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PATENTING IN THE SHADOW OF COMPETITORS*

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ABSTRACT

This article empirically examines the patenting behavior of new biotechnology firms that have different litigation costs. I show that firms with high litigation costs are less likely to patent in subclasses with many other awards, particularly those of firms with low litigation costs. This pattern is consistent with the literature on costly litigation, which suggests that firms that have high litigation costs will take greater precautions to avoid litigation. These results are robust to a variety of control variables and modifications that seek to test alternative explanations.

I. INTRODUCTION

THIS article contrasts the patenting behavior of new biotechnology firms that have different litigation costs. I show that firms with high litigation costs are less likely to patent in subclasses with many other awards, particularly those of firms with low litigation costs. This pattern is consistent with the literature on costly litigation, which suggests that firms that have high litigation costs will take greater precautions to avoid litigation.

Interest in the influence of litigation on behavior dates back to the early days of the law-and-economics literature.[1] Beginning with Janusz Ordover,[2] a series of theorists has examined how litigation costs affect the willingness of firms to take precautions against harming others. Potential

* Keith Head, Jenny Lanjouw, Robert Merges, Lisa Meulbroek, Kathryn Spier, Alan Sykes (the editor), an anonymous referee, and seminar participants at Berkeley, Columbia, Harvard, the National Bureau of Economic Research Productivity and Output Measurement Group, the Western Economic Association, and the Wissenschaftszentrum Berlin für Sozialforschung provided helpful comments. I thank Mark Edwards of Recombinant Capital, Edward Lentz of SmithKline Beecham, Jesse Reyes of Venture Economics, and several legal librarians and patent attorneys for providing access to and advice about data sources. Research assistance was provided by Ben Conway, Tim Dodson, and Wendy Wood; financial support by Harvard Business School, Division of Research. Any errors and omissions are my own.

[1] R. H. Coase, The Problem of Social Cost, 3 J. Law & Econ. 1 (1960).

[2] Janusz A. Ordover, Costly Litigation in the Model of Single Activity Accidents, 7 J. Legal Stud. 243 (1978).

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injurers are typically seen as minimizing the sum of the cost of precaution and legal claims, which is in turn the product of the probability of causing harm and the expected cost of litigation with the injured party. A general conclusion of this literature is that, as the cost of litigation increases for a potential injurer, he or she exercises greater caution to avoid such injuries and litigation.[3] Less frequently addressed is the question of whether the potential plaintiff's litigation costs affect the willingness of the potential injurer to take precautions against causing harm. Several models, however, suggest that as the plaintiff's litigation costs increase, the potential injurer takes less care to avoid disputes.[4]

This article, motivated by these suggestions, examines the patenting behavior of firms with various levels of litigation costs. I anticipate that all else being equal, firms should avoid pursuing innovations that are likely to lead to the payment of settlements to rivals, regardless of whether the disputes are actually litigated. The patent system allows me to assess the impact of costly litigation on firm behavior without having to analyze the suits that are actually filed. A problem with the latter approach is that in many cases the disputants engage in extensive bargaining prior to the filing of a suit. If a potential plaintiff can credibly threaten to sue, many disputes should be settled before a formal filing. Any analysis of suits will consequently face selection biases, whose effects are difficult to predict.[5]

This article examines the patenting behavior of 419 new biotechnology firms. I characterize the awards using the U.S. patent classification scheme, which provides a detailed, objective mapping of the technologies that a firm is pursuing. Since virtually all biotechnology discoveries are patented, I avoid several biases that might appear in a sample including

[3] This relationship is a feature of, among other models, Keith N. Hylton, The Influence of Litigation Costs on Deterrence under Strict Liability and under Negligence, 10 Int'l Rev. L. & Econ. 161 (1990) (Proposition 2); Robert D. Cooter & Daniel L. Rubinfeld, Economic Analysis of Legal Disputes and Their Resolution, 27 J. Econ. Literature 1067 (1989) (discussion following eq. 12); and Ivan Paak Liang Png, Litigation, Liability, and Incentives for Care, 34 J. Pub. Econ. 61, 72 (1987) (but only for the higher-quality potential injurers in his model).

[4] An increase in plaintiffs' litigation costs leads to a decrease in product quality in Marilyn J. Simon, Imperfect Information, Costly Litigation, and Product Quality, 12 Bell J. Econ. 171, 172 (1981). An increase in the plaintiffs' litigation costs leads to more aggressive behavior by potential injurers in Png, *supra* note 3. A closely related body of literature examines the distribution of sham litigation—cases with negative expected value for the plaintiff, were they to go to trial—and suggests that these suits will be most frequent when defendants have high litigation costs and plaintiffs have low costs (reviewed in Cooter & Rubinfeld, *supra* note 3).

[5] These concerns are discussed at length in James W. Hughes & Edward A. Snyder, Policy Analysis of Medical Malpractice Reforms: What Can We Learn from Claims Data? 7 J. Bus. & Econ. Stat. 423 (1989).

other industries. I use as proxies for the cost of litigation the number of previous patent suits in which the firm has been involved and the firm's financial resources, as measured by paid-in capital. I justify the use of these two proxies below through references to practitioner discussions and empirical studies of economies of scale in litigation.

I demonstrate that the patenting behavior of firms varies with litigation costs in two ways. First, firms with high litigation costs are less likely to patent in subclasses with many previous awards by rival biotechnology firms. Firms with the highest litigation costs are twice as likely as others to patent in subclasses with no rival awards. When high-litigation-cost firms do patent in subclasses in which rival biotechnology firms have already patented, they tend to choose less crowded subclasses. In the case of firms with high litigation costs, the preceding award to a rival was 303 days earlier. In the case of other firms' patents, an interval of 208 days separated the last prior rival award.

Second, firms with high litigation costs are less likely to patent in subclasses where firms with low litigation costs have previously patented. A patent awarded to a firm with low litigation costs is followed by an award to a firm with high litigation costs 11 percent of the time; awards to other firms are followed by a patent to a firm with high litigation costs 21 percent of the time. The results are robust to controls for a variety of sample selection biases, such as the changing mixture of firms over time and the different technological focuses of various vintages of firms. The results are also robust to analyses that seek to control for alternative hypotheses suggested by the industrial organization literature.

The issue explored in this article is important for two reasons. The first is the persistent public policy debate about the "litigation explosion." Claims that protracted and costly litigation is leading to distortions in our economy have led to repeated calls for reform. This contention, for instance, was an important motivation for the recommendations of the President's Council on Competitiveness to overhaul the discovery and trial process.[6] More specifically, the U.S. patent system has seen a dramatic increase in both litigation and administrative proceedings over the past decade. Critics have suggested that the 1982 reform of the patent system has led to aggressive efforts by large firms to extract favorable settlements from smaller concerns and consequent distortions in the innovative activity of smaller concerns.

This article is related to several strands of empirical work examining the costs of litigation, and the impact of these costs. First, a series of

[6] President's Council on Competitiveness, Agenda for Civil Justice Reform in America: A Report from the President's Council on Competitiveness (1991).

papers has sought to document the distribution and determinants of civil litigation costs.[7] Second, studies have examined how the disposition of cases (e.g., whether suits go to trial) varies with the costliness of the class of litigation and the litigation rule in force.[8] Most closely related to this work is a set of studies that document how corporate behavior changes with the legal environment. For instance, the liability system has been shown to affect the industrial accident rate; the cost of liability insurance, the rate of product innovation.[9]

The organization of this article is as follows. In Section II, I summarize the patenting process. Section III describes the data set. In Section IV, I present the empirical analyses. Section V concludes the article.

II. The Patenting Process

This section sketches the U.S. patent application, classification, and litigation process.[10] A patent application to the U.S. Patent and Trademark Office (USPTO) essentially consists of a series of claims and supporting documentation. Some of the claims in a patent application will be cast in very specific terms; others may be sweeping. A supervising primary examiner reviews each incoming patent application and assigns it to one of the over 120,000 U.S. patent subclasses. This classification determines which examining group reviews the application.

A patent examiner in the assigned group then evaluates the proposed patent. To assess the novelty of the application, he searches previous patents issued in the original and related subclasses and several on-line databases. If the application appears to conform to the other standards for patentability, the patent examiner will then determine whether the claimed innovation conflicts with any in-process applications or recent

[7] David M. Trubeck *et al.*, The Costs of Ordinary Litigation, 31 UCLA L. Rev. 72 (1983); B. Peter Pashigian, A Theory of Prevention and Legal Defense with an Application to the Legal Costs of Companies, 25 J. Law & Econ. 247 (1982).

[8] Gary M. Fournier & Thomas W. Zuehlke, Litigation and Settlement: An Empirical Approach, 71 Rev. Econ. Stat. 189 (1989); Edward A. Snyder & James W. Hughes, The English Rule for Allocating Legal Costs: Evidence Confronts Theory, 6 J. L. Econ. & Org. 345 (1990).

