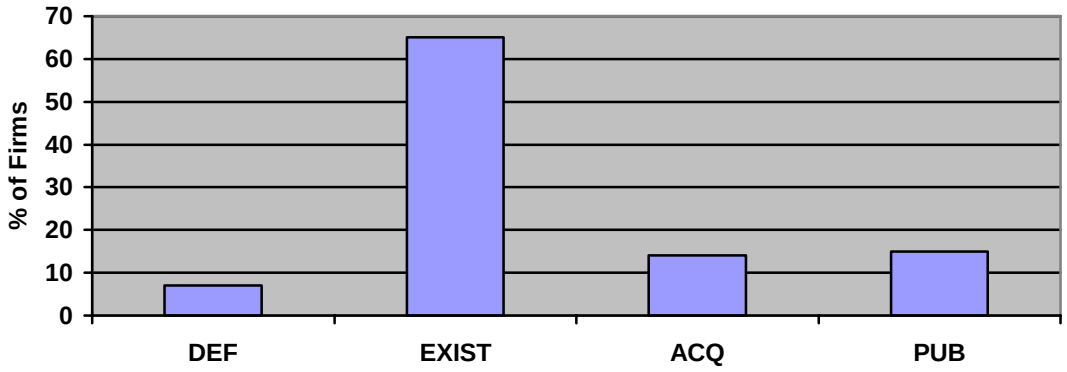
3. Exit Status of the Firm.--Another possible indicator of the success of the investment is the ultimate ability of the firm to succeed in the marketplace. Thus, at its simplest, a firm that has failed between the time of its first financing and the collection of the data can be treated as less successful 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 Figure 5 shows, more than half of the firms remain in private hands and thus have not exited, 10% of the firms have been acquired, 5% have gone public, and only 7% are shown as having failed. Also, interestingly enough, about three times the share of biotech firms have gone public (15%) as software firms (5%).

FIGURE 5: EXIT STATUS



For comparative purposes, Figure 6 notes the exit status for biotech firms, which is considerably different, with fewer acquired firms and more public firms:

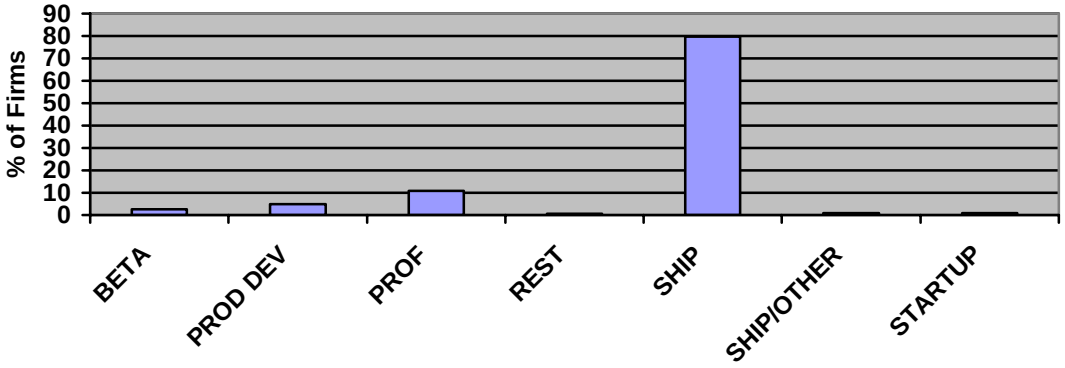
FIGURE 6: EXIT STATUS (BIOTECH)



The VentureOne dataset includes an entirely distinct categorization of exit status of the firms, ranging from beta testing and product development through shipping product. Because that categorization uses more functional categories than the VentureXpert exit status, we hoped that it might produce results that more closely tracked the performance of the firm. Unfortunately, as shown in Figure 7, the overwhelming majority of the firms (almost 80%) were in the "shipping" category at the last measured

point (often the data of acquisition or IPO), which lowers the value of the metric. Not surprisingly, analysis of that data was inconclusive.

FIGURE 7: VENTUREONE EXIT STATUS



As with the analysis in the previous section, we used several patenting variables as independent variables. Table 8 summarizes the results. Perhaps the most interesting thing not evident from the table is that the analysis indicates that most of the significance for the post-financing patenting variables (in either industry) comes from differences in the number of firms that went public. The results are different for the prefinancing variable, where the Chi-square and ANOVA analysis attribute the significance to different sectors (acquired and public in one case, acquired and active in the other). We attribute less weight to that finding because it is not duplicated for other dependent variables.

TABLE 8: PATENTING AND EXIT STATUS

PATENTING VARIABLE	P-VALUE (CHI-SQUARE)	P-VALUE (ANALYSIS OF VARIANCE)	EXPLANATORY POWER (%)
Total Patents	n/a	**<.0001******	3.7474
Total Patents (Biotech)	n/a	**.0005*****	8.1406
Patents/Not	**<.0001******	**<.0001******	3.8362
Patents/Not (Biotech)	**.0061****	**.0057****	5.8492
Multiple Patents	**<.0001******	**<.0001******	3.1131
Multiple Patents (Biotech)	**.0027****	**.0024****	6.6788
Patent Issued Before Round 1	**.0158***	**.0157***	1.1801
Patent Before Round 1 (Biotech)	.1248	.1258	2.7086

4. Late-Stage Financing.--The next metric of firm progress 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. Figure 8 shows how the latest stage of financing that each firm obtained falls within that categorization. Figure 9 presents analogous information for the biotech firms, which generally indicates a much smaller share of the firms surviving to a late stage.

FIGURE 8: LATEST STAGE OF FINANCING

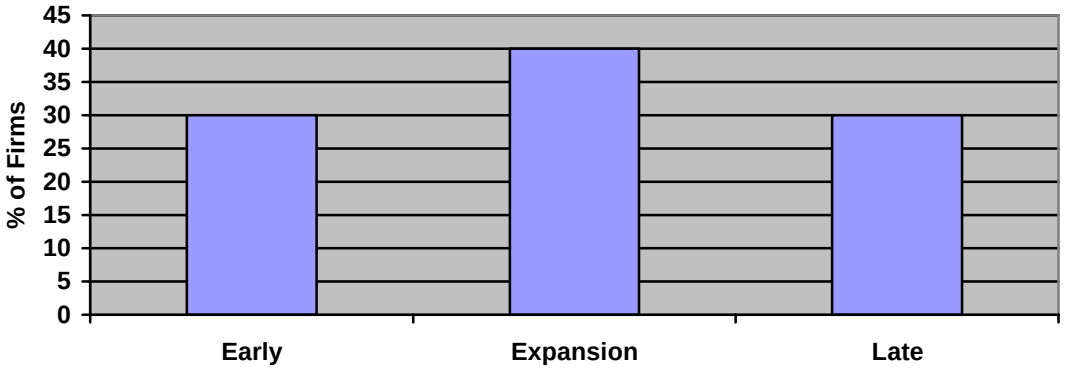
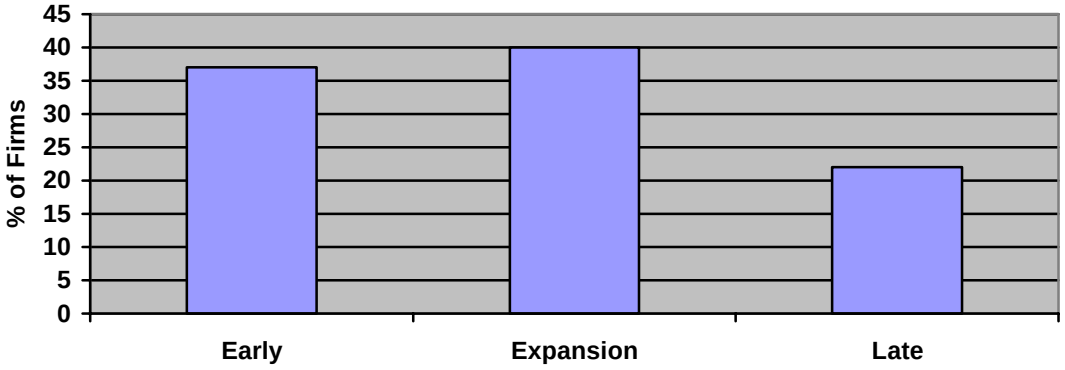


FIGURE 9: LATEST STAGE OF FINANCING (BIOTECH)



Taking the view 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 the relation between that data and our three 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 Chi-square test for independence. We report the results in Table 9. 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. {The biotech analysis is

slightly different. In that dataset, there are large differences in the rate of multiple patenting in both firms that stop at the early financing stage and those that reach the late stage.}

TABLE 9: PATENTING AND LATE-STAGE FINANCING

PATENTING VARIABLE	P-VALUE (CHI-SQUARE)	P-VALUE (ANALYSIS OF VARIANCE)	EXPLANATORY POWER (%)
Total Patents	n/a	**<.0001******	2.3893
Total Patents (Biotech)	n/a	**.0509***	3.0082
Patents/Not	**<.0001******	**<.0001******	2.6536
Patents/Not (Biotech)	**<.0001******	**<.0001******	14.0842
Multiple Patents	**.0009*****	**.0009*****	1.6342
Multiple Patents (Biotech)	**<.0001******	**<.0001******	9.9844
Patent Issued Before Round 1	0.2576	0.2583	.3177
Patent Before Round 1 (Biotech)	.4841	0.4882	.7328

5. Longevity and Patenting.--The last variable that we examined was longevity. In some contexts, longevity alone might not be characterized as success, but in the context of a venture-backed firm, 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.[25]

Unfortunately, longevity is not an easy variable to analyze directly because it is difficult to measure either the beginning or end point of our firms. For the beginning

[25] For details on that process, see Ronald J. Mann, *An Empirical Investigation of Liquidation Choices of Failed High-Tech Firms*, 82 WASH. U.L.Q. 1375 (2005).

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 of days to the various VentureXpert status categories, as indicated below, resting on the assumption that no firm is likely to fail within six 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 January 1, 2005.*
>
> *Unknown or Defunct: Months from first financing to six months after last financing.*
>
> *Acquired: Months from first financing to the later of last financing or acquisition date.*
>
> *IPO: Months from first financing to January 1, 2005. This assumes that all IPO firms were alive as of January 1, 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 same three patenting variables as independent variables and longevity as the dependent variable. As with the other proxies for performance, the data for the software industry show correlations with strong significance, summarized in Table 10.

TABLE 10: PATENTING AND LONGEVITY

INDEPENDENT VARIABLE	EXPL. POWER (ANOVA) (%)	P-VALUE (ANOVA)	P-VALUE (REGR.)	EXPL. POWER (REGR.)	COEFF. (days/ Unit)
Number of Patents	2.4887	0.1115	**0.0013****	1.1834	45
Number of Patents (Biotech)	13.36	0.5190	0.0593	1.6830	n/a
Patents/No Patents	n/a	n/a	**0.0054****	0.8830	179
Patents/No Patents (Biotech)	n/a	n/a	.7837	0.0360	n/a
Multiple Patents	n/a	n/a	**0.0190***	0.6275	193
Multiple Patents (Biotech)	n/a	n/a	0.4033	.3328	n/a
Patent Issued Before Round 1	n/a	n/a	0.2431	.1557	n/a
Patent Issued Before Round 1 (Biotech)	n/a	n/a	0.4056	.3297	n/a

An obvious concern with our results is the possibility that the results we observe are attributable entirely to longevity: that firms simply get more patents as they survive, without regard to any other indicators of success. To investigate that question, we conducted a series of analyses to control for longevity. That analysis suggests that longevity alone is not explaining the significant effects that we discuss above. Specifically, that analysis indicates that each of the main patenting variables (number of patents, having a patent, and having multiple patents) is significantly related to number of round, to total investment, and to attaining late-stage financing, even controlling for longevity. {Conversely, when we control for longevity, having a patent before the first round is not significantly related to any of the performance variables.} The analysis of final status 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 final status categories. We will post the full analysis of those questions on our Web site before the final paper is published.

D. 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 success 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 explanatory variables for the number of dependent success variables.[26] Table 11 summarizes the results of that analysis.

[26] We considered using multivariate regressions here, but the analysis we report here is a simpler and more straightforward statistical technique that should be more reliable for disentangling the effects of industry group and patent status.

TABLE 11: CONTROLLING FOR INDUSTRY GROUP (ROUNDS, TOTAL INVESTMENT, LONGEVITY)

INDEPENDENT VARIABLE	EXPL. POWER (ANOVA) (%)[27]	P-VALUE (ANOVA)	P-VALUE (REGR.)	EXPL. POWER (REGR.)	COEFF.
Rounds					**Rounds/ Unit**
Number of Patents	5.7340	**0.0065****	**<.0001******	4.0182	.14
Patents/No Patents	n/a	n/a	**<.0001******	4.4107	.729
Multiple Patents	n/a	n/a	**0.0008*****	3.4361	.70
Patent Issued Before Round 1	n/a	n/a	0.9021	2.1645	n/a
Total Investment					**$M/Unit**
Number of Patents	5.5769	**.0014****	**<.0001******	4.2815	2.7
Patents/No Patents	n/a	n/a	**<.0001******	3.4825	10.6
Multiple Patents	n/a	n/a	**<.0001******	3.3374	13.0
Patent Issued Before Round 1	n/a	n/a	0.2341	1.6239	n/a
Longevity					**Days/Unit**
Number of Patents	3.6453	0.0998	**0.0013****	2.2792	45
Patents/No Patents	n/a	n/a	**0.0048****	2.0165	183
Multiple Patents	n/a	n/a	**.0211***	1.7164	191
Patent Issued Before Round 1	n/a	n/a	.2429	1.2665	n/a

We conducted a similar analysis for the biotech firms, but do not report it here because the industry group standing alone did not show a significant relation. With the exception of longevity (which showed no significant relation in the basic analysis reported above), that analysis suggested significant relations for each of the biotech explanatory variables with the post financing patent variables, controlling for industry group.

[27] The explanatory power in this column is for both the patenting variable and industry group combined, although the significance that we report is for the patenting variable alone (controlling for industry group).

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 it is useful to attempt to locate the particular sectors in which significant differences appear.

Recognizing those difficulties, our approach has been to run a chi-square analysis for each separate industry group, for both of the categorical variables, which identifies the particular industry groups in which there appears to be a significant relation. We then calculate an overall assessment for the significance of the relation, controlling for industry group (a Cochran-Mantel-Haenszel test). 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 not the Cochran-Mantel-Haenszel test, 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. Table 12 reports summary results of that analysis.

TABLE 12: CONTROLLING FOR INDUSTRY GROUP (EXIT STATUS, FINANCING STAGE)[28]

INDEPENDENT VARIABLE	CMH STAT.	SIGNIFICANT SECTORS	SOURCE OF SIGN.
Financing Stage			
Patents/No Patents	**<.0001******	**(Applications)*****	Stage Zero
Multiple Patents	**.0008*****	**(Applications)***	Stage Zero
		Internet**	Stage One
Patent Issued Before Round 1	0.2129	n/a	
Final Status			
Patents/No Patents	**<.0001******	**Comm/Networking***	(Defunct)
		(Applications)***	Public
		Internet**	Public
Multiple Patents	**<.0001******	**Systems***	Public
		Comm/Networking*	Public
		(Applications)*	Public
		Internet*	Public
Patent Issued Before Round 1	**.0133***	**Comm/Networking***	Acquisition

IV. ANALYSIS

The data presented in Part III are limited in a number of ways – the most obvious of which is the narrow slice of the software industry that is represented in our dataset. First, it includes only young firms and thus sheds no light on the role patents play in mature firms. As explained in the related paper, patents obviously play quite a different role in mature firms. Second, even among young firms, our dataset includes only venture-backed firms. There is good reason to think that the commercialization strategies of firms that are not venture-backed might be different from the strategies of those that

[28] Parentheses in Table 11 indicate sectors and statuses with lower than normal 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.

are venture-backed.[29] Thus, for example, it might be that patents are less important for firms that are not venture-backed because those firms are less likely to pursue cooperative commercialization strategies for which patents are useful. Also, as noted above, our dataset is limited to firms that received financing shortly before the market crash in 2001. We believe there are good reasons to select firms from that period – the industry is too young to select older firms and the crash is too recent to analyze post-crash firms – but our choice must be noted in considering the appropriate weight to give our results. In our view, given the importance to the industry of the sector our data does describe, the details of the data illuminate several issues about the role of patents in the development of successful firms in the software industry.

We also note again the ambiguity of causation – funding might cause patenting or the potential for patenting might be a precursor of the success that justifies the continued funding. As discussed above, it is not clear that this possibility substantially undermines our understanding of the data. If funding triggers patenting, then it must be that the firm in fact has patentable ideas. If a firm without patentable ideas is funded, for example, the funding cannot conjure patentable ideas out of nothing. To be sure, a firm with patentable ideas but little money will defer patenting as a calculated risk. Then, upon funding, the firm might view patenting as insurance that it now can afford.[30] That scenario does not, however, suggest that the funding is causing the innovation, so much as it suggests that the funding causes patentable technology to mature into formal patents.

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[29] See Hsu, *supra* note 4.

[30] See Mann, *supra* note 12.

Finally, we emphasize that our data do not shed direct light on the 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 that does not exclude the possibility (frequently discussed in the existing literature) that the transaction costs generated by those patents exceed the value they provide to the firms that obtain them.[31]

Patenting Rates

The most obvious point of the data and, to us, the most surprising 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. That is much lower than the comparable rate for biotech firms (more than 50%), even though biotech firms are much more likely than software firms to rely on patented technology licensed from third parties and thus not developed in-house. Nor can this 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 five years been in the Software 500 (an index of the nation's largest software firms). Thus, more than ¾ of the firms that ever will receive patents already will have them at this early stage.

In our view, the best understanding of the data reported above relates to the variety of business models included in the software industry, which includes many sectors in which patents have considerable importance and many sectors in which patents have little value. The most basic indication of this is the data reported above that show

[31] See Mann, *supra* note 12 (discussing that possibility).

such a strongly significant correlation between patents 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 basic distinction between products firms and services firms[32] seems to be of great importance here.[33] In sectors dominated by products firms, patents often 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 weight.

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. That is not to say that there are *no* venture-backed software services firms: there certainly are quite a few (as Cusumano discusses). It is to say, 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, the variation in our dataset in patenting is for the most part a variation in the usefulness of patents to different types of products firms. Roughly speaking, we posit 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,

[32] See Cusumano, *supra* note 1.

[33] One of us is testing that hypothesis with a dataset of patents held by the 500 largest software firms. Preliminary results support the discussion in the text.

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 patent for the applications sector, which would fall within the first group discussed above. Of course, IP still may be important in the first group of sectors, but copyright law may provide adequate protection, particularly in areas where the visual aspects of the interface are important to product differentiation.[34]

Similarly, there probably is some distinction based on the nature of the customers: firms that rely on a long-term contract with a large customer may worry less about 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. More generally, 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.[35] Thus, our inability to provide a more complete explanation for sectoral differences at this time is understandable.

Another notable point is the relatively small number of patents held by the firms with patents: an average of three in the software industry compared to an average of almost ten 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,

[34] See Mann, *supra* note 12.

and that the number of patents depends on the nature of the technology. 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, with different types of innovations being more suited to protection by larger and smaller number of patents. 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,[36] there is some reason to think that patent portfolios will have relatively little value for those firms.

Patents and Performance

The most important question for us is the one at the heart of the paper: the relation between patents and performance. As reported above, there are strongly significant correlations between variables of patenting, on the one hand (especially the patent/no patent variable), 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. As discussed above,

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[35] See Mann, *supra* note 12.

[36] See Mann, *supra* note 12 (making that argument).

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 patenting firms went public by 2005, while only 3% of the non-patenting firms did (22% and 5% respectively of the biotech firms).

The Timing of Patenting

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.[37] 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.[38] Specifically, there was no

[37] See Mann, *supra* note 12 (making that argument).

[38] This resonates strongly with the analysis in Mann, *supra* note 12, indicating 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, *supra* note 4 (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).

significant indication that the existence of patents or applications before the first financing had a positive impact on the variables for the number of rounds, total investment, late-stage financing, or longevity. The only relation was with final status, and that one was (by comparison to the other relations apparent in our data) not strongly significant.

Second, most of the firms that are ever going to 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 have patents in an industry in which only 30% of the most substantial mature firms have patents. To get some more specific information on that point, we allocated each patent to a period defined by reference to the date of the firm's first financing. Figures 10 and 11 show the results of that exercise. As you would expect, that figure indicates that the number of patents obtained grows substantially over time, even as the number of firms that survive long enough to obtain them diminishes. Figures 12 and 13 show corresponding data for the timing of applications, based on applications for patents issued by the end of 2004.[39] Those figures suggest that firms do take steps to protect their IP early in their life cycle, long before the patents are likely to be useful. One possibility suggested by the data is that portfolio firms obtain the patents not so much 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

[39] The dropoff in applications for the closing years in both industries doubtless is an artifact of the fact that the only applications shown for those years are applications for which patents already have been issued, which means that the application figures for those years are likely to be significantly truncated.

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.[40]

[40] See Scott Shane, Selling University Technology: Patterns from MIT, 48 Management Sci. 122 (2002) (proposing a similar mechanism to explain patterns in licensing of patents assigned to MIT).

FIGURE 10: TIMING OF PATENTING

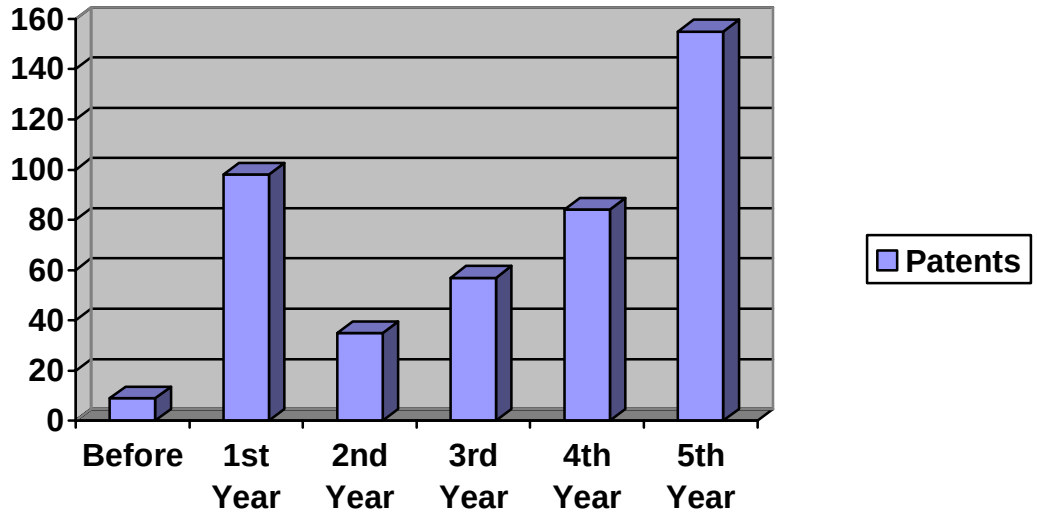


FIGURE 11: TIMING OF APPLICATIONS

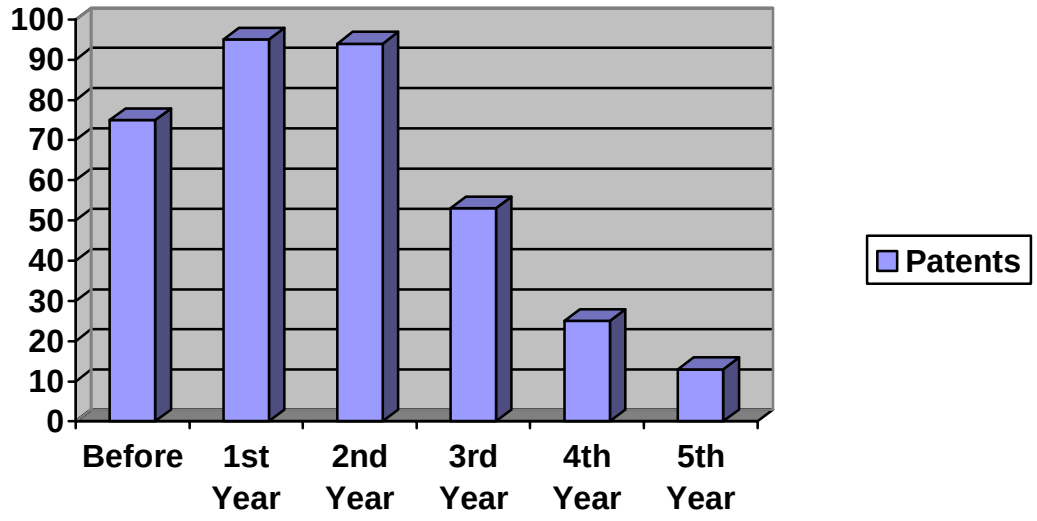


FIGURE 12: TIMING OF PATENTING (BIOTECH)

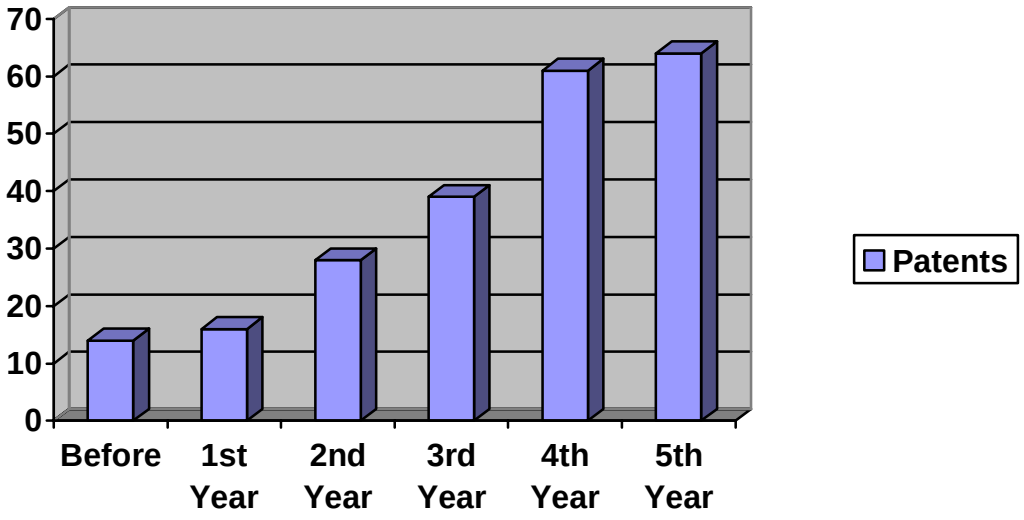
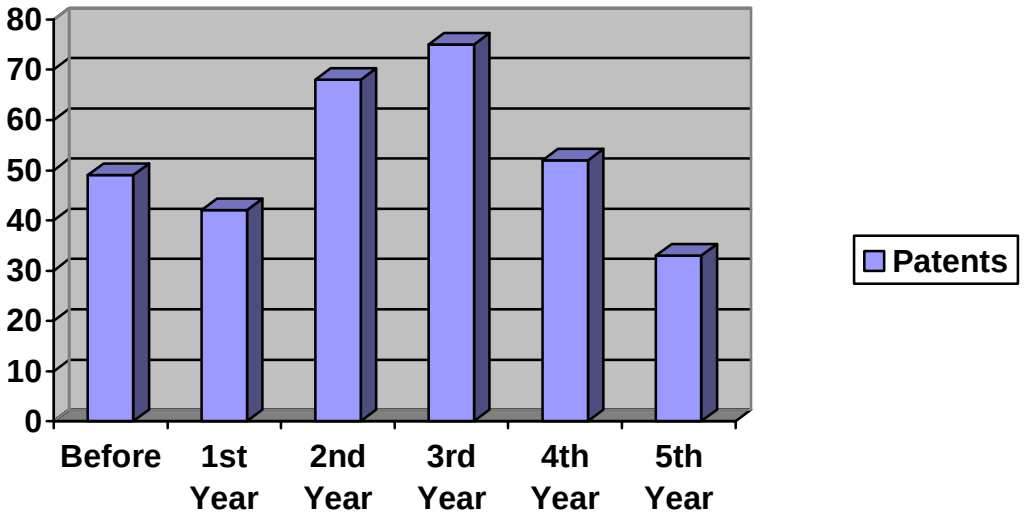


FIGURE 13: TIMING OF APPLICATIONS (BIOTECH)



As that chart suggests, patenting begins quite rapidly after the first financing, especially in the software industry. Coupled with the general irrelevance of patents held *before* the first financing, that resonates strongly with the argument that the importance of patents shifts substantially as the firm passes through the venture financing cycle.

V. CONCLUSION

The question of whether patents actually foster innovation is an intractable one that cannot 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 investment decisions.[41] Even that work, however, cannot say anything about the net effect on innovation.

Thus, the goals of this paper are more modest, to investigate 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 support for the understanding of the role of patents for software firms set out in the related paper. Most obviously, the low explanatory power and irrelevance of pre-financing patents is directly 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 proxies for success 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, they 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

[41] Petra Moser, How Do Patent Laws Influence Innovation? Evidence from Nineteenth-Century World Fairs (NBER Working Paper 9909) (August 2003).

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 my 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 those firms, the analysis here suggests two important countervailing effects. The first is the possibility that patents support firm entry, thus helping to stabilize the relatively decentralized structure of the industry and forestall the forces that drive the industry toward greater concentration and the market power that goes with it. The second is the possibility that patents facilitate the intraindustry 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.[42] 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 basic point of this paper is that a serious debate about the propriety of patents in the software industry must account not only for the theoretical

possibility that patents might impose substantial costs, but also for the empirically evident likelihood that they also provide substantial benefits.

[42] Arora & Merges, Specialized Supply Firms, *supra* note 11; Arora & Merges, Property Rights, *supra* note 11; Ashish Arora, Andrea Fosfuri & Alfonso Gambardella, Markets for Technology: The Economics of Innovation and Corporate Strategy (2001).

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