The Patent Litigation Explosion

James Bessen and Michael J. Meurer[*]

This Article provides the first look at patent litigation hazards for public firms during the 1980s and 1990s. Litigation is more likely when prospective plaintiffs acquire more patents, when firms are larger and technologically close and when prospective defendants spend more on research and development ("R&D"). The latter suggests inadvertent infringement may be more important than piracy. Public firms face dramatically increased hazards of litigation as plaintiffs and even more rapidly increasing hazards as defendants, especially for small public firms. The increase cannot be explained by patenting rates, R&D, firm value or industry composition. Legal changes are the most likely explanation.

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INTRODUCTION

The annual number of patent lawsuits filed in the United States more than tripled since 1990.[1] Is this cause for concern?

Other research suggests that patent litigation can affect innovation incentives. Economic historian Zorina Khan argues that the introduction of the patent examination system during the nineteenth century reduced the relative number of patent lawsuits and that this substantially spurred inventive activity.[2] Josh Lerner finds that the threat of litigation deters biotech firms from innovating in some technology fields.[3] Lanjouw and Lerner find that the use of preliminary injunctions by large firms discourages research and development ("R&D") by small firms.[4] Does the recent jump in patent litigation reduce the incentives firms have to innovate?

The answer depends on what is driving the increase. To understand this, we take a comprehensive look at the factors that cause the disputes that result in litigation. Our analysis is based on a formal theoretical model presented in a companion paper.[5]

1. *See* PRICE WATERHOUSE COOPERS, 2012 PATENT LITIGATION STUDY 6 (2012), *available at* http://www.pwc.com/en_US/us/forensic-services/publications/assets/2012-patent-litigation-study.pdf (reporting an annual 6.4% growth in patent actions filed from 1991 through 2011); *see also id.* at 6 fig.1 (documenting the number of patent case filings made and patents granted from 1991 to 2011). As discussed below, this figure represents case filings reported by the United States Patent and Trademark Office and this series only captures about two-thirds of all filings. However, the degree of under-reporting is stable over time, so the nature of the trend in total filings is the same.

2. *See* B. ZORINA KHAN, THE DEMOCRATIZATION OF INVENTION: PATENTS AND COPYRIGHTS IN AMERICAN ECONOMIC DEVELOPMENT, 1790–1920, at 60 (2004) (explaining that the patent examination system "reduced uncertainty about the validity of patents" and "enabled financially disadvantaged inventors to appropriate returns through the market for invention").

3. Josh Lerner, *Patenting in the Shadow of Competitors*, 38 J.L. & ECON. 463, 463 (1995).

4. Jean O. Lanjouw & Josh Lerner, *Tilting the Table? The Use of Preliminary Injunctions*, 44 J.L. & ECON. 573, 573 (2001).

5. *See* James Bessen & Michael J. Meurer, *Patent Litigation with Endogenous Disputes*, 96 AM. ECON. REV. 77, 77 (2006) (presenting a model of patent disputes that considers behavior by

In an ideal world, patents would work like real property and be largely self-policing: technology adopters would either completely avoid patented technologies or they would obtain ex ante licenses before sinking funds into development and commercialization. But unlike real property, where, say, few disputes arise over land boundaries after buildings have been erected, technology adopters do end up in court for investments they have made in allegedly infringing technologies.

Two different stories might explain the origin of these disputes. In one, the patent holder may not know about the infringer. In this "cheating" story, the technology adopter observes and imitates a patented technology, and may take steps to avoid detection. This behavior induces the patent holder to expend resources monitoring for infringement and, on the occasion that infringement is discovered, to expend additional resources on negotiating a license and/or on litigation. These costs effectively increase the cost of patenting, making patents less attractive, and thus ultimately reducing R&D incentives.

In the other story, the adopter develops its own technology and is unaware of another firm's putative patent rights. This kind of innocent infringement occurs because patent rights often have uncertain boundaries or questionable validity. Patents differ from real property where the boundaries of a plot of land and the validity of a title usually can be verified at little cost and with little uncertainty. In contrast, the validity of a patent may be challenged and firms often have difficulty determining whether a technology infringes the boundaries of a patent's claims. Indeed, even district court judges have difficulty determining the boundaries of patent claims—30–40% of their claim interpretation decisions are reversed on appeal.[6] In addition, the sheer number of patents facing a typical innovator makes careful assessment quite burdensome. Furthermore, patent claims are often hidden (sometimes strategically) until after firms have sunk technology investments.

We call this the "exposure" story, because the more that firms invest in technology, the more they are exposed to the risk of a patent dispute. These disputes yield litigation or licensing under the threat of litigation, and sap rents from innovative firms. The reduction in rents relative to a situation with clearly defined and certain property rights can be viewed as the cost of patent disputes. This cost reduces innovators' incentives to invest in R&D.

potential infringers and patent infringement "defendants who 'invent around' a patent, and defendants who are unaware of the patented technology").

6. Kimberly A. Moore, Markman *Eight Years Later: Is Claim Construction More Predictable?*, 9 LEWIS & CLARK L. REV. 231, 246 (2005).

These two stories affect the significance of the increase in patent litigation. If the "exposure" story is correct, then there is reason for concern. We find that the risk of being sued for infringement has increased by about 70% per R&D dollar. In this case, then, the increased rate of litigation means that innovative firms have lower incentives to invest in R&D.

If, on the other hand, the "cheating" story is correct, then the impact of the patent litigation explosion is less troubling. This is because the expected number of suits *per patent* has not risen much, so patent holders may not face markedly higher costs of enforcement per patent. Of course, there still may be a negative effect on alleged infringers' R&D (which may be socially beneficial) and litigation may waste resources, but the "cheating" story does not generate such a clear concern about litigation.

Our empirical analysis aims to nest both stories, to distinguish between them and to evaluate which factors are driving the increase in litigation. We conduct this analysis at two levels. First, we study the probability that one randomly selected firm files suit against another randomly selected firm in the same industry in a given year. Among the right hand side variables we include the size of each firm's patent portfolio, employment, R&D spending and market value and the technological proximity of the two firms. This allows us to test various theoretical explanations of firm litigation. Second, we perform an aggregate analysis, studying the hazards that a firm will engage in patent litigation as a plaintiff and, separately, as a defendant against all possible other parties. This gives us a more comprehensive estimate of the contribution of different factors to the increase in aggregate litigation.

Our Article differs from previous research in two principal ways. First, our model of litigation addresses the origin of patent disputes, not just dispute settlement. With the important exception of Crampes and Langinier,[7] most of the theoretical literature on litigation takes the existence of a dispute as a given and then asks what factors determine whether the disputants will settle or proceed to trial.[8] Much of the

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7. Claude Crampes & Corinne Langinier, *Litigation and Settlement in Patent Infringement Cases*, 33 RAND J. ECON. 258, 258–74 (2002) (studying decisions faced by a firm that is already a patent owner, such as how to monitor patents and react to infringement).

8. For recent surveys, see Bruce Hay & Kathy Spier, *Settlement of Litigation*, *in* THE NEW PALGRAVE DICTIONARY OF ECONOMICS AND THE LAW 442, 442–51 (1998); Jean O. Lanjouw & Josh Lerner, *The Enforcement of Intellectual Property Rights: A Survey of the Empirical Literature* (Nat'l Bureau of Econ. Research, Working Paper No. 6296, 1997). Models of patent settlement used in empirical research are found in Dietmar Harhoff & Markus Reitzig, *Determinants of Opposition Against EPO Patent Grants—The Case of Biotechnology and Pharmaceuticals*, 22/4 INT'L J. INDUS. ORG. 443, 443–80 (2004), and Deepak Somaya, *Strategic Determinants of Decisions Not to Settle Patent Litigation*, 24 STRATEGIC MGMT. J. 17, 17–38 (2003), *available at*

empirical literature follows suit.[9] But the rate of lawsuit filing depends as much on the frequency of disputes as the frequency of bargaining breakdown. Our model incorporates both. We assume patent-related investments by one firm and investments related to the development and adoption of technology by another firm interact to create patent disputes. Attention to the origins of disputes is important because our data suggest that (after controlling for the number of inventions) more frequent disputes, not more frequent bargaining failures, are driving the increase in patent lawsuit filing.