[9] Examples include James R. Chelius, Liability for Industrial Accidents: A Comparison of Negligence and Strict Liability Systems, 5 J. Legal Stud. 293 (1976); Price V. Fishback, Liability Rules and Accident Prevention in the Workplace: Empirical Evidence from the Early Twentieth Century, 16 J. Legal Stud. 305 (1987); and W. Kip Viscusi & Michael J. Moore, Product Liability, Research and Development, and Innovation, 101 J. Pol. Econ. 161 (1993).

[10] Much of this section is based on Maurice H. Klitzman, Patent Interference: Law and Practice (1984); Herbert F. Schwartz, Patent Law and Practice (1988); and U.S. Department of Commerce, Patent and Trademark Office, Manual of Patent Examining Procedure (1992).

patent awards. Unlike most nations, the United States grants patents to the party that is "first to invent" a new product or process rather than the one who is "first to file" for an award. If the application appears to supersede another application or a recent award, the examiner will declare the patent application to be in interference. Disputes are turned over to USPTO's Board of Patent Appeals and Interferences. The firm whose patent has been interfered with (the senior party) is notified, and each party reviews the other's application. The Board will hold a hearing to determine which inventor first made the discovery. It will decide whether the junior party's patent should be allowed in its entirety or whether some claims should be disallowed. If the senior party's patent has not yet been issued, its claims may be scaled back or even rejected entirely. If the senior party's patent has been issued, the Board cannot take away the award or retroactively reduce its scope. A finding casting doubt on the senior party's patent, however, can be used by the junior party if and when it challenges the patent in federal court.[11]

Thus, prior to the award of the junior party's patent, the two parties are often aware of each other's patent position. The lengthy interference process serves to bring firms together early in the dispute process and facilitates the negotiation of a cross-licensing agreement to settle the controversy. In recent years, 80 percent of the interferences have been settled prior to a final hearing by the Board.[12]

At the time of award, the patent examiner assigns the patent to one or more U.S. patent subclasses. The examiner has a strong incentive to classify these patents carefully, because he uses these classifications in his searches of the prior state of the art. To insure the accuracy of the classification and to maintain consistency across examining groups, an official known as a "postclassifier" reviews the classification of all issuing patents.

One difficulty with the U.S. patent classification scheme is its dynamism. Examiners have considerable discretion to add new patent subclasses, which they exercise frequently. When a new patent subclass

[11] Often applicants will provoke interferences. The standard approach is for the firm to "copy claims"; that is, to include in its application the same wording as in another firm's claim. Even though USPTO holds pending applications confidential, firms often provoke interferences with patents that are still pending. They are able to do so because of the timing of the patent application process. To receive European patent protection, firms must file an application at the European Patent Office (EPO) within 1 year of the U.S. application. Eighteen months after the original application, EPO publishes the key information about the pending patent.

[12] Ian A. Calvert & Michael Sofocleous, Interference Statistics for Fiscal Years 1989 to 1991, 74 J. Pat. [& Trademark] Off. Soc'y 822 (1992).

is created, USPTO examiners review previously awarded patents. Any patents that would have been classified in this category had it existed at the time of their award will receive this new classification.[13] Thus, to compare the classification of patents that were awarded at different times, one must employ the revised classification rather than that made at the time of the award.

After the patent is issued, the primary forum for formally resolving disputes is the federal courts. The federal courts have exclusive jurisdiction over disputes involving the infringement of patents, as well as over appeals of USPTO decisions. Other disputes—for instance, a disagreement between a firm and an employee over a royalty—are routinely referred back to the state courts. If a firm believes that a patent is being infringed, it may sue the infringer for damages and/or injunctive relief (a judgment ordering the defendant to cease infringing the patent). Conversely, the alleged infringing firm may preemptively sue the other firm for declaratory relief (a judgment that the plaintiff is not infringing any patent held by the defendant).

In either event, the initial litigation must be undertaken in a district court. Prior to 1982, appeals were heard in the court of appeals of the district in which the case was tried. These circuit courts varied considerably in their interpretation of patent law, and the resolution of these differences through appeals to the U.S. Supreme Court was a lengthy and uncertain process. Consequently, the Court of Appeals for the Federal Circuit (CAFC) was established as the appellate court for all patent-related Federal cases. The CAFC's decisions may still be appealed to the U.S. Supreme Court, but the latter seldom agrees to hear such appeals.

At any point in the litigation process, the adversarial parties may settle their dispute. This agreement may or may not be accompanied by compensation for retroactive relief and/or a patent license or cross-license agreement. If the settlement is reached before the filing of a suit or a decision within USPTO, the existence of the dispute is unlikely to become public knowledge. The settlement of interferences or postaward disputes are rarely announced, and certainly not in any systematic manner.

Practitioner accounts suggest that the impact of patent litigation has grown with the strengthening of patent rights. This shift toward a more "propatent" policy has been effected partially through legislation—for example, the Computer Software Protection of Act of 1980 and the Semiconductor Chip Protection Act of 1984—but even more so through the

[13] U.S. Department of Commerce, Patent and Trademark Office, Examiner Handbook on the Use of the U.S. Patent Classification System (1984).

decisions of the CAFC. When the CAFC was created in 1982, its stated purpose was to be a streamlined venue for treating patent cases in a systemized manner. But as Robert Merges notes, "While the CAFC was ostensibly formed strictly to unify patent doctrine, it was no doubt hoped by some (and expected by others) that the new court would make subtle alterations in the doctrinal fabric, with an eye to enhancing the patent system. To judge by results, that is exactly what happened."[14] This claim is supported through a comparison of CAFC's rulings with previous appellate decisions in patent infringement cases. Between 1953 and 1978, circuit courts affirmed 62 percent of district court decisions holding patents to be valid and infringed and reversed 12 percent of the decisions holding patents to be invalid or not infringed.[15] In the years 1982–90, the CAFC affirmed 90 percent of district court decisions holding patents to be valid and infringed and reversed 28 percent of the judgments of invalidity or noninfringement.[16]

As a consequence, corporate patent litigation today appears to be quite frequent. In an analysis of intellectual property litigation involving a sample of 530 firms based in Middlesex County, Massachusetts, I found that these firms engaged in 78 distinct patent suits between January 1990 and June 1994 in Federal District for Massachusetts and Middlesex County Superior Court.[17] During the same period, these firms were awarded 2,533 patents. Because firms generally attempt to litigate cases in the district encompassing their headquarters,[18] this litigation probably represents

[14] Robert P. Merges, Patent Law and Policy, at 9 (1992).

[15] Gloria K. Koenig, Patent Invalidity: A Statistical and Substantive Analysis (1974).

[16] Robert L. Harmon, Patents and the Federal Circuit (1991). In the steady state, such comparisons can be misleading, as plaintiffs and defendants may adjust their willingness to license and litigate: see Michael J. Meurer, The Settlement of Patent Litigation, 20 RAND J. Econ. 77 (1989). This measure, however, can provide a rough indication of the short-run changes in judicial behavior.

[17] Josh Lerner, The Importance of Trade Secrecy: Evidence from Civil Litigation (unpublished manuscript, Harvard Univ. 1994).

[18] Because there was considerable variation in the interpretation of patent laws across the federal circuits before the creation of the CAFC in 1982, firms frequently attempted to litigate cases in districts that they believed were predisposed to their arguments. The creation of the centralized appellate court led to a considerable reduction in the differences in intellectual property law across the circuits. As a result, "forum shopping"—the filing of cases in districts perceived to be favorable—declined sharply. Firms today generally attempt to litigate these cases in the same district as their headquarters. This allows them to employ the same outside lawyers that they usually utilize and to make greater use of internal corporate counsel. See Jack L. Slobodin, What to Do from Getting the Case—to Trial: An Overview for the Patent Infringement Lawyer, in 1 Patent Litigation (Tom Arnold, Roy E. Hofer, & Laurence H. Pretty eds. 1993). The claim that litigation in the judicial district nearest the firm represents about one-half the firm's intellectual property disputes is also

about one-half the patent suits involving these firms. The analysis suggests that approximately six patent suits are filed for each 100 corporate patent awards. Particularly striking, practitioner accounts suggest, has been the growth of litigation—and threats of litigation—between large and small firms. Several well-capitalized firms, including Texas Instruments, Digital Equipment, and Intel, have established groups that approach rivals to demand royalties on old patent awards. In addition to litigation in the courts, in recent years nearly 4,000 quasi-judicial administrative procedures have been conducted annually within the USPTO.[19]

These suits lead to significant expenditures by firms. Based on historical costs, the patent litigation within USPTO and the federal courts begun in 1991 will lead to total legal expenditures (in 1991 dollars) of about $1 billion,[20] a substantial amount relative to the $3.7 billion spent by U.S. firms on basic research in 1991.

Litigation also leads to substantial indirect costs. The discovery process is likely to require the alleged infringer to produce extensive documentation, as well as time-consuming depositions from researchers and general managers. The firm may be portrayed unfavorably in the trade press and be disparaged by rival salesmen. In addition, the CAFC has repeatedly emphasized a patentee's "affirmative duty to exercise due care to determine whether or not he is infringing" other firms' patents.[21] If the infringement is held to be willful, the firm risks being assessed trebled damages, opponent's legal fees, and court costs. Its officers and directors may also be held individually liable.

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confirmed through an examination of the "Litigation" section in the most recent 10-Ks filed by the 130 firms in the Middlesex County sample that are publicly traded. Firms must report litigation that is material. Cases in the judicial district nearest the firm represent about 42 percent of the cases apparently involving intellectual property issues that are mentioned.

[19] U.S. Department of Commerce, Patent and Trademark Office, Annual Report: Fiscal Year 1991 (1991).

[20] This estimate is based on several sources. For the cost of procedures within USPTO, I use Calvert & Sofocleous, *supra* note 12; and William Kingston, Is the United States Right about "First-to-Invent"? 14 Eur. Intell. Prop. Rev. 223 (1992). For procedures within the federal courts, I use Breton August Bocchieri, Obtaining Attorney Fees in Intellectual Property Cases: Rule 11 and Other Sanctioning Mechanisms, 33 IDEA 211 (1993); Ronald B. Coolley, Obtaining Attorney's Fees for Corporate Patent Counsel's Assistance in Litigation, 72 J. Pat. [& Trademark] Off. Soc'y 212 (1990); and the decisions cited in these articles. The volume of litigation is from U.S. Department of Commerce, *supra* note 19. The USPTO's estimate of the number of patent suits is likely to be low, because (i) many cases that involve patents are classified as contract, miscellaneous tort, or other cases, and (ii) many suits classified as patent cases are nonetheless not reported by the federal clerks to USPTO. See discussion in Lerner, *supra* note 17.

[21] Underwater Devices, Inc. v. Morrison-Knudsen Co., 717 F.2d 1380, 1389; 219 U.S.P.Q. (BNA) 569 (Fed. Cir. 1983).

Event studies can provide one indication of the total costs of litigation. Sanjai Bhagat, James Brickley, and Jeffrey Coles examine the market reaction to the filing of 20 patent infringement lawsuits between 1981 and 1983 where (i) the filing was reported in the *Wall Street Journal,* (ii) there is only one plaintiff and defendant, and (iii) both the plaintiff's and defendant's stock returns are included in the Center for Research in Security Prices' (CRSP) Daily Returns File.[22] In the 2-day window ending on the day the story appears in the *Wall Street Journal,* the combined market-adjusted value of the firms fell by an average of −3.1 percent (significant at the 1 percent confidence level). I replicate their analysis using the patent suits involving pairs of biotechnology firms in my sample between 1980 and 1992 where there is a clearly dated press announcement of the suit and stock prices of the plaintiff and defendant's securities are available through CRSP. (The sample is described in Section III; the sources I employ to identify suits are indicated in the Appendix.) I follow their procedure as closely as possible.[23] In these 26 cases, the average 2-day market-adjusted change in combined capitalization, −2.0 percent, is significant at the 1 percent confidence level. The average reduction in shareholder wealth is $67.9 million; the median, $20.0 million.

These developments have sparked concern that the pattern of costly litigation—or payments to forestall litigation—are leading to reductions or distortions in innovative investments, particularly for small firms.[24] This anecdotal evidence is supported by more formal examinations. Jean Lanjouw uses European patent renewal data and a model of patenting

[22] Sanjai Bhagat, James A. Brickley, & Jeffrey L. Coles, The Costs of Inefficient Bargaining and Financial Distress: Evidence from Corporate Lawsuits, 35 J. Fin. Econ. 221 (1994).

[23] One exception is the timing of the event windows. If the first announcement of the suit is a newspaper story, I (as in the earlier study) use the 2-day event window ending on the day the story was printed. If the first report is a press release or a news wire story, I use the 2-day window beginning on the announcement date. To limit my analysis to events where suits clearly convey news, I include neither countersuits filed after an initial lawsuit nor cases where a firm files multiple patent lawsuits against several rivals within a 2-day period.

[24] Several examples are discussed in Nancy Rutter, The Great Patent Plague, Forbes ASAP, March 29, 1993, at 58–66. For additional citations, see Michael Paul Chu, An Antitrust Solution to the New Wave of Predatory Patent Infringement Litigation, 33 Wm. & Mary L. Rev. 1341 (1992). The targeting of small firms by Refac International (a technology licensing company that frequently litigates patents) is discussed in Refac Int'l Inc. v. IBM Corp. *et al.*, 710 F.Supp. 569, 11 U.S.P.Q.2d (BNA) 1476 (D.N.J. 1989). (Refac's president has argued that "it only makes sense to use the cost of litigation as a bargaining leverage to force a settlement on terms favorable to the party that can litigate the matter to death without worrying about cash flow" (*Refac, supra* at 571).) These concerns also appear to have been an important motivation for the Department of Justice's emphasis on "innovation markets" in their proposed new intellectual property guidelines.

behavior to estimate how litigation affects the pace of innovation. Her simulations suggest that a doubling of legal costs will lead about a 30 percent reduction in the value of the average patent.[25] Claims regarding differences with firm size are corroborated by a 1990 survey of 376 firms. This survey found that the time and expense of intellectual property litigation was a major factor in the decision to pursue an innovation for 55 percent of the enterprises with under 500 employees, but was a major concern for only 33 percent of larger businesses. In general, small firms believed that their patents were infringed more frequently, but were considerably less likely to litigate these infringements.[26]

III. The Sample

This section describes the rationale for the choice of the biotechnology industry, as well as the construction of the sample. Biotechnology is among the industries most reliant on patents. In most other industries, survey evidence suggests that only a fraction of discoveries are patented.[27] Fearful of the disclosure entailed in the patent process, firms instead rely heavily on trade secrecy. Because of the mobility of scientific personnel and the industry's strong academic roots, biotechnology firms do not consider trade secrecy a viable alternative. One can be relatively certain that biotechnology firms will attempt to protect key discoveries through patents. Thus, my analysis of patenting behavior does not encounter the biases that would plague a similar analysis of an industry in which whole classes of inventions were not patented.

Identifying biotechnology firms, however, is problematic. Directories of biotechnology firms typically list many firms specializing in medical devices, generic pharmaceuticals, and other areas. This is because these directories are typically based on survey responses. Many firms whose involvement in biotechnology is quite limited may nonetheless feel that the visibility of a directory listing is helpful. I thus restrict my analysis to firms in two compilations that carefully scrutinize their listings.

The first of these is Venture Economics' Venture Intelligence Database. Venture Economics, a subsidiary of Securities Data Company,

[25] Jean Olson Lanjouw, Economic Consequences of a Changing Litigation Environment: The Case of Patents (Working Paper No. 4835, National Bureau of Economic Research 1994).

[26] Mary S. Koen, Survey of Small Business Use of Intellectual Property Protection: Report of a Survey Conducted by MO-SCI Corporation for the Small Business Administration (1991).

[27] Richard C. Levin *et al.*, Appropriating the Returns from Industrial Research and Development, Brookings Papers Econ. Activity: Microecon. 783 (1987).

gathers information about the activities of venture capital funds from institutional investors. The organization prepares a profile of each venture-backed company's activities and assigns it a four-digit industry classification number. I use firms in the 4000 class, "Biotechnology." The second source is Recombinant Capital. This consulting firm specializes in gathering information about biotechnology firms. It identifies these firms from filings with the U.S. Securities and Exchange Commission (SEC) and state records. (In many states, private firms must make detailed filings documenting their financial and operating performance, which become part of the public record.) Using these two sources, I identify 419 private and public U.S. firms active between the industry's birth in the early 1970s and the end of 1992.[28] Summary statistics on these firms are presented in panel A of Table 1.

The USPTO's two CD-ROM databases (which are marketed as the BIB and ASSIST files of the CASSIS database) and BRS Information Technologies' PATDATA database are used to identify patent awards to these firms from their inception (the earliest award is from 1973) through December 1992. I include awards to these firms' subsidiaries, joint ventures, and research and development limited partnerships. I identify these affiliated entities, as well as corporate name changes, from a variety of reference sources.[29] I find a total of 2,048 awards. I determine the updated classifications for these patents using USPTO's October 1993 CASSIS/BIB file. These patents are assigned into a total of 2,703 subclasses. I summarize the patent sample in panels B and C of Table 1.

I confine my analysis to patents awarded to new biotechnology firms. I do not consider biotechnology patents awarded to large corporations or universities. If I included these firms, I would then have to face the problem of disaggregating patents based on biotechnology from those derived from more traditional pharmaceutical research. A natural way to do this would be through the patent classification scheme. In this case, however, subsequent analyses in this article (which examine the distribution of patents in various subclasses) would be affected. For instance, I might identify which patents awarded to pharmaceutical companies involved biotechnology by examining the patenting patterns of biotechnol-

[28] These data sources are described in detail in Josh Lerner, Venture Capitalists and the Decision to Go Public, 35 J. Fin. Econ. 293 (1994).

[29] Especially useful are Teena Lerner, Biorelationships: A Guide to Business Relationships Involving Biotechnology Companies and Their Corporate Partners (1989); North Carolina Biotechnology Center, Biotechnology Information Division, North Carolina Biotechnology Center Documentation for Actions Database (1990); BioScan: The Worldwide Biotech Industry Reporting Service (1992); and Predicasts, Inc., Predicasts F&S Index of Corporate Change (1992).

TABLE 1

SUMMARY STATISTICS

	Mean	SD	Minimum	Maximum
A. New biotechnology firms:				
Patent awards through December 31, 1992	4.89	14.96	0	197
Patent lawsuits through December 31, 1992	.27	1.25	0	14
Age of firm on December 31, 1992*	8.70	4.01	.20	31.50†
Paid-in capital on December 31, 1991‡	61.41	93.15	.21	676.23
B. 2,048 patents awarded to firms in sample:				
Award date	8/89	2.6 years	3/73	12/92
Number of U.S. Patent and Trademark Office subclasses	7.27	5.02	1	29
C. 2,703 subclasses with patents, by firms in sample				
Patent awards to firms in sample, 1973–92§	5.50	14.20	1	351
Date of first award in subclass	3/88	3.5 years	3/73	12/92

* Only for those firms awarded a patent in 1992 (expressed in years).

† The oldest firm, after being established as a contract research organization, shifted its focus to biotechnology.

‡ Only for those firms awarded a patent in 1992 (expressed in millions of current dollars).

§ Most patent awards are assigned to several subclasses.

ogy firms or by surveying patent attorneys or examiners. In this case, I would probably disproportionately select patents in subclasses with many previous patents. This would bias my conclusions regarding the willingness of firms of different sizes to patent in classes with many awards.[30]

At the same time, the exclusive focus on new firms introduces some concerns. First, while I examine whether new biotechnology firms patent near each other, I do not assess whether they patent near pharmaceutical company patents. While the omission of these patents will clearly add noise to my analyses (reduce the goodness of fit), it does not appear to introduce systemic biases. Second, I do not anticipate that the behavior of these new biotechnology firms will be representative of all firms. In a number of industries, established firms have signed broad patent cross-licensing agreements, which limit the possibility of costly patent battles.

[30] A related concern is that the proxies for litigation costs that I employ may be less meaningful for established pharmaceutical firms. For instance, I employ paid-in capital as a proxy. Large pharmaceutical firms are likely to have raised their last external equity many years before. These firms may consequently have relatively modest paid-in capital, even though their financial resources are substantial.

Among young biotechnology firms, such arrangements are far less frequent. Thus, I expect that these firms represent an extreme on the spectrum of patenting behavior.

IV. Empirical Analyses

A. Developing the Proxies for Litigation Costs

I cannot observe each firm's cost of litigation directly. Instead I use two proxies: the firm's previous experience in patent litigation and its paid-in capital. My justification for using the first proxy is the specialized nature of the patent litigation process. Practitioner accounts suggest that there is a substantial "learning curve" in patent litigation, as firms become more efficient in managing internal and external counsel.[31]

Concerning the second proxy, there are three reasons to expect that litigation will be less costly for larger firms. First, larger firms are likely to have a greater ability to employ internal corporate patent counsel rather than being obliged to rely exclusively on outside counsel. While the quality-adjusted price of outside and inside counsel may be similar, a Price Waterhouse study shows that firms with lower legal costs tend to rely heavily on internal counsel for certain functions.[32] Second, previous work has demonstrated that smaller firms have relatively higher litigation costs.[33] In a similar vein, bankruptcy costs,[34] drug approvals,[35] and environment and safety regulations[36] display significant economies of scale. Indirect evidence is provided by Bhagat, Brickley, and Coles's event study, which documents that thinly capitalized defendants have significantly more negative stock price reactions to the filing of lawsuits than do other firms.[37] Third, even if smaller firms spend the same amount on litigation, these expenditures are likely to be more costly in terms of the

[31] Examples include James J. Foster, How to Manage the Cost of Patent Litigation: Suggestions of Trial Counsel, 68 J. Pat. [& Trademark] Off. Soc'y 127 (1986); and Slobodin, *supra* note 18.

[32] Jonathan P. Bellis & Bernard H. Gustin, Comparing the Cost of Outside and Inside Counsel, 8 Corp. Couns. Q. 80 (1992).

[33] Pashigian, *supra* note 7.

[34] James S. Ang, Jess H. Chua, & John J. McConnell, The Administrative Costs of Corporate Bankruptcy: A Note, 37 J. Fin. 219 (1982).

[35] Lacy Glenn Thomas, Regulation and Firm Size: FDA Impacts on Innovation, 21 RAND J. Econ. 497 (1990).

[36] B. Peter Pashigian, The Effect of Environmental Regulation on Optimal Plant Size and Factor Shares, 27 J. Law & Econ. 1 (1984); Ann P. Bartel & Lacy Glenn Thomas, Predation through Regulation: The Wage and Profit Effects of the Occupational Safety and Health Administration and the Environmental Protection Agency, 30 J. Law & Econ. 239 (1987).

[37] Bhagat, Brickley, & Coles, *supra* note 22.

dilution of management's equity ownership.[38] I use paid-in equity rather than market valuation because I wish a measure of the current scale of the firm's resources. Very young firms exploring promising technologies, but which have raised only a modest amount of equity, may nonetheless command substantial valuations.[39]

There is no single source that identifies all the litigation involving these patents. To avoid selection biases, I search over seven databases. The Appendix describes these sources. While none of these sources is complete in and of itself, together the search appears to be quite comprehensive and free from significant biases. I identify 90 distinct suits involving firms in this sample filed through December 31, 1992. Thus, over the sample period there are 5.5 patent suits for every 100 patent awards.[40]

I compute each patentee's capitalization as of December 31 of the year immediately prior to the patent award. I include in this measure the capital raised by subsidiaries over which the firm exercises effective control, such as research and development limited partnerships and publicly traded research and development subsidiaries ("SWORDs"). Since well over half of these firms were privately held throughout this period, I use several sources to determine this measure. For the firms that are public (or filed to go public but withdrew their proposed initial public offerings), I find this information in SEC filings. For some acquired firms, I obtain financial information from the acquirers' SEC filings. For the remaining firms (where no SEC disclosures have been filed), I employ the records of Venture Economics and Recombinant Capital. In total, I can determine the capitalization of the patentee in the year prior to 98.4 percent of the patent awards.

[38] Small firms, especially those without tangible assets, often find it difficult to issue debt. Equity investors in a small firm may demand to purchase shares at a discount, as compensation for their need to provide oversight to the firm. The smallest firms, which have not yet issued public equity, should face especially high dilution, as investors will also demand compensation for the illiquidity of the shares.

[39] While firms with promising prospects may also be more aggressive and/or successful in raising equity capital, biotechnology firms typically take many years to produce a commercial product. Consequently, funds are usually not raised long before they are needed: venture capital is typically provided in stages, and public firms make frequent equity issues.

[40] It may be thought puzzling that the ratio of suits to patents is lower among these new biotechnology firms than in the cross-industry sample discussed above, given the importance of patents in biotechnology. A primary reason for the difference is that many firms in the cross-industry sample, unlike the biotechnology concerns, are already established at the beginning of the period. As a result, they are litigating not only newly issued patents but also previous awards. As the biotechnology firms' patent stocks grow over the sample period, the ratio of suits to patent awards increases. (For instance, in 1992, the ratio was almost eight suits for every 100 awards.)

Two concerns can be raised concerning the interpretation of these proxies. First, in deciding whether to engage in behavior that may injure others, firms should be influenced by the expected cost of litigation.[41] This can be viewed as the product of the probability that a suit will be filed times the expected cost of any litigation that results. For firms involved in many previous suits, the change in expected trial costs may be ambiguous. While these firms may be able to litigate awards in a cost-effective manner, the nature of their technology or their specific market segment may lead to a greater probability of litigation. This leads to some ambiguity about the relationship between the provision of care and this proxy.

A second problem is that fear of costly litigation is not the only interpretation of the results. In Section IV*D* below, I employ control variables and other modifications to address several alternative hypotheses suggested by the industrial organization literature.[42]

B. Patenting and the Number of Previous Awards

I first examine whether firms that have different litigation costs, as measured through these two proxies, vary in their propensity to patent in subclasses with previous awards by rival biotechnology firms. Table 2 presents the basic pattern. I divide the firms into those that had been involved in zero, from one to five, from six to 10, and 11 or more previous patent lawsuits. I also divide the patentees into quartiles, based on the paid-in capital. For each group of patentees, I present two measures. First, I indicate the percent of patents where no rivals had previously patented in the subclass. For those firms that patented in a subclass with an earlier rival patent, I also indicate the number of days since the last patent in the subclass.[43]

[41] For instance, in Cooter and Rubinfeld (*supra* note 3), potential injurers solve $\min_x x + p(x)L(x)$, where x is the cost of taking care, $p(x)$ is the expected probability of being sued, and $L(x)$ the anticipated cost of litigation.

[42] One issue that I cannot empirically analyze is the impact of the fee arrangements between the disputants and their outside counsel. The decision to litigate has been shown to be sensitive to the contracts between lawyers and their clients: see, for instance, Patricia Munch Danzon, Contingent Fees for Personal Injury Litigation, 14 Bell J. Econ. 213 (1983). Conversations with practitioners suggest that explicit contingent fee arrangements are rare in corporate patent litigation. Law firms specializing in high technology, however, frequently offer services to start-ups at a reduced rate, with the expectation of receiving future patronage. In some cases, lawyers may also invest in the young firms that they represent.

[43] I employ the days to the previous patent in the subclass, rather than the number of previous patent awards in the subclass. This is because in the latter case, the dependent variable (the number of prior patents) would not be independent across observations. This could lead to an overstating of the significance levels in the correlation and regression analyses.

TABLE 2

PERCENTAGE OF PATENTS THAT ARE IN A SUBCLASS WITH NO EARLIER RIVAL PATENTS, AND DAYS SINCE PREVIOUS PATENT AWARD BY A RIVAL IN THE SUBCLASS

	% of Patents with No Rival in Subclass	Days since Last Patent in Subclass
A. Patentees divided by the number of patent lawsuits prior to award:		
Patentee involved in no previous patent suits	31.4	270.5
Patentee involved in 1–5 previous patent suits	14.9	182.9
Patentee involved in 6–10 previous patent suits	9.1	153.6
Patentee involved in 11 or more previous patent suits	6.6	192.2
B. Patentees divided by paid-in capital at end of year prior to award:		
Patentee's paid-in capital is in bottom quartile	40.6	302.5
Patentee's paid-in capital is in third quartile	25.6	251.6
Patentee's paid-in capital is in second quartile	19.7	216.4
Patentee's paid-in capital is in top quartile	11.0	164.1

NOTE.—The first column indicates the percentage of the firm's patents that are in subclasses with no earlier patents by rivals. The second column indicates, for those patents that are in subclasses where a rival has patented previously, the mean number of days since the previous award by a rival. Patentees are divided by two proxies for litigation costs at the time of the award, the number of previous patent lawsuits, and paid-in capital (in millions of current dollars). Each subclass of each patent award is used as a separate observation (with a total of 14,885 observations).

The table documents that firms with proxies for high litigation costs—that is, firms involved in no previous patent suits or in the lowest quartile of paid-in capitalization—are more likely to patent in subclasses without rivals (31.4 percent and 40.6 percent). When they patent in subclasses where rivals have previously patented, the most recent rival patent is further in the past. For instance, firms in the bottom quartile of capitalization patent 303 days after the previous patent by a rival; firms in the topmost quartile, 164 days.

I then examine these patterns statistically. I examine whether the litigation cost proxies differ for firms patenting in subclasses with and without previous rival patents. In part A of Table 3, I perform a *t*-test comparing the previous litigation experience and paid-in capital of these groups. I find that in both cases the differences are significant at the 1 percent confidence level.

Two objections may be raised concerning selection biases in this analysis. First, this effect may simply reflect the changing distribution of firms.

TABLE 3

t-TEST AND PROBIT REGRESSION ANALYSES OF PATENTS IN SUBCLASSES, WITH AND WITHOUT EARLIER RIVAL PATENTS

A. *t*-TESTS COMPARING PATENTS IN SUBCLASSES, WITH AND WITHOUT RIVAL PATENTS			
	In Subclass with Rival	In Subclass without Rival	*p*-Value, *t*-Test
Previous patent suits involving patentee	2.30	.94	.000
Paid-in capital of patentee	117.3	60.0	.000

B. PROBIT REGRESSION ANALYSIS (Dependent Variable: Patent Is in Subclass with Rival Patent(s))			
	(1)	(2)	(3)
Previous patent suits involving patentee	.08	. . .	.03
	(17.54)		(4.80)
Paid-in capital of patentee	. . .	.003	.002
		(19.18)	(9.99)
Date of the award	.14	.13	.13
	(30.19)	(27.95)	(28.03)
Constant	−275.78	−261.60	−261.88
	(30.12)	(27.91)	(27.98)
Log likelihood	−7,316.10	−7,196.89	−7,185.24
χ^2-Statistic	1,531.11	1,578.71	1,602.01
p-Value	.000	.000	.000

NOTE.—Part A compares two proxies for the patentee's litigation costs at the time of the award, the number of previous patent lawsuits, and paid-in capital (in millions of current dollars) for patents in subclasses with and without rival patents. Each subclass of each patent award is used as a separate observation (with a total of 14,885 observations). Part B estimates a probit regression, in which the dependent variable is whether the patent is in a subclass where a rival has patented previously (1.0 denotes such a case). I use as independent variables the number of previous suits involving the patentee, the patentee's paid-in capital at the time of award, and the date of the award (July 1, 1992, is expressed as 1992.5, etc.). Absolute *t*-statistics are in parentheses.

Patentees later in the period under study have on average somewhat larger paid-in capital. By late in the period, many more subclasses had been patented in by rivals. The correlation between firms' capitalization and their propensity to patent in subclasses already occupied by rivals may thus be spurious.

I address this concern in two ways. First, in an unreported analysis, I divide firms into quartiles based on paid-in capital in a different manner. I compare the capital of the firm receiving the patent only to those firms which received a patent in the same year. This procedure should eliminate the time bias. The magnitude of differences remains the same. An *F*-test indicates that the differences across quartiles are strongly significant.

Second, as reported in part B, I estimate a probit regression. I use as the dependent variable a dummy, which takes on the value one when the patent is in a subclass with earlier rival awards. I alternatively use as independent variables the number of prior patent suits involving the patentee and the patentee's paid-in capital. I also control for the date of the award (a patent awarded on July 1, 1992, is coded as 1992.5). The two proxies for litigation costs remain statistically and economically significant. At the mean of the independent variables, a 1 standard deviation increase in previous patent suits decreases the probability that the patent is alone in its subclass from 21 percent to 14 percent. A 1 standard deviation increase in capital decreases the probability from 21 percent to 13 percent. In the third regression, I include both litigation cost proxies. A joint test of the null hypothesis that these variables do not differ from zero produces a χ^2-statistic of 454.62, allowing me to reject the null hypothesis at the 1 percent confidence level. In unreported regressions, I also use the square of time and employ dummy variables for each 2-year period. The proxies for litigation costs remain of the same magnitude and significance.

A second concern relates to my use of multiple observations for many patents. Patents are frequently assigned to several subclasses. In this analysis, each subclass assignment is regarded as a distinct observation. My rationale is that the patents themselves usually consist of several distinct claims. It is unlikely that these complex patents would fall into one subclass. But if the subclass assignments are not really independent, my approach might inflate the number of observations and distort the significance levels of my tests. I repeat the analysis, using only one subclass assignment, the reference originally assigned by the supervising primary examiner. The results, as well as those in the regressions below, remain statistically significant at the 1 percent confidence level.

I then examine the relationship between the patentee's litigation costs and the number of days elapsed since the previous rival patent award in the subclass. I only use patents where a rival has patented earlier in the same subclass. Panel A of Table 4 shows that the correlation coefficients are highly significant.

I examine this relationship in a regression framework. I use as the dependent variable the number of days since the previous award. Reflecting the distribution of the independent variable, I employ an exponential regression specification. (The results are little altered when I assume a more general Weibull distribution.) I alternatively use as independent variables the number of prior patent suits involving the patentee and the patentee's paid-in capital. I also control for the total number of patents awarded to sample firms in the year of the award. Since the

TABLE 4

CORRELATION AND EXPONENTIAL REGRESSION ANALYSES OF DAYS SINCE PREVIOUS PATENT AWARD TO A RIVAL IN SUBCLASS

A. CORRELATION COEFFICIENTS AND p-VALUES

	Correlation Coefficient	p-Value
Previous patent suits involving patentee and days since last award	−.080	.000
Paid-in capital of patentee and days since last award	−.085	.000

B. EXPONENTIAL REGRESSION ANALYSIS
(Dependent Variable: Days since Last Rival Patent in Subclass)

	(1)	(2)	(3)
Previous patent suits involving patentee	−.04	. . .	−.02
	(15.57)		(5.71)
Paid-in capital of patentee	. . .	−.0009	−.0004
		(14.26)	(3.88)
Patents in year of award	−.0001	−.0001	−.0001
	(11.47)	(10.81)	(11.27)
Constant	5.78	5.78	5.79
	(209.88)	(212.10)	(210.20)
Log likelihood	−23,553.54	−23,326.73	−23,310.65
χ^2-Statistic	403.98	394.68	426.85
p-Value	.000	.000	.000

NOTE.—Part A examines the correlation between two proxies for the patentee's litigation costs at the time of the award, the number of previous patent lawsuits and paid-in capital (in millions of current dollars), and the mean number of days since the previous award to a rival in the subclass. The analysis is restricted to those patents who are in subclasses where a rival has patented previously. Each subclass of each patent award is used as a separate observation (with a total of 11,579 observations). The second panel estimates an exponential regression, in which the dependent variable is the days since the last rival award. I use as independent variables the number of previous suits including the patentee, the paid-in capital of the patentee at the time of the award, and the total number of awards to sample firms in the year of the observation. Absolute t-statistics are in parentheses.

number of biotechnology firms patenting varies over the period, the mean time between awards may vary as well. (In unreported regressions, I also control for the date of the award.) Firms with lower litigation costs appear to patent in more crowded subclasses, with the two proxies for litigation costs remaining statistically and economically significant. At the mean of the independent variables, a 1 standard deviation increase in previous patent suits decreases the number of days since the previous award from 227 to 199 days. A 1 standard deviation increase in paid-in capital decreases the number of days since the previous award from 225 to 200 days. I again include both litigation cost proxies in a third regression. A

joint test of their significance yields a χ^2-statistic of 218.26, allowing me to reject the null hypothesis at the 1 percent confidence level.

I also undertake an (unreported) Tobit analysis. In this case, I use as the dependent variable the reciprocal of the years since the previous rival patent award in the subclass. I code the dependent variable as zero in cases where there was no prior award to a rival. I estimate a Tobit regression, which treats the observations as censored at zero. The two proxies for litigation costs remain economically and statistically significant.

The span from patent application to award is typically several years. It may be wondered whether firms can anticipate when filing a patent application whether subclasses will be crowded at the time of the award. There are several responses. First, biotechnology firms tend to monitor closely the progress of competitors. They can do so because their competitors' research plans are often apparent at an early date: in many cases, firms trumpet their plans to attract investors and encourage researchers to publish in scientific journals. Second, the patent application process is a dynamic one. The majority of applications in this sample have been modified over the course of the application. One of the most common mechanisms is the "continuation-in-part," in which one component of the application is refined, while the remainder is abandoned.[44] Thus, as information about competitors' activities becomes apparent through U.S. patent awards and European Patent Office applications, firms may adjust their portfolio of pending applications.

C. Patenting and the Characteristics of Previous Patentees

I then examine whether firms with high litigation costs avoid potential conflicts with firms with low litigation costs. As discussed above, theoretical work suggests that firms will go to greater pains to avoid disputes in these instances. I examine the characteristics of rivals that patent in a subclass after an earlier award. I divide the observations by the characteristics of the original patentee. Panel A of Table 5 shows that awards to firms that have engaged in many patent suits are likely to be followed by awards to firms with more litigation experience and greater paid-in capital. A similar pattern appears when patentees are divided by paid-in capital in panel B.

I then examine statistically whether potential plaintiffs' litigation costs affect the willingness of firms to take precautions. Table 6 shows that the correlation coefficients of the litigation costs of the original patentee and

[44] For an analysis, see U.S. General Accounting Office, Biotechnology: Backlog of Patent Applications (1989).

TABLE 5

CHARACTERISTICS OF FIRST RIVAL TO PATENT IN A SUBCLASS AFTER AN EARLIER PATENT

	Mean Patent Suits by First Rival	Mean Paid-in Capital of First Rival
A. Patentees divided by the number of patent lawsuits prior to award:		
Patentee involved in no previous patent suits	1.83	97.18
Patentee involved in 1–5 previous patent suits	2.41	127.25
Patentee involved in 6–10 previous patent suits	2.68	143.31
Patentee involved in 11 or more previous patent suits	2.48	176.29
B. Patentees divided by paid-in capital at end of year prior to award:		
Patentee's paid-in capital is in bottom quartile	1.35	77.50
Patentee's paid-in capital is in third quartile	1.86	96.88
Patentee's paid-in capital is in second quartile	2.33	121.51
Patentee's paid-in capital is in top quartile	2.67	146.23

NOTE.—The first column indicates the average number of previous patent suits by the first rival to patent in a subclass after a prior award. The second column indicates the average paid-in capital (in millions of current dollars) of the first rival to patent in a subclass after a prior award. Patentees are divided by two proxies for litigation costs at the time of the award, previous lawsuits and paid-in capital. Each subclass of each patent award is used as a separate observation (with a total of 11,579 observations).

TABLE 6

CORRELATION ANALYSES OF CHARACTERISTICS OF FIRST RIVAL TO PATENT IN A SUBCLASS AFTER AN EARLIER PATENT

	Correlation Coefficient	*p*-Value
Previous patent suits involving patentee and first rival's patent suits	.070	.000
Paid-in capital of patentee and first rival's patent suits	.111	.000
Previous patent suits involving patentee and first rival's paid-in capital	.128	.000
Paid-in capital of patentee and first rival's paid-in capital	.207	.000

NOTE.—The table examines the correlation between two proxies for the patentee's litigation costs at the time of the award, the number of previous patent lawsuits and paid-in capital (in millions of current dollars), and these proxies for the next rival patenting in the subclass. The analysis is restricted to those patents that are followed by a patent award to a rival in the same subclass. Each subclass of each patent award is used as a separate observation (with a total of 11,579 observations).

the first rival are positive and significant at the 1 percent confidence level. Not only are firms with high litigation costs less likely to patent in a subclass occupied by a rival, they are particularly unlikely to patent in the same subclass as a firm with low litigation costs.

Two alternative explanations involving selection biases could account for these correlations without involving fears of costly litigation. First, the results could reflect the changing composition of firms in the sample over time. In later years, the average firm in the sample is more likely to have litigated a past award as well as to have greater paid-in capital.

Second, the different vintages of firms could be focusing on different technologies and thus patent in different areas. Recently formed rivals (which tend to be concentrated in the lowest capitalization quartile and to have the least prior litigation) may be pursuing technologies distinct from those of older firms (which may be in higher capitalization quartiles and have prior patent litigation experience). If the newer firms were less likely to patent in the same subclasses as older companies, such a pattern could result.

I address these concerns through regression analyses. I use as dependent variables the previous patent litigation experience and paid-in capital of each firm patenting in a subclass after a rival's award. Reflecting the ordinal nature and skewed distribution of the patent litigation variable, I employ a Poisson specification. (The results are robust to an ordinary least squares (OLS) specification.) In the regressions using paid-in capital, I employ an OLS specification. I once again use the two proxies for the patentee's litigation costs as independent variables.

I also use control variables that address selection biases. To control for the greater representation of frequent litigators and better capitalized firms in later years, I use the date of the patentee's award as an independent variable. If these effects are being caused by the changing representation of such firms, the date should control for much of the effect. In unreported regressions, I also use the square of the date and employ dummy variables for each 2-year period.[45] To address the possibility that different vintages of firms may focus on different technologies, I employ in unreported regressions the age of the firm as an independent variable. I also employ the square of age and dummy variables for various age ranges.

The proxies for litigation costs retain significant explanatory power,

[45] I also repeat the analyses using the quartile of the patentee's paid-in capital as an independent variable. I assign quartile rankings based on firms' capitalization relative to other patentees in the year of the award. In this way, I counteract the time effects introduced by the changing mix of capitalization. The results are robust to this change.

even controlling for these alternative explanations. In the leftmost regression in Table 7, a 1 standard deviation increase in previous patent suits at the mean of the independent variables increases the number of patent suits that the next rival has engaged in by 7 percent (from 2.06 to 2.20). In the rightmost regression, a 1 standard deviation increase in paid-in capital increases the paid-in capital of the next rival by 17 percent (from $115 million to $135 million).

The coefficients remain significant and of the same magnitude in the unreported regressions described above. When I include both proxies, a joint test of their significance in the Poisson regression yields a χ^2-statistic of 273.74; the F-statistic testing their significance in the ordinary least squares regression is 146.88. In both cases, the null hypothesis of no difference from zero is rejected at the 1 percent confidence level. I also

TABLE 7

REGRESSION ANALYSES OF CHARACTERISTICS OF FIRST RIVAL TO PATENT IN A SUBCLASS AFTER AN EARLIER PATENT

	DEPENDENT VARIABLE (Specification)			
	Previous Patent Suits of First Rival (Poisson)		Paid-in Capital of First Rival (Ordinary Least Squares)	
	(1)	(2)	(3)	(4)
Patent suits involving patentee	.02	. . .	3.35	. . .
	(10.64)		(9.63)	
Paid-in capital of patentee	. . .	.0008	. . .	.16
		(16.77)		(16.64)
Date of patent award	.10	.09	10.69	9.58
	(32.41)	(29.21)	(23.13)	(20.35)
Constant	−189.97	−175.39	−21,149.96	−18,956.71
	(32.33)	(29.11)	(23.01)	(20.25)
Log likelihood	−33,686.10	−33,334.34	. . .	. . .
χ^2-statistic	1,411.93	1,572.41	. . .	. . .
Adjusted R^2	. . .	. . .	.06	.08
F-statistic	. . .	. . .	367.53	469.42
p-value	.000	.000	.000	.000

NOTE.—The table examines the relationship between two proxies for the patentee's litigation costs at the time of the award, the number of previous patent lawsuits and paid-in capital (in millions of current dollars), and these proxies for the next rival patenting in the subclass. The analysis is restricted to those patents that are followed by a patent award to a rival in the same subclass. Each subclass of each patent award is used as a separate observation (with a total of 11,579 observations). I estimate a Poisson regression, in which the dependent variable is the number of previous patent lawsuits of the first rival to patent in the subclass; and an ordinary least squares regression, in which the dependent variable is the paid-in capital of the first rival. I use as independent variables the number of previous suits involving the patentee, the patentee's paid-in capital, and the date of the award (July 1, 1992, is expressed as 1992.5, etc.). Absolute t-statistics are in parentheses.

rerun the regressions using an instrumental variable approach. I use one of the proxies for litigation costs as an instrument for the other. If these two proxies are correlated with each other but not with the noise in each measure, then this approach should provide a consistent estimate of the relationship. Using this approach, the estimated relationship remains of the same magnitude and significance. I also repeat the analysis reported in Table 4, using the characteristics of the current and immediately prior patentees as independent variables. An award to a firm with lower litigation costs significantly discourages subsequent patenting; the low-cost firms remain significantly more likely to patent shortly after another firm.

D. Alternative Interpretations of the Litigation Cost Proxies

A significant concern with the above analysis is my interpretation of the results. Rather than measuring the impact of costly patent litigation, these proxies may be capturing a variety of other strategic interactions between these firms. For instance, smaller firms may be reluctant to patent near awards of established corporations, but not because of fear of costly litigation. Rather, they may have other reasons for being reluctant to compete with these firms. My interpretation of the number of previous patent lawsuits may also be questioned. Firms that have engaged in many patent disputes in the past may continue to act in ways that provoke disputes. In this section, I seek to address these concerns by examining three alternative explanations for the results.

I first examine two explanations suggested by the industrial organization literature. Firms may be reluctant to pursue innovations where rivals have a significant lead. An extensive theoretical literature examines "patent races."[46] For instance, in the multistage patent race of Drew Fudenberg, Richard Gilbert, Joseph Stiglitz, and Jean Tirole, a firm will continue to pursue an innovation as long as it is no more than one patent behind the leader. When the firm falls two patents behind, however, it will drop out of the competition.[47] The pattern documented above could be a consequence of farther-behind firms (which may have less paid-in capital or litigation experience) strategically deciding not to pursue a much farther-advanced firm (which might measure high on these proxies).

Alternatively, firms may be reluctant to enter into product market com-

[46] For an overview, see Jennifer F. Reinganum, The Timing of Innovation: Research, Development and Diffusion, in 1 Handbook of Industrial Organization (Richard Schmalensee & Robert D. Willig eds. 1989).

[47] Drew Fudenberg *et al.*, Preemption, Leapfrogging, and Competition in Patent Races, 22 Eur. Econ. Rev. 3 (1983).

petition with larger firms, which may enjoy substantial economies of scale. These are likely to be important in marketing, which constitutes more than 22 percent of the sales price of a typical drug.[48] Basic models of price competition suggest that the bulk of the profits will go to the low-cost providers, whether firms engage in "cutthroat" Bertrand competition or Cournot competition. Consequently, firms with higher marketing costs may be reluctant to pursue innovations in areas where firms with low marketing costs have strong positions.

To control for the racing hypothesis, I undertake regressions using the number of previous patents in the subclass as an additional independent variable. I measure how many previous patents the original patentee has received in the subclass. This hypothesis suggests that newer firms are reluctant to pursue established rivals not because of the low litigation costs, but rather because of their strong patent positions. In this case, the earlier patentee's previous stock of patents in the subclass should have much of the explanatory power, and his capitalization or previous litigation experience less power. As the first two regressions in Table 8 demonstrate, the litigation cost proxies remain positive and significant. While I only report two regressions, the other analyses are also robust to the addition of this independent variable.

To address the second concern, I examine whether the results can be explained by the unwillingness of biotechnology firms to compete with established firms with substantial economies of scale in marketing. Specifically, I concentrate on those biotechnology firms that have marketing agreements with larger pharmaceutical companies. These firms need not worry about directly confronting established firms in the product market, but almost all of them stand to lose if their intellectual property is litigated.[49] I repeat the above analyses, restricting the observations to patent

[48] U.S. Office of Technology Assessment, Pharmaceutical R&D: Costs, Risks and Rewards (1993). Larger pharmaceutical and biotechnology firms spend much of their marketing budget on "detailers," who promote drugs to doctors in one-on-one sessions. Being able to promote several drugs in a single visit is likely to bring substantial cost savings. One area where economies of scale are much less likely to be important is manufacturing. Not only does the Office of Technology Assessment study document that the costs of manufacturing drugs are considerably lower than marketing them, but clinical evidence suggests that there are few economies of scale in biotechnology manufacturing. Biotechnology products are typically produced not by large flow processes, but rather by using the same laboratory procedures employed in the original discovery, repeated many times. Differences between pharmaceutical and biotechnology manufacturing are discussed at length in Gary P. Pisano, Knowledge, Integration, and the Locus of Learning: An Empirical Analysis of Process Development (Harvard Business School Working Paper no. 95-006, Harvard Univ. 1994).

[49] The biotechnology firm typically continues to be responsible for paying for the cost of defending its patents, even after undertaking a strategic alliance. (This claim is important,

TABLE 8

REGRESSION ANALYSES OF ALTERNATIVE INTERPRETATIONS OF THE LITIGATION COST PROXIES

	DEPENDENT VARIABLE (Specification)			
	With Patentee's Earlier Awards in Subclass as Independent Variable		Using Only Patents Where Rival Has Marketing Agreement	
	Previous Patent Suits of First Rival (Poisson)	Paid in Capital of First Rival (Ordinary Least Squares)	Previous Patent Suits of First Rival (Poisson)	Paid-in Capital of First Rival (Ordinary Least Squares)
Paid-in capital of patentee	.0008	.16	.0003	.12
	(15.53)	(15.32)	(2.52)	(6.28)
Date of patent award	.09	9.55	.08	14.26
	(29.13)	(20.22)	(11.11)	(12.03)
Patentee's prior awards in subclass	.0002	.13	. . .	. . .
	(.18)	(.59)		
Constant	−175.32	−18,909.74	−156.65	−28,263.63
	(29.03)	(20.13)	(11.04)	(11.98)
Log likelihood	−33,334.33	. . .	−6,012.67	. . .
χ^2-statistic	1,572.44	. . .	177.13	. . .
Adjusted R^2	. . .	.08	. . .	.11
F-statistic	. . .	313.05	. . .	127.92
p-value	.000	.000	.000	.000

NOTE.—The table examines the relationship between two proxies for the litigation costs of the patentee and the next rival patenting in the subclass, the number of previous patent lawsuits and paid-in capital (in millions of current dollars). The analysis is restricted to those patents that are followed by a patent award to a rival in the same subclass. I estimate a Poisson regression, in which the dependent variable is the number of previous patent lawsuits of the first rival to patent in the subclass, and an ordinary least squares regression, in which the dependent variable is the paid-in capital of the first rival. I use as independent variables the patentee's paid-in capital and the date of the award (July 1, 1992, is expressed as 1992.5, etc.). In the first set of regressions, I add an independent variable that controls for the number of previous patent awards in that subclass by the patentee. Each subclass of each patent award is used as a separate observation (with a total of 11,579 observations). In the second set, I restrict the analysis to patents awarded while a licensing, distribution, or marketing agreement between the rival and a larger pharmaceutical company was effective and whose abstract appears to be within the scope of the agreement (with a total of 2,082 observations). Absolute t-statistics are in parentheses.

because if pharmaceutical firms assumed the cost of litigating patents of their biotechnology partners, then biotechnology firms that have marketing agreements would be unaffected by the prospect of either product market competition or costly patent litigation.) An analysis of provisions relating to patent defense and third-party patents in 315 technology licensing agreements that have been signed by biotechnology firms and have been coded by Recombinant Capital supports this assertion. I find that in 70 percent of these contracts, the party licensing the technology must either pay directly for the patent litigation and any royalties and damages to third parties or reduce his royalty demands by this amount (or some fraction of this amount). In only 3 percent of the cases does the licensee assume the obligation to litigate the patents at his own expense. (In the remaining contracts, this issue is not discussed in the contract or has been redacted in the copy filed with the SEC, or else each firm is free to defend the patents as it sees fit.) One interpretation is that by agreeing to shoulder these expenses, the biotechnology firm provides a potentially costly signal of the strength of its intellectual property position.

awards where the biotechnology firm had already signed a marketing agreement for products in this technology with a major pharmaceutical firm. If marketing is a key factor in the decision to pursue an innovation, then once the sample is restricted to firms with product market agreements, the effects that I am interpreting as being driven by litigation costs should be much less pronounced.

I determine whether a firm had signed a collaborative agreement in a given technology using a database of almost 2,000 such agreements compiled by Recombinant Capital. These agreements are obtained from the same federal and state filings from which it gathers financial records. I repeat the analyses reported in Tables 3, 4, and 7, only including patents (i) awarded while a licensing, distribution, or marketing agreement between the firm and a larger pharmaceutical company was effective, and (ii) whose abstract appears to be within the scope of the agreement.[50] (This leads to the inclusion of 14 percent of the observations.) As the third and fourth regressions in Table 8 display, the litigation cost proxies remain positive and significant, though the magnitude of the coefficient in the third regression is lower. (While I only report two regressions, the other analyses are also robust to the use of this subset of the observations.) Even among these firms, where concerns about product market competition should be much less pronounced, I find a strong relationship between the proxies for litigation costs and patenting behavior.

A concern with the number of patent suits as a proxy for litigation costs is that it may measure any fixed aspect of firm behavior. These firms could be more likely to confront other companies, whether because of the nature of the technology in which they are working, the confrontational nature of management, or a number of other reasons. One way to control—at least partially—for this tendency is to run a fixed-effects regression, adding a dummy variable for each firm. In this way, I control for the overall propensity of firms to patent near other concerns and only examine whether this tendency changes with the proxy for litigation costs. When I repeat the analysis of the paid-in capital of the next rival to patent in the subclass in an unreported regression, the coefficient of the litigation cost proxy is somewhat reduced in magnitude, but remains significant at the 5 percent confidence level.

V. Conclusion

This article examines the relationship between patenting behavior and two proxies for litigation costs. Firms with high litigation costs appear

[50] These determinations were made with the assistance of a research assistant with 3 years' experience licensing biotechnology patents in a variety of subfields.

less likely to patent in the same subclass as rivals. These firms seem particularly reluctant to patent after awards to firms that have low litigation costs. These results are robust to controls for a variety of selection biases, including the changing mix of awardees over time and the presence of vintage effects. The effects remain significant after controlling for several alternative interpretations of the litigation cost proxies suggested by the industrial organization literature. The findings support theoretical suggestions about the impact of costly litigation on the willingness of firms to take care.

In addition to addressing the theoretical literature on costly litigation, this article contributes to our understanding of the patenting process. The effectiveness of patent protection has received little empirical attention despite its importance in several theories of socially optimal patent policy. The theoretical analyses of the impact of costly litigation—and their corroboration in this analysis—also raise questions about the recent shift to stronger patent rights discussed above. Shifting the costs and potential rewards of litigation can affect firms in subtle ways: for instance, "propatent" judgments awarding large amounts to plaintiffs may have detrimental effects on smaller firms with higher litigation costs. The implications of the shift to strengthened intellectual property protection seem worthy of further consideration by policy makers.[51]

One question that this analysis cannot answer is whether these patterns are unique to patent litigation. Patent litigation has several special features that may facilitate this sort of strategic behavior, such as a specialized patent bar and judiciary. In other fields, firms without a full understanding of the cost or expected outcome of the dispute may behave differently. Since formal models of strategic behavior may lead to sharply different results once the participants do not share common knowledge,[52] in other disputes firms with low litigation costs may be less successful in inducing other firms to avoid confrontation. At the same time, after reviewing several hundred case files in the course of another research project,[53] I find it striking how much of intercorporate litigation is triggered

[51] For two useful theoretical discussions of the effectiveness of patent protection and social welfare, see Nancy T. Gallini, Patent Policy and Costly Imitation, 23 RAND J. Econ. 52 (1992); and Michael Waterson, The Economics of Product Patents, 80 Am. Econ. Rev. 860 (1990). Empirically, two surveys document the extent to which managers believe that patents provide effective protection across industries: Levin *et al.*, *supra* note 27; and Edwin Mansfield, R&D and Innovation: Some Empirical Findings, in R&D: Patents and Productivity (Zvi Griliches ed. 1984).

[52] See the discussion, for example, in Jean Tirole, The Theory of Industrial Organization (1988).

[53] Lerner, *supra* note 17.

by a few types of events, such as the hiring of an employee who has signed a noncompetition agreement at another firm or the refusal to accept a delivery of goods not meeting the specification in a sales contract. Furthermore, at least in the county that is the focus of this study, most cases of each type are handled by a small group of lawyers, who informally specialize in this form of dispute. In contrast to Tolstoy's dictum that unhappy families are all different, corporate disputes appear strikingly similar. Thus, patent litigation may not be not as atypical as it may initially seem.

APPENDIX

Sources for Identifying Patent Litigation

1. LEXIS's PATENT/ALL database contains the full text of each patent. An additional field, LIT-REEX, identifies the litigation in which the patent has figured. This information is based on reports compiled by USPTO. By law, clerks of each district court must notify USPTO of any such actions. Many cases, however, are not reported. There seems to be little pattern in the omitted cases: they include both obscure and highly visible cases. For instance, no litigation is recorded as associated with Amgen's 4,703,008 patent, "DNA sequences encoding erythropoietin," which has been the subject of well-publicized battles with Genetics Institute, Chugai, and other firms.

2. Research Publications, Inc., prepares several listings of patent litigation, which are marketed under the name of Lit-Alert. These are based not only on the information provided by the clerks to USPTO, but also on the firm's independent searches of activity in the district courts. I check for litigation involving these patents using a printed compilation prepared by Research Publications, then purchase the litigation records from the vendor.[54]

3. A compilation of biotechnology-related intellectual property litigation is prepared by the American Intellectual Property Law Association's District Court Litigation Subcommittee.[55] This group of patent attorneys has made a concerted effort to list all biotechnology patent or trade secrecy cases. They produce a volume containing brief digests of the complaints and decisions in each case.

4. All published decisions (and some unpublished rulings) in postaward litigation in the federal courts are reported in LEXIS's PATENTS/FEDCTS database. The "Background" section in the decisions will frequently contain an overview of all prior litigation involving the firms. I search the database using each patent number and firm name.

5. I search several databases for news stories and press releases on patent litigation involving these firms. Two of these are available through NEXIS: GENBIO, a compilation of stories since 1980 in biotechnology and genetic engineering–related publications, and WIRES, a compilation of wire service stories and press releases. I also use the library of wire service and news stories marketed

[54] Research Publications, Inc., Patent Status File (1993).

[55] American Intellectual Property Law Association, Biotechnology Litigation Report (1993).

by Dow Jones News Service, and the ACTIONS database, a database of news stories about biotechnology firms compiled by the North Carolina Biotechnology Center.

6. Firms are required to report any material litigation in their annual 10-K filings with the SEC. Firms vary considerably, however, in the standards they employ to decide whether a suit is material. I check "Litigation" sections in all 10-Ks filed by these firms, as well as all initial public offering prospectuses.

7. Firms engaged in patent litigation are often contesting other patents through interference proceedings. If the interference is not settled, it will be considered by the Board of Patent Appeals and Interferences. In its decisions, the Board will sometimes discuss the status of other patents by the inventor. Any published interference decisions—as well as some unpublished ones—are recorded in LEXIS's PATENT/PATAPP database. The decisions often do not mention the inventor's firm and refer to patents by application number, but a USPTO index allows me to identify the decisions that involved patents awarded to firms in my sample.[56]

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[56] U.S. Department of Commerce, Patent and Trademark Office, Index to Trial Decisions of the Board of Appeals and Patent Interferences (unpublished computer tabulation, Patent and Trademark Office 1993).

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