Second, our analysis differs from most previous research in that we use the firm as the unit of analysis as well as randomly selected pairs of firms. Our aim is to understand how firm choices affect litigation rates and how firms are affected by litigation hazards, so this is a natural modeling choice. With the important exception of Rosemarie Ziedonis's study of semiconductor industry patent litigation,[10] most studies have either looked at the rate of litigation per patent[11] or have looked at aggregate litigation rates.[12] Although these statistics are informative, our model provides a richer, multi-factor picture of firm litigation behavior that can distinguish between a variety of possible explanations for the increase in litigation rates.

The rest of this Article proceeds as follows. Part I describes our model of patent disputes, some hypotheses from this model and the specification of equations we estimate. Part II describes our data and Part III reports our empirical results. Part IV discusses the interpretation of these results

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http://onlinelibrary.wiley.com/doi/10.1002/smj.281/pdf.

9. *See e.g.*, Michael J. Meurer, *The Settlement of Patent Litigation*, 20 RAND J. ECON. 77, 77–91 (1989) (discussing a "settlement bargain between a patentee and a potential patent challenger"); Somaya, *supra* note 8, at 17–18 (documenting empirical studies to better understand the role of patent litigation in technology firm strategy).

10. Rosemarie Ham Ziedonis, *Patent Litigation in the U.S. Semiconductor Industry*, *in* PATENTS IN THE KNOWLEDGE-BASED ECONOMY 180, 182 (Wesley M. Cohen & Stephen A. Merrill eds., 2003) (examining the characteristics of patent-related lawsuits in the semiconductor industry from 1973 to 2001).

11. *See, e.g.*, John R. Allison, Mark A. Lemley, Kimberly A. Moore & R. Derek Trunkey, *Valuable Patents*, 92 GEO L.J. 435, 435–79 (2004) [hereinafter Allison et al., *Valuable Patents*] (studying litigated patents in an effort to identify characteristics of the most valuable patents); Jean O. Lanjouw & Mark Schankerman, *Protecting Intellectual Property Rights: Are Small Firms Handicapped?*, 47 J.L. & ECON. 45, 45–74 (2004) [hereinafter Lanjouw & Schankerman, *Small Firms*] (analyzing the rate of litigation per patent to show that individuals or small firms owning few patents face greater litigation risk than firms with larger patent portfolios).

12. *See, e.g.*, WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW (2003); Jon F. Merz & Nicholas M. Pace, *Trends in Patent Litigation: The Apparent Influence of Strengthened Patents Attributable to the Court of Appeals for the Federal Circuit*, 76 J. PAT. & TRADEMARK OFF. SOC'Y 579, 579–80 (1994) (analyzing aggregate litigation rates to show how the Court of Appeals for the Federal Circuit contributed to increased predictability and enforceability of patents).

and a conclusion follows.

I. MODEL AND SPECIFICATION

A. Dispute, Filing and Settlement

Our model concerns the probability that firm 1 will file a lawsuit against firm 2. We present just a brief overview of the model and the intuitions that lead to testable hypotheses. The details of the model are available in a companion paper.[13] Initially, the firms simultaneously choose their levels of R&D spending. Firm 1 also chooses the quantity and quality of patents it obtains. In addition to choosing to obtain more patents, firm 1 can "refine" the (private) quality of its patents by delaying the issuance of some of its patents through continuation practice, crafting multiple claims, investing in high quality claims and disclosures and conducting a careful prior art search.

At this stage, the firms do not know the probability that firm 1 will win a lawsuit if it files one. They do, however, know the distribution of these probabilities. In addition, each firm's investments may alter this distribution. If firm 1 gets more patents or better quality patents, then it will be more likely to win. Firm 2's R&D investment may also alter the probability of a win. If firm 2 invests R&D in "inventing around," then firm 1 will be less likely to win. Alternatively, firm 2's investment in new technology may expose it to greater risk of infringement, increasing the probability that firm 1 will win a suit.

After the investments are made, the actual probability is revealed and the firms choose actions with four possible outcomes: firm 2 may decide to abandon its investment (or seek an ex post license); firm 1 may ignore firm 2; or they may enter a dispute. In this last case, they either negotiate a settlement without filing a lawsuit, or firm 1 files a lawsuit (subsequent settlement may still occur).

We make a simple assumption to analyze the factors that will affect the probability of litigation: we assume that the distribution of win probabilities is skewed to the left, meaning that most randomly selected pairs of firms have a low probability of suing each other and winning.[14] This means that factors that shift the probability distribution to the right (left) will increase (decrease) the probability of litigation.

Given this set up, the following intuitions can be formally

13. Bessen & Meurer, *supra* note 5, at 77–79.

14. More precisely, we assume that the probability density decreases monotonically. We also assume that firm variables are correlated with business unit variables, for example, larger firms have larger product markets. This is important because the model really concerns the interaction between business units of the two firms, but our observed variables are at the firm level.

demonstrated:

H1: Technological Distance. The probability of litigation between two firms increases with their proximity in technological space, all else equal.

The intuition here is simply that a firm pursuing technology "near" another firm's patent portfolio exposes itself to greater risk of infringement.

H2: Stakes. The probability of litigation between two firms increases with the size of the stakes, all else equal.

Greater stakes mean that firm 1 will prefer to sue rather than settle for a greater range of situations. Greater stakes also mean that firm 2 will rather litigate than abandon development for a greater range of situations.

H3: Patent Portfolio. The probability that firm 1 sues firm 2 increases with the patent portfolio size of firm 1, all else equal.

This hypothesis captures the notion that firm 1 increases its probability of winning with a greater number of patents, all else equal. A larger number of patents means that a rival may be more likely to trip over one (exposure). Also, a patent "fence" may limit the opportunities for rivals to invent around.[15] If the probability distribution is shifted to the right, this means a greater probability of litigation. Note that in general this increase need not be proportional, that is, the elasticity of the probability of filing with respect to firm 1's patent portfolio size may be less than one.

H4: Defensive Patenting. If firms use patent portfolio trading to avoid litigation, then the probability that firm 1 sues firm 2 will decrease with firm 2's patent portfolio size, all else equal.

That is, firm 2's "defensive" portfolio will increase the probability of settlement and reduce the probability of filing.

The next two hypotheses concern the relationship between firm 2's development investment and the probability of filing.

H5: Inventing Around. Controlling for the stakes of each firm, if firm 2 uses development investment to "invent around" patents, then the probability of litigation should decrease with firm 2's R&D, all else equal.

The intuition here is that those prospective defendants who invest more

15. Patent fencing is "a specific [patent] filing strategy to use multiple related patents to further enhance value appropriation." Christian Sternitzke, *An Exploratory Analysis of Patent Fencing in Pharmaceuticals: The Case of PDE5 Inhibitors*, 42 RES. POL'Y 542, 542 (2013). For a discussion of patent fencing, see Wesley M. Cohen, Richard R. Nelson & John P. Walsh, *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* 1–5 (Nat'l Bureau of Econ. Research, Working Paper No. 7552, 2000).

in inventing around will be less likely to be found to infringe firm 1's patents, so firm 1 will be less likely to sue them. Those firms that simply imitate without expending resources to invent around will be more likely to be sued.

On the other hand,

H6: Exposure Effect. Controlling for the stakes of each firm, if firm 2 increases its exposure to infringement by investing in technology, then the probability of litigation should increase with firm 2's R&D, all else equal.

This hypothesis captures the notion that prospective defendants who invest more in development (deliberately or inadvertently) expose themselves to greater risk of infringement. Inadvertent infringement may be common because of the difficulty determining whether a technology is likely to infringe a patent, and because relevant patents may issue after development and even adoption is completed.

These hypotheses encompass several variations of the model that may be helpful to understand what drives patent litigation and what may explain the trends in litigation.

B. Specification

These hypotheses can be nested in a simple regression. We define a general logit regression equation:

$$(1)\quad \begin{aligned} y_{ABt} &\equiv P[\text{firm A sues firm B in year t}] = \frac{e^{z+\delta_t}}{1+e^{z+\delta_t}} \\ z &\equiv \alpha X_{At} + \beta X_{Bt} + \gamma X'_{At} X_{Bt} + \varepsilon \end{aligned}$$

where X_{it} is a vector of firm characteristics for firm *i* at time *t* and δ_t is a time dummy. Following the above discussion, this vector might include the R&D spending, scale (employment), patent portfolio sizes of both firms and the technological distance between them. This equation is estimated over pairs of firms who are potential litigants.

Because the potential number of pairs of firms is very large and because we want to understand the aggregate effect of litigation on firms, it is also helpful to calculate firm hazards. As long as the probability that firm *A* sues firm *B* is independent of the probability that firm *A* sues firm *C*, etc., the expected number of suits can be calculated as sums of these

$$h^p_{At} \equiv E[\text{number of suits filed by A in year t}] = \sum_{j\neq A} y_{Ajt}$$

$$h^d_{Bt} \equiv E[\text{number of suits filed against B in year t}] = \sum_{j\neq B} y_{jBt}$$

probabilities:

Note further that if z and y are sufficiently small, $y_{ABt} \approx e^{\delta_t}(1+z)$. Using this approximation,

$$
\begin{aligned}
&\ln h_{At}^{p} \approx \phi X_{At} + \mu_t + \varepsilon \\
(2)\quad &\phi = \alpha + \gamma \overline{X} \\
&\mu_t = \delta_t + \ln(N-1) + \beta \overline{X}_t + \gamma(\overline{X}_t - \overline{X})
\end{aligned}
$$

where $\overline{X}_t$ is the mean over firms and $\overline{X}$ is the mean over firms and years. Note that this form is the familiar log linear Poisson regression. A similar expression can be derived for the defendant's hazard,

$$(3)\quad \ln h_{Bt}^{d} \approx \psi X_{Bt} + \eta_t + \varepsilon$$

Finally, note that if there are no interaction terms in (1), that is, if $\gamma = 0$, then $\phi = \alpha$ and $\psi = \beta$. In words, the coefficients of the Poisson regressions, (2) and (3), should match those of the corresponding variables in the logit pairs regression, (1).

II. DATA DESCRIPTION

A. Data Sources

Our research matches records from three data sources: lawsuit filings from Derwent's Litalert database, firm financial data from Compustat and patent data from the United States Patent and Trademark Office ("USPTO") made available by The National Bureau of Economic Research ("NBER").

As in most of the prior research, we use lawsuit filings as our measure of litigation. Patent disputes are properly viewed as a process consisting of many stages where settlement is possible at each stage and costs are incurred during each stage. Although a trial is the costliest stage, the majority of legal costs occur prior to trial[16] and opportunity costs experienced by the firm (e.g., postponed business) may also be quite large.[17] Furthermore, significant costs may be incurred even when patent

16. AM. INTELLECTUAL PROP. ASS'N, REPORT OF THE ECONOMIC SURVEY 16 (2003).

17. *See* Catherine Tucker, *Patent Trolls and Technology Diffusion* 1–28 (Tilberg Law and Econ. Ctr., Discussion Paper No. 2012–030, 2013) (documenting how a patent troll's lawsuit against an imaging software sales company caused sales to decline by one-third due to a "lack of incremental product innovation" throughout litigation).

disputes are resolved prior to filing a lawsuit.[18] Thus the event of a filing represents a foregone opportunity to settle and a credible commitment to incur some level of litigation cost that could have been avoided.

Our primary source of information on lawsuit filings is Derwent's Litalert database, a database that has been used by several previous researchers.[19] Federal courts are required to report all lawsuits filed that involve patents to the USPTO and Derwent's data is based on these filings. Beginning with the Derwent data from 1984 through 2000, we removed duplicate records involving the same lawsuit as identified by Derwent's cross-reference fields. We also removed lawsuits filed on the same day, with the same docket number and involving the same primary patent. Sometimes firms respond to lawsuits by filing counter-suits of their own, perhaps involving other patents. Since our main focus is on disputes rather than on lawsuit filings per se, we also removed filings made within ninety days of a given suit that involved the same parties. Finally, we removed filings where the current USPTO Commissioner was a party. This left us with 16,534 lawsuits filed from 1984 through 2000 (see Figure 1). Almost all of these lawsuits involved utility patents, including re-issued patents.[20]

Previous researchers have found that apparently not all lawsuits involving patents do, in fact, get reported to the USPTO. The Federal Judicial Center ("FJC") collects data directly from the administrative office of the courts and the FJC consistently reports a larger number of filings. Two potential problems arise from under-reporting: (1) a possible change in the reporting ratio over time, leading to spurious trends in the Derwent data; and (2) possible selection bias. After de-duplicating FJC data, we found that our database had only 64% of the number of lawsuits contained in the FJC data. However, although there was some year-to-year variation in this ratio, it appeared to be stable over time: the ratio averaged 63.9% from 1984–90 and 64.1% from 1991–99. There thus appears to be no significant trend in this reporting ratio.[21] Also, using an

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18. *See* James E. Bessen & Michael J. Meurer, *The Direct Costs from NPE Disputes*, 99 CORNELL L. REV. (forthcoming 2014) (manuscript at 16–17, 30 tbl.3) (on file with author) (finding that "non-litigated patent assertions are responsible for much of the direct costs imposed by [non-practicing entities] on operating companies").

19. *See, e.g.*, Lanjouw & Schankerman, *Small Firms*, *supra* note 11, at 45; Ziedonis, *supra* note 10, at 196–98.

20. In a small percentage of cases Derwent did not report a patent or listed a design patent.

21. Lanjouw and Schankerman report that their comparable ratio was stable during the 1990s. Lanjouw & Schankerman, *Small Firms*, *supra* note 11, at 50. At the suggestion of Zorina Khan, we also compared our data to counts of lawsuit activity from LexisNexis, even though these data are not directly comparable. The ratio of LexisNexis counts to FJC data, however, did exhibit marked variation over time.

extensive match between the two files, Lanjouw and Schankerman find no difference between reported and unreported cases over a range of variables, providing no suggestion of selection bias.[22] Since the FJC data do not report all parties to a lawsuit, we chose to use the Derwent data despite this under-reporting. In the tables below, when we report firm litigation hazards, these estimates have been corrected for under-reporting (they have been divided by .64).

To explore characteristics of firms involved in these lawsuits, we matched the listed plaintiffs and defendants to the Compustat database of U.S. firms from 1984–99 that report financials (excluding American Depository Receipts of foreign firms traded on U.S. exchanges). These data were based on merged historical data tapes from Compustat and involved an extensive process of tracking firms through various types of re-organization and eliminating duplicate records for firms (e.g., consolidated subsidiaries listed separately from their parent companies).[23]

The lawsuit data were matched to the Compustat data by comparing the litigant name with all domestic firm names in Compustat and also a list of subsidiary names used in Bessen and Hunt.[24] At least one party was identified as a publicly traded U.S. firm in 42% of the 16,534 cases.

To check the validity and coverage of this match, we randomly selected a number of parties to suits and then checked them manually using various databases including PACER, LexisNexis, the Directory of Corporate Affiliations and the LexisNexis M&A databases. Although we were not able to definitively identify all parties, the rate of false positives was not more than 3% (no more than 5 of 165 parties were found to have been falsely matched) and the rate of false negatives was no more than 7% (no more than 34 of 502 public companies were not matched).

To obtain information about each firm's non-litigated patents, we also matched Compustat firms to the NBER patent database.[25] To match the USPTO assignee name to the Compustat firm name, we began with the

22. *Id.*

23. This work was conducted by Bob Hunt and Annette Fratantaro at the Federal Reserve Bank of Philadelphia for an earlier project and we thank them for graciously sharing it with us.

24. James Bessen & Robert M. Hunt, *An Empirical Look at Software Patents* 12–13, 42 (Bos. Univ. Sch. of Law, Working Paper No. 03–17/R, 2004). A software program identified and scored likely name matches, taking into account spelling errors, abbreviations and common alternatives for legal forms of organization. These were then manually reviewed and accepted or rejected. Note that this match is based on the actual parties to litigation, not the original assignee of the patent at issue.

25. *See* Bronwyn H. Hall, Adam B. Jaffe & Manuel Trajtenberg, *The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools* 3 (Nat'l Bureau of Econ. Research, Working Paper No. 8498, 2001) (describing the NBER database on U.S. patents).

match file provided by the NBER. To this we added matches on subsidiaries developed by Bessen and Hunt,[26] manually matched names for large patenters and R&D-performers and matched a large number of additional firms using a name-matching program.[27] In addition, using data on mergers and acquisitions from the Thomson Reuters Securities Data Company Platinum ("SDC") database,[28] we tracked patent assignees to their acquiring firms. Since a public firm may be acquired, yet still receive patents as a subsidiary of its acquirer, we matched patents assigned to an acquired entity in a given year to the firm that owned that entity in that year.[29] This matched group of firms includes 10,736 patent assignees matched to one of 8444 owning firms in Compustat, with as many as five different owners matched to each assignee. This matched group accounts for 96% of the R&D performed by all U.S. Compustat firms, 77% of all R&D-reporting firms listed in Compustat and 62% of all patents issued to domestic non-governmental organizations during the sample period. Sample statistics show that this matched sample is broadly representative of the entire Compustat sample, although it is slightly weighted toward larger and incumbent firms. Testing our match against a sample of 131 semiconductor industry firms that had been manually matched, we correctly matched 90% of the firms that accounted for 99.5% of the patents acquired by this group.[30]

B. Variables

The main variables of interest are as follows:

The number of suits per firm per year. This is the number of suits to which the firm is a party. We also sought to determine whether the firm was attempting to enforce a patent or whether the firm was seeking to defend against a patent. The Derwent data do not distinguish whether the suit filed is an infringement suit or a declaratory judgment suit. As a prerequisite to filing a declaratory action, a firm must show it has been threatened with an infringement suit; the declaratory action aims for a judgment that the patent is uninfringed or invalid. To classify each suit,

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26. Bessen & Hunt, *supra* note 24; *see also supra* text accompanying note 24.

27. A similar software program determined matches between the two files by identifying firm names that matched after taking into account spelling errors, abbreviations and common alternatives for legal forms of organization. In addition, a separate program identified Compustat firms with unique names that were not found in the USPTO assignee file. These were classified as firms that did not obtain patents through 1999.

28. SDC PLATINUM, http://thomsonreuters.com/sdc-platinum/ (last visited Nov. 6, 2013).

29. This dynamic matching process is different from that used in the original NBER data set, which statically matched a patent assignee to a Compustat firm. These data were developed with the help of Megan MacGarvie, to whom we are indebted.

30. Thanks to Rosemarie Ziedonis, who originally compiled this data, for sharing it with us.

we first identified whether the patent assignee at issue matched one of the parties to the suit. If the assignee matched a plaintiff, the suit was classified as an infringement suit; if the assignee matched a defendant, the suit was classified as a declaratory action. We were able to match the assignee for 83% of the suits, and of these, only 17% were declaratory actions.[31] If the assignee did not match a party to the suit, then it was classified as an infringement suit because there are relatively few declaratory actions.[32] This classification then allowed us to create two new variables: (1) the number of suits per year for which the firm was a "patentee litigant" (that is, plaintiff in an infringement suit or defendant in a declaratory action); and (2) the number of suits per year for which the firm was an "alleged infringer" (the reverse).[33] Below, when we speak of one firm "suing" another, we mean the suing firm is a patentee litigant and the other is an alleged infringer, even though the suing firm may not actually be the plaintiff.

Portfolio size. To obtain a measure of firm patent portfolio size, we used the number of patents assigned to the firm over the previous eight years. We chose eight years because this number allowed us to capture a reasonable measure of the patents effectively in force without consuming too much of our sample. This is our main proxy for patent refinement effort.

Patent characteristics. We also estimated the "adjusted" number of claims per patent, citations made per patent (backward citations) and citations received per patent (forward citations) for the litigated patents and also for the firm's entire patent portfolio. Since these characteristics tend to change across patent classes, the "adjusted" characteristics are estimated as deviations from the mean of the patent's class.

Newly public firm. This dummy variable is set to one only during the first five years in which the firm appears in Compustat. This group largely consists of firms that have recently gone public, and these are largely young firms.

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31. These numbers are quite similar to findings by Moore, Lanjouw and Schankerman. *See* Lanjouw & Schankerman, *Small Firms*, *supra* note 11, at 50 (reporting that 85% of patent suits were infringement suits, as opposed to declaratory judgments); Kimberly A. Moore, *Jury Demands: Who's Asking?*, 17 BERKELEY TECH. L.J. 847, 853 n.19 (2002) (finding that the "accused infringer, rather than the patent holder, filed suit in the form of a declaratory judgment action" in 15% of cases).

32. We ran our analysis after excluding cases without a matched assignee and the results were broadly similar.

33. There are some observable differences between, say, plaintiffs in infringement cases and defendants in declaratory actions (the latter tend to be somewhat larger firms). However, we ran our analysis separately for these different groups and the results were broadly similar. For this reason, we only report the combined results here.

Industry groups. We divide firms into eight industry groups according to their primary product category as identified by Compustat: SIC 28 (chemicals, including pharmaceuticals), SIC 35 (machinery, including computers), SIC 36 (electronics), SIC 38 (instruments), other manufacturing (SIC 20–39, excluding the above), SIC 73 (business services including software), SIC 50–59 (retail and wholesale) and other non-manufacturing. These classifications use the SIC code assigned by Compustat for the primary line of business of the firm for the given year.

Technological closeness. Two firms may use similar technologies or very different technologies. To measure their technological "closeness," we calculate a measure developed by Jaffe.[34] This measure is computed by first calculating the share of each firm's patents the USPTO assigns to each technology class as the patent's primary classification. For each firm we get a vector of 426 class shares. The technological closeness of two firms is calculated as the uncentered correlation of the two corresponding vectors. We do this calculation for all public firms with patents over two time periods: 1984–91 and 1992–99. Also, for each firm, we compute weighted sums of other firms' patent portfolio sizes and other firms' R&D expenditures using the closeness measure as a weight. These measures represent the number of patents and R&D spending in the firm's "neighborhood."

Firm financial and other data. These include: employees in thousands; R&D, cashflow and sales all deflated by the GDP deflator; capital defined as property, plant and equipment deflated by the NIPA capital goods deflator; and firm market value (long term debt plus the market value of common and preferred stock).

C. Characteristics of the Samples

We use two main samples in our analysis. The first is the matched sample described above with 118,495 firm-year observations from 1984–99. The second sample is generated from the first. It consists of observations of pairs of firms for each year and we use this to explore the probability that one firm will sue another. All pairs of firms that share the same primary line of business (at the four-digit SIC level) are included twice (firm 1 sues firm 2 and firm 2 sues firm 1), comprising 1,240,580 observations from 1984–99 after excluding cases with missing variables and firms in retail and wholesale industries.

Table 1 shows means and medians of several variables estimated for firm-years from the basic Compustat sample. The first column shows all

34. Adam B. Jaffe, *Technological Opportunity and Spillovers of* R&D*: Evidence from Firms' Patents, Profits, and Market Value*, 76 AM. ECON. REV. 984 (1986).

firm-years and the second shows just those observations with positive patent portfolio size. The third column then shows observations where the firm was involved in one or more patent suits.

Firms who patent tend to be larger and less likely to be newly public than all firms. Firms involved in litigation tend to be much larger than these, although they are no less likely to be new firms. Patent litigation is very much dominated by large, R&D-intensive firms in absolute terms. Below we look at relative hazards by size.

The last two columns compare patentee litigants with alleged infringers.[35] If patent infringement were largely a matter of low-tech copyists imitating patented products or processes, then we should see a much lower level of R&D spending among alleged infringers and much higher percentages of firms reporting no R&D and having no patent portfolios. This is hardly the case. Alleged infringers spend about the same on R&D as their accusers (more in the mean, slightly less in the median). Alleged infringers do have a somewhat greater propensity to be firms who do not report R&D or who do not obtain patents (bear in mind, some defendants are distributors). It is possible, of course, that relatively more low-tech copyists are found among unlisted firms.

Patent litigants, both patentees and alleged infringers, tend to have relatively large patent portfolios on average. We also report mean "adjusted" characteristics of these portfolios. We adjust for differences over patent technology classes by reporting the means as deviations from the mean of the respective patent classes. Thus public firms in general have more highly refined patents that contain more claims and make more citations than all patents in matching patent classes, presumably reflecting greater effort put into patent prosecution. Public firms also receive more subsequent patent citations.

But note that patentee litigants appear to put greater effort into patent refinement (they make more citations) than do other public firms. Alleged infringers obtain patents with fewer claims and backward citations. This suggests a degree of endogeneity: firms anticipate that they may assert their patents and so they put extra resources into refining them so that they will more likely be held valid and infringed.

Finally, note that patentee litigants have patent portfolios that receive more subsequent citations. Thus, the average patent and not just the litigated patents owned by patent-asserting firms are cited more often,

35. The last column excludes firms in the retail and wholesale industries. Firms in these industries are often named in suits because they distribute allegedly infringing goods, but only rarely for making or using such goods themselves. We exclude them here to provide a clearer picture of the extent to which alleged infringers are low-tech copyists. Including these firms does not change the estimates substantially.

perhaps suggesting that forward patent citations are in part a response to litigious behavior. This, plus the evidence above, suggests that the observed correlation other researchers have found between litigation and patent characteristics[36] may involve causality that runs in both directions.

III. EMPIRICAL RESULTS

A. Basic Measures of Litigation Hazard

Table 2 shows mean measures of litigation hazard for public firms with positive patent portfolios and positive R&D spending. The first two columns show statistics for the hazard of the firm enforcing its patents as a patentee litigant and the first three rows show the overall hazards and the hazards for 1987 and 1999. The first column shows the expected number of such suits per year. The hazard grew substantially from 1987 to 1999.

The second column imputes a litigation rate per patent. This is calculated as the mean annual number of suits in which firms are patentee litigants divided by the mean number of patents granted to firms per year. This estimate represents the mean number of suits per patent over the observed time period.[37] In contrast to previous research, however, this estimate reflects the effective patent term.[38] We estimate a hazard of 1.18% of lawsuits per patent. By comparison, Lanjouw and Schankerman report a rate of 1.04% lawsuits per patent for a sample of public firms.[39] We might expect our figure to be somewhat higher because our estimate takes into account effective patent term and our sample of public firms includes many more small firms, who tend to have higher rates of litigation per patent. Still, the correspondence is close.

As Lanjouw and Schankerman point out, the hazard of litigation per

36. *See, e.g.*, Allison et al., *Valuable Patents*, *supra* note 11, at 437–39 (studying characteristics of litigated patents to determine characteristics of valuable patents); Jean O. Lanjouw & Mark Schankerman, *The Quality of Ideas: Measuring Innovation with Multiple Indicators* 2 (Nat'l Bureau of Econ. Research, Working Paper No. 7345, 1999) (reporting correlations between litigation and four indicators: the number of patent claims, forward citations, backward citations and family size).

37. Suppose the effective patent term is T, the grant rate is n and the litigation rate is l. Then the firm's effective patent portfolio at any time is $n\ T$, so the annual number of suits per patent is $l\ /\ nT$ and over the entire effective patent term the expected number of suits per patent is just $l\ /\ n$. Since the means are estimated over a limited time period, these estimates effectively assume that the litigation rate per patent is the same before, during and after the sample period. Since the patent term is factored out, this estimate is robust to variation in T by construction.

38. The effective patent term may be shorter than the statutory term of twenty years from the grant date because of failure to pay maintenance fees, because the technology becomes obsolete or because of financial distress to the assignee. Patent terms can also be extended because of regulatory delay; this is common for pharmaceutical patents.

39. Lanjouw & Schankerman, *Small Firms*, *supra* note 11, at 56.

patent did not change much during the 1990s.[40] We show a small increase (11% over the interval from 1987 to 1999). In effect, the increase in firm patenting rates largely offset the increase in the rate of litigation per firm.

The measures for litigation hazards where the firm is the alleged infringer are shown in columns three and four. The rate of litigation per R&D dollar is calculated as the sample mean rate of litigation per firm divided by the sample mean deflated R&D expenditure.[41] In general, the hazard of a public firm being an alleged infringer has been slightly less than the hazard of the firm being a patentee litigant. But the hazard of being an alleged infringer increased sharply, more than doubling from 1987 to 1999. Moreover, measured relative to R&D spending, the rate still increased sharply—the hazard of being sued for each dollar of R&D increased by 70% from 1987 to 1999.

The next three rows show these measures for firms of different sizes and for newly public firms. Lanjouw and Schankerman report that small firms have a much higher rate of litigation per patent,[42] and we find the same. A firm with fewer than 500 employees faces an enforcement hazard per patent that is about four times larger than the hazard faced by a larger firm. In addition, we find that the hazard of being sued relative to R&D spending is nearly six times larger for a small firm. Newly public firms show a similar pattern of increased relative hazards.

These large differences emphasize that multiple factors influence these hazards. A simple model where, say, the hazard of being a plaintiff is proportional to a firm's patent portfolio size is likely to fit the data poorly. Instead, we need to use a multiple regression approach to understand the factors giving rise to trends in the hazards.

Finally, the bottom of Table 2 shows these statistics reported for different industry groups. Different industries seem to exhibit very different patterns. The instruments industry has high hazards relative both to its patents and its R&D, while the business services industry has low litigation rates by both measures. Chemicals including pharmaceuticals have a high rate of litigation per patent, but a low rate per R&D. Electronics has the reverse: a low rate per patent and a high

40. *Id.* at 50.

41. If the rate of litigation per billion dollars of R&D is instead calculated as the mean individual ratio of the number of suits to R&D expenditures and this figure is trimmed of the upper 1% tail, the mean rate is 3.7 for the entire period, 1.3 for 1987 and 3.8 for 1999. This represents a 193% increase from 1987 to 1999. The weighted mean (weighted by R&D) increased 73% from 1987 to 1999 (from 1.1 to 1.9).

42. *Id.* at 63–70.

rate per R&D dollar.[43]

Again, mono-causal explanations are unlikely to explain these diverse patterns. For example, the semiconductor industry is sometimes described as having a low rate of litigation per patent because the complex technology gives rise to patent trading based on "mutually assured destruction."[44] But this explanation by itself seems unable to account for the above average rate of litigation relative to R&D spending in semiconductors.

B. What Difference do Industry and Technological Closeness Make?

We next look at characteristics of the pairs of firms involved in lawsuits. Do firms tend to sue firms within their own industry or those in other industries? Do they tend to sue firms that patent similar technologies or those that patent more remote technologies? Table 3 provides some simple analysis for suits where both plaintiffs and defendants are public firms.

Surprisingly, only 29% of these suits occurred between firms whose primary line of business is in the same four-digit SIC industry. But 28% involved firms that did not have a business segment in common even at the three-digit SIC level. Compustat reports major business segments by industry of firms since 1985. The second column of the Table includes pairs of firms who share businesses in the same three-digit classification but whose primary businesses are in different industries. This is a very broad classification and likely includes many pairs that are not direct competitors (e.g., computer manufacturers and stapler manufacturers are in the same three-digit SIC classification). Nevertheless, a substantial number of suits appear to involve firms that are not market competitors.[45]

Perhaps many of these suits are between firms that use similar technologies. We use the technology closeness measure described above to consider this possibility. Firms within the same industry tend to have high closeness measures, but the closeness measure also varies independently of industry, e.g., Apple Computers and Intel do not compete directly in their major markets, but they have a closeness of 0.53. The first row in Table 3 shows the percentage of pairs with closeness of less than 0.5 and the second row those pairs with closeness greater than or equal to 0.5. Still, 24% of the pairs neither share an industry segment

43. *See* Ziedonis, *supra* note 10, at 184 (reporting similar numbers for the semiconductor industry).

44. Allison et al., *Valuable Patents*, *supra* note 11, at 468.

45. Some of these suits are probably against distributors of infringing products. The Table excludes firms in the retail and wholesale industries for this reason. However, manual inspection of some of the reported suits revealed that many are not against distributors.

nor are technologically close.

Thus, although many suits, probably the majority, occur between firms that are close either in the market place or in their patent portfolios, a substantial percentage also occur between firms that are distant. This suggests that it might be prohibitively expensive for firms to clear their innovations for possible infringement accurately. There may simply be too many patent holders that pose a litigation threat but who have dissimilar technologies and products. If so, then inadvertent infringement will not occur infrequently.

C. Regression Analysis of Pairs

To analyze what drives litigation, we begin by estimating logit regressions of the probability that a firm with given characteristics will sue a firm with other characteristics in a given year. For tractability, we estimate this probability out of a sample of all pairs of firms who share the same primary industry. We also exclude firms that are not matched to the patent database and firms in the retail and wholesale industries (there litigation is likely to be quite different and there were no intra-industry suits in these industries). Excluding observations missing key data, there were 1,240,580 such pair-year observations from 1984–99.

Table 4, column one shows the simplest estimates. Firm employment size is clearly significant for both parties with a coefficient of .54 for the patentee litigant and .39 for the alleged infringer. Both coefficients are significantly greater than zero, suggesting that scale matters both for plaintiffs and defendants because it is associated with larger stakes in litigation.[46] But both coefficients are also significantly less than one. This may be because larger companies may also be more diversified, so that the stakes for the particular business unit at risk do not grow as fast as the overall firm size. If we imagine that employment simultaneously grows for both the firms, then we see that the probability of litigation grows by almost the same proportion (because .54 + .39 = .93). Thus, we see evidence that a general increase in stakes is associated with an increasing in filing (Hypothesis 2).

All the other continuous variables are scaled by firm employment. The coefficient on the log of the patentee litigant's patent portfolio per employee is also positive and highly significant, consistent with Hypothesis 3. More patents mean that the patentee has better chances of winning in court against the prospective infringer. This coefficient is also significantly less than one.

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46. To some extent, employment size may also pick up some measure of the number of enforcement opportunities and the degree of exposure to other firms' patents.

The coefficient on the log of the alleged infringer's patents per employee is negative, but not significantly different from zero, providing weak support for Hypothesis 4 (defensive patenting).

Regarding the two parties' R&D spending per employee, the coefficient for the patentee litigant is not significantly different from zero. This result holds for all of the variations shown in Table 4. On the other hand, the coefficient for the alleged infringer's R&D is positive in all variations and highly significant in all but the last column. This result is consistent with Hypothesis 6 (exposure effect) and inconsistent with Hypothesis 5 (inventing around), however, this regression does not completely control for the stakes of each firm. It is possible that the coefficient on firm 2's R&D might be positive because this investment increases the stakes (profits) that firm 2 makes. Employment size captures the magnitude of firm stakes to the first order, however, there might be some additional variation picked up by this coefficient. Given that firm 1's R&D does not seem to have such a positive effect on firm 1's stakes, this explanation seems unlikely. To explore this issue more carefully, we will add further controls on firm stakes below.

Column 2 adds our measure of technological proximity. The coefficient is economically large and statistically highly significant, supporting Hypothesis 1. This is a strong effect, especially since the sample only includes pairs that are already in the same primary SIC industry. The addition of this variable reduces the scale coefficients a bit, perhaps suggesting that firms of larger size within an industry may also inevitably have more overlapping technology.

Also, the coefficient on the alleged infringer's patent portfolio size becomes more negative and statistically significant. This suggests a possible interaction between "defensive" patenting and technological proximity. This idea is explored further in column 3 where both patent portfolio size variables are interacted with a categorical variable indicating whether the firms have a technological closeness greater than or less than 0.5 (about 8% of the samples have technological closeness greater than 0.5). Both of the close coefficients have larger magnitudes in absolute value than their distant counterparts. This suggests that defensive patenting mainly affects litigation among firms that are close to rivals in technology space.

The fourth column repeats the regression of the first column, but adds a term capturing the interaction of the two parties' log patent portfolio sizes. The coefficient of this term is not statistically significant. We also tested a variety of other interactions to see if there were possible size interaction effects or asymmetric patent portfolio effects (e.g., large portfolio suing small portfolio). None of these were significantly different from zero.

The fifth column repeats the regression of the first column, adding variables for log market value per employee and log capital per employee. The market value variable may capture aspects of the firms' stakes at risk in litigation that are not captured by other variables. The positive coefficients suggest this may be so. The measure of capital intensity may indicate the extent to which the firm is at risk of holdup. Alleged infringers with large capital costs may be particularly vulnerable to patent injunctions, so they may settle more readily, avoiding litigation. The coefficient on the alleged infringer's capital intensity is negative and significant at the 5% level, providing some support for this hypothesis. The coefficient on the patentee litigant's capital intensity is also negative (but only significant at the 10% level), perhaps suggesting that capital intensive patent holders also settle more frequently to avoid holdup associated with counter-suits.

With the additional control for firm stakes, the coefficient for firm 2's R&D is still positive, however, it is no longer statistically significant. This provides weak support for Hypothesis 6 (exposure effect). We will revisit this estimate in the next Section, where we measure the equivalent coefficient with greater precision.

D. Regression Analysis of Aggregate Hazards

As described above, the firm hazard of being a patentee litigant equals the sum of the probabilities of litigation for all possible firms the patentee might sue, assuming these probabilities are independent. The hazard of being an alleged infringer is likewise a sum over possible plaintiffs. This means that the coefficients of firm hazards may have a simple relationship to the coefficients estimated in Table 4. In particular, if the coefficients on interaction terms involving a variable are zero, then the coefficients on that variable should match. On the other hand, we estimate the hazards over a different sample than the sample used in Table 4—the new sample includes suits where the opposing party may be in a different industry and may not be a public firm.

Table 5 reports estimates of firm hazard Poisson regressions for all public firms from 1984 to 1999. The dependent variable in the upper panel is the number of times that the firm is a patentee litigant in a year; in the lower panel, the dependent variable is the number of times that the firm is an alleged infringer in a year. As before, the continuous variables are scaled by firm employment.

Despite the difference in samples, the coefficients in column 1 are close to those in column 1 of Table 4: the coefficient on the patentee litigant's log portfolio size per employee is .39 in both tables, the coefficient on log employment is .47 compared to .54 in Table 4; the coefficient on the alleged infringer's log deflated R&D per employee is .26 compared to .25 in Table 4, and that on log employment is .48 compared to .39. The only substantial difference is in the coefficients on the alleged infringer's log patent portfolio per employee which is now .10, but was -.08 in Table 4. Since we suggest above that this coefficient may be influenced by technological closeness, and since the current sample includes many more firms that are more distant (since they are no longer constrained to be in the same industry), this may reflect less defensive patenting among firms that are not technologically close.

We tested this and all the other regressions in this Table for over-dispersion, which we found to be significant. For this reason, we use standard errors that are robust to heteroscedasticity.[47] Also, we ran negative binomial regressions (not shown). The coefficients on these were quite similar to those from the Poisson regressions.

Column 2 adds the patentee litigant's log R&D to employment (and a dummy variable for zero reported R&D) and log capital per employee in both regressions. Column 3 further adds log market value per employee, the log of other firms' closeness-weighted patent portfolios and the log of other firms' closeness-weighted R&D. As discussed above, the coefficients on capital intensity may reflect evidence of strategic patenting and they are both negative and significant. The distance-weighted measures do not appear to have significant effects, perhaps because other variables already capture the effect of close competitors.

Note that now the coefficient on the alleged infringer's R&D remains positive and highly significant, even when controlling for firm market value and employment. Given these controls, the positive coefficient cannot be explained by any effect R&D might have on firm stakes. Instead, this finding rejects Hypothesis 5 (inventing around) and is consistent with Hypothesis 6 (exposure effect).

Table 5 also shows the coefficients on industry dummies ("Other non-manufacturing" is the excluded category).[48] The pattern is quite similar to the pattern observed in Table 2. Firms in chemical, pharmaceutical and instruments industries are more likely to sue; firms in non-manufacturing industries are much less likely to sue. Firms in electronics and instruments and retail/wholesale industries are more likely to be sued.

47. The negative binomial estimates are inconsistent if the true distribution is not actually negative binomial. The Poisson estimates, on the other hand, will still be consistent even with over-dispersion, so we prefer to present Poisson estimates using heteroscedasticity-robust standard errors.

48. Table 4 regressions also included industry dummies but these were not displayed because their standard errors are substantially larger than those in Table 5.

Firms in business services including software and other non-manufacturing are less likely to be sued.

Table 5 does not display the year dummies, but the year dummies for both regressions in column 3 are displayed in Figure 2. Also, Table 5 displays the average annual increase in the year dummies for each regression from 1987 to 1999. The year dummies can be interpreted as relative (log) residuals, that is, as the portion of the hazard rate not explained by the observed right hand variables. Trends in the residuals indicate the portion of the growth in firm litigation hazards that is not explained by these variables. In particular, column 3 includes variables that correspond to many of the obvious explanations for the increase in litigation: patent portfolio variables capture the increase in patenting rates, R&D and capital variables capture the increase in both types of investment, market value variables capture otherwise unobserved changes in "innovative fertility" and other sources of firm value, employment variables capture changes in firm scale and the closeness-weighted measure captures changes in technological density.

The residual growth rates and the pattern shown in Figure 2 clearly show that most of the increase in both litigation hazards is not explained by these factors. The residual accounts for most (68%) of the 5.5% annual growth rate in the hazard of being a patentee litigant and most (75%) of the 8.4% annual growth rate in the hazard of being an alleged infringer.

In column 3, the log of market value per employee captures otherwise unobserved differences in the value of firms' technologies. Another way to capture these is by using forward patent citations, although this does reduce the sample size. Column 4 shows a regression with the adjusted (for patent class) mean number of forward citations for each firm's patent portfolio.[49] Having a more highly cited patent portfolio does make a firm more likely to sue; it also makes a firm more likely to be sued. The latter finding may suggest that some portion of causation runs from litigation to patent characteristics rather than the other way.

Table 6 repeats the regressions from column 2 of Table 5 for different sub-samples (we also added a dummy variable for newly public firms). The first pair of columns conducts the regressions separately for firms in SIC 28 (chemical and pharmaceutical industries) and for a group of industries where strategic patenting behavior has been observed (SIC 35, 36, 38 and 73, machinery including computers, electronics, instruments and business services including software). One difference that stands out

49. We also ran regressions using backward citations and claims. The coefficient on backward citations was statistically significant, but small. That on claims was insignificant on both counts.

is that patent portfolio size tends to be a relatively stronger determinant of litigation in the latter group while R&D tends to be a stronger influence in chemicals and pharmaceuticals. This is, perhaps, not surprising given the relative importance the "thicket" industries place on patent portfolios. The larger coefficient on the patentee's R&D in pharmaceuticals may suggest that R&D increases firm stakes; alternatively, it may simply be an artifact of the unusual role that generic manufacturers play in this industry's litigation—R&D intensive drug manufacturers are more likely to sue than are low-R&D generic manufacturers.

The second comparison is between large and small firms. Generally, both patents and R&D tend to be more strongly associated with litigation among large firms than among small.

Finally, the last pair of columns compares the regression at the beginning and end of the sample period. Although the time dummies have increased dramatically during this period, the slope coefficients have not, in general, changed significantly.

Table 7 shows estimates of the growth rate of the residuals for different sub-samples. Here the regression is conducted from 1987–99 and includes a linear time trend instead of individual year dummies. The Table reports the coefficient of the time trend (with standard error) expressed as an annual percentage rate. Only one growth rate shows a statistically significant difference from the mean: the growth rate in the residual hazard for instrument firms as patentee litigants.

IV. Interpretation

A. Drivers of Litigation: "Cheating" or "Exposure"?

Summarizing the above results, the main factors influencing litigation hazards are the scale of the firms, the number of patents held by prospective plaintiffs, the R&D performed by prospective defendants, the capital intensity of the parties and, for the probability of litigation between a given pair of firms, the technological distance between them. Measured technological distance does not seem to matter much for the aggregate litigation hazards.

This evidence supports several of our hypotheses. Technological proximity matters for pairs of firms (H1). Firm scale should be an important variable because it relates to the magnitude of what the firms have at stake in litigation (H2). The importance of the prospective plaintiff's patent portfolio size underlines the importance of refinement (H3)—firms can improve their prospects in patent disputes by building a larger patent portfolio, among other things.

Our findings also cast considerable doubt on the idea that most patent litigation is caused by outright piracy or other forms of "cheating" such as inventing around. Most alleged infringers are not low-tech copyists who imitate to avoid R&D; instead, most invest heavily in R&D. Moreover, the probability of patent litigation increases with the level of the prospective defendant's R&D spending even after controlling for firm size and market value. This suggests that this R&D is not being directed to "inventing around," rather, greater investment in technology seems to increase the firm's exposure to infringement. And the difficulty of avoiding inadvertent infringement is highlighted by the significant portion of lawsuits that occur between firms that are in completely different industries and are also technologically distant.

Several other findings also cast doubt on the "cheating" story. In a model of monitoring like that developed by Crampes and Langinier,[50] one would expect large firms to monitor more intensively, leading to less infringement and less litigation. But the probability of litigation increases with the size of the prospective plaintiff. Also, one would expect litigation to be far less in those industries where reverse engineering costs little. But the computer and instruments industries have high rates of litigation per patent despite having well-developed practices of reverse engineering. Indeed, this suggests a reason why relatively little litigation seems to be generated by cheating: cheating can occur only if firms find it costly or difficult to monitor for infringement. However, if monitoring (reverse engineering) is costly or difficult, then trade secrecy is probably relatively effective and firms may therefore be less likely to patent in the first place.

We conclude that although cheating certainly occurs in some instances, most litigation appears to be driven by "exposure," and, consequently, firms' rapidly growing hazard of being sued for infringement likely reduces their R&D incentives.

B. The Effect of Patent Portfolio Size

The data in Table 2 imply that litigation imposes a much larger burden on small firms. Lanjouw and Schankerman find evidence of large differences in litigation rates per patent across size groups.[51] Our evidence affirms theirs and, in addition, we find evidence that small firms have much higher rates of litigation as alleged infringers per R&D dollar.

Lanjouw and Schankerman suggest that this "portfolio size effect" may be due to two forms of strategic interaction: (1) patent trading where

50. Crampes & Langinier, *supra* note 7, at 260–62 (modeling monitoring decisions using one static game scenario and two alternative sequential games).

51. Lanjouw & Schankerman, *Small Firms*, *supra* note 11, at 63.

firms with large patent portfolios more easily cross-license and settle rather than litigate, and (2) repeated interaction between large firms, also inducing more frequent settlement.[52] These explanations attribute the size effect to the interaction between the firms—there is less litigation when the alleged infringer is able to retaliate with a countersuit using its own patents either in the disputed market or, given repeated interactions, in other markets and at other times.

We do find significant evidence of some such interaction between firms: a firm with greater capital intensity is less likely to sue, perhaps because of the greater risk of retaliation; a firm with greater capital intensity is less likely to be sued, perhaps because such firms settle more readily. However, a standard deviation change in capital intensity only changes the probability of litigation by about 20%, so this cannot explain the large observed differences in litigation per patent.

We also find some evidence of patent trading and defensive patenting. However, defensive patenting only seems to play a limited role reducing litigation between firms that are technologically close. The size of the defendant's portfolio does not reduce litigation hazard in the aggregate.

Instead, our regressions suggest that there may be a more basic explanation for the portfolio size effect that does not depend on strategic interaction between firms, namely, that there may be diminishing returns to patent portfolio size. In all of our regressions, the coefficient on the plaintiff's patent portfolio size per employee is well below one. Of course this ignores the effect of the plaintiff firm's size. Our regressions cannot fully distinguish between the effect of the plaintiff's scale, which may affect litigation because it changes the plaintiff's stake, and the direct effect of patent portfolio size. But even assuming that the coefficient on log employment is entirely due to the greater number of patents held by larger firms, the sum of the two coefficients in Table 5 is still significantly less than one. For example, in column 5, the combined effect of employment and patents per employee has an elasticity of 0.86.

At first glance, the idea of diminishing returns to patent portfolio size may seem counter-intuitive. After all, if two firms merge, pooling their patent portfolios, why should this affect the rate of litigation per patent? But such a merger would affect the probability of winning a suit against a third firm—the probability of winning a suit will typically *not* double.[53]

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52. *Id.* at 46–47.

53. *See* Gideon Parchomovsky & R. Polk Wagner, *Patent Portfolios*, 154 U. PA. L. REV. 1, 36 (2005) (showing that while individual patents may not proportionally increase litigation rates, patent portfolios can "serve as important defense mechanisms in a highly litigious environment"); James Bessen, Patent Thickets: Strategic Patenting of Complex Technologies 3 (Oct. 3, 2002) (unpublished manuscript), *available at* http://www.researchoninnovation.org/thicket.pdf (expl-

For example, this will be the case if each patent has an independent probability of being found valid and infringed. And this means that the probability of litigation need not double either. Patent portfolio size exhibits diminishing returns to the probability of winning a suit. This means, in turn, that the probability of litigation increases less than proportionately with the plaintiff's patent portfolio size.

C. The Growth in Hazard Rates

Measured firm characteristics seem to explain only a fraction of the growth in firm litigation hazards. The majority of the increase cannot be explained by the growth in R&D spending, the value of firm technology, the growth in technological crowdedness or the growth in patenting (either because of "innovative fertility" or because of greater patent propensity).

What else might explain this rapid growth? We can think of two broad classes of factors: technology and legal changes. Technology might cause increased litigation if technological changes tended to erode industry norms of cooperation or mutual forbearance. For example, as technologies mature, industries often experience shake-outs. This might give rise to sales of patents to "trolls" by distressed firms or to anti-competitive actions by established firms, both possibly increasing litigation. However, this explanation seems unlikely, given that the growth of the residual in Table 7 does not vary sharply across industries. It does not seem likely that all industries experienced shakeouts in the 1990s.

Technology might have also increased the cost of monitoring for infringement, leading to more "cheating" and more detected disputes. But this explanation does not seem promising because the increase in litigation seems to occur across all technologies, and thus we need to identify some far-reaching event that has increased the cost monitoring for patent infringement in all sorts of technology. The Internet and other improvements in communications probably have reduced the cost of monitoring.

Another technological factor might be the greater use of general-purpose technologies. Suppose that firms in a wide variety of industries began using general purpose technologies more intensively and also patented these technologies. This might lead to greater litigation for two reasons: first, firms might be more likely to innocently infringe because they do not search applications outside of their own industry as

aining that "the more patents a firm has related to a given product, the greater the joint probability of prevailing at trial").

intensively (and there may be many more patents to search); second, inter-industry disputes might be less likely to settle because disputants are not likely to interact repeatedly.

One candidate for such general-purpose technology patents is software, which, of course, also went through a change in legal status. Software patents are obtained across a wide variety of industries and are used in a wide variety of applications. Using a definition of software patent from Bessen and Hunt,[54] we found that software patents accounted for 3% of the main patents litigated in 1984 and 17% in 1999. Moreover, note that some of the industries that use software do tend to have somewhat higher residual growth rates in Table 7, especially as alleged infringers. So software patents contributed to the growth in the litigation residual. However, this does not seem to be the main factor, especially since, again, Table 7 indicates that all industries exhibited substantial growth in the residual.

This leaves various legal changes as the likely candidates for the dominant factors affecting the growth in the litigation residual. Landes and Posner suggest that the creation of a unified appeals court for patent cases increased the uncertainty of legal outcomes instead of improving the predictability of patent law, leading to increased litigation.[55] Our results are consistent with this view, especially greater "noise" regarding the interpretation of standards of patentability and vaguer boundaries of patent claims.

Another factor may have been a pro-patentee shift in the law. Such a shift might lead to more litigation (although in some circumstances it might just lead to less infringement). Litigation may have become more attractive if the risk of patent invalidation (e.g., for obviousness) were decreased. Lunney presents evidence of just such a switch—reviewing appellate decisions, he finds a sharp decrease in the portion of patents found invalid, although he also finds an increase in the portion of patents found not to be infringed.[56]

These legal changes would tend to affect firms in all industries, consistent with our estimates. And the fact that the rapid growth in litigation began after 1987—just five years after the creation of the Court

54. Bessen & Hunt, *supra* note 24, at 8 (defining a "software patent" as one that "involves a logic algorithm for processing data that is implemented via stored instructions; that is, the logic is not 'hard-wired'").

55. LANDES & POSNER, *supra* note 12, at 334–53.

56. Glynn Lunney, Jr., *Patent Law, the Federal Circuit, and the Supreme Court: A Quiet Revolution*, 11 SUP. CT. ECON. REV. 1 (2004); *see also* Matthew D. Henry & John L. Turner, *The Court of Appeals for the Federal Circuit's Impact on Patent Litigation*, 35 J. LEGAL STUD. 85, 90 (2005) (analyzing how the Court of Appeals for the Federal Circuit's stronger presumption of validity impacts litigation outcomes at the district court level).

of Appeals for the Federal Circuit—adds weight to this interpretation. Thus, barring some explanation we have not considered, legal changes seem to be the dominant factor accounting for the rapid rise in litigation.

CONCLUSION

Most of the rapid increase in patent litigation hazards over the 1990s cannot be explained by firm patenting rates, R&D spending, firm value or industry composition. Looking at a variety of explanations, we conclude that legal changes may be the dominant factor driving this increase. This implies that the increase in patent litigation represents a growing disincentive to R&D that is not likely offset by growth in the number or value of innovations.

Furthermore, we find evidence that this disincentive is borne by firms not only in their roles as patent holders, but also as innovators having to defend against patent lawsuits. We find that the more R&D a firm performs, the more likely it is to be sued. In most industries, this pattern of litigation is inconsistent with the view that most defendants in patent lawsuits are simple pirates or imitators. Instead, patent defendants are, to a large degree, innovators themselves, spending as much on R&D as the plaintiffs. Moreover, about a quarter of patent lawsuits occur between firms that are in different industries and are also "technologically distant," suggesting that ex ante licensing and avoidance of patent disputes are difficult. Thus an important part of the burden of patent disputes falls on defending firms. This distinction is important because although the rate of litigation per patent among public firms as plaintiffs did not increase much from 1987 to 1999, the rate of litigation per R&D dollar among public firms as defendants increased 70%.

Also, as Lanjouw and Schankerman find,[57] the risk of litigation falls disproportionately on small firms. However, this does not appear to be mainly the result of better dispute resolution among large firms through patent trading and "defensive" patenting. We find that the defendant's portfolio size has, at best, only a limited effect on the probability of litigation, mainly among firms that are technologically close. Any optimism that "defensive" patenting might serve to reduce the growth of litigation is probably misplaced.

Finally, our results shed some light on the changes in litigation hazards, but our results are limited in that they say nothing about the actual costs associated with filing lawsuits and subsequent litigation and the effects of these costs on R&D. Nevertheless, there is cause for concern. Event studies find that the joint market value of plaintiffs and

57. Lanjouw & Schankerman, *Small Firms*, *supra* note 11, at 63.

defendants falls by 2–3% on the filing of a patent lawsuit,[58] suggesting that the economic burden on litigants may be substantial. So the recent doubling of litigation hazards may well impose substantial costs.

58. *See, e.g.*, 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, 230–31 (1994) (reporting wealth effects of corporate lawsuits); Lerner, *supra* note 3, at 471 (finding that the combined market value of firms fell by an average of 3.1% in the two days after the *Wall Street Journal* reported the lawsuit filing).

TABLES AND FIGURES

Table 1. Sample Characteristics

	Means				
				Litigants by type	
	All Firms	All Patenters	All Litigants	Patentees	Alleged Infringers
R&D	37.6	69.8	244.8	261.9	307.1
Employment	5.2	10.0	23.7	24.4	28.5
Sales	846.7	1933.9	5147.6	5382.7	6195.5
Portfolio size	44.1	92.7	375.8	424.6	442.7
Portfolio adjusted claims/patent		3.0	2.8	2.9	2.5
Portfolio adjusted cites made/patent		2.0	2.2	2.4	2.1
Portfolio adjusted cites rec'd/patent		3.1	3.5	3.8	3.2
New firm	38%	22%	19%	16%	19%
No R&D	70%	31%	21%	16%	22%
No Patents	77%		13%	8%	16%
	Medians				
R&D	2.9	6.4	25.8	33.7	29.6
Employment	0.5	1.2	4.4	5.1	5.5
Sales	64.9	171.1	654.4	832.9	793.6
Portfolio size	0	6	31	51	30

Note: Litigants exclude firms in retail and wholesaling industries and in SIC 6794, patent holding & franchising companies. 118,495 observations from 1984–99. Employment is in thousands. R&D and sales are deflated by the GDP deflator. New firms are observations where the firm has been listed in Compustat for five or fewer years. Portfolio size is the number of patents granted over the previous eight years.

Table 2. Litigation Hazards for Firms with Patent Portfolios and Positive R&D

	As Patentee Litigant		As Alleged Infringer	
	Expected Suits per year	Suits per 1000 patents	Expected Suits per year	Suits per $billion R&D
All Firms	0.223	11.8	0.185	2.5
1987	0.198	10.5	0.116	1.7
1999	0.271	11.7	0.256	2.9
Small firms (employment<500)	0.079	42.5	0.064	12.3
Large firms (employment>=500)	0.304	10.7	0.254	2.2
New firms	0.114	30.3	0.095	5.9
BY INDUSTRY				
Chemicals/pharmaceuticals	0.334	14.4	0.229	2.1
Machinery/computers	0.217	13.0	0.170	2.3
Electronics	0.202	8.8	0.194	3.6
SIC 3674	0.216	7.8	0.225	3.2
Instruments	0.216	17.6	0.191	6.4
Other manufacturing	0.230	10.3	0.188	1.8
Business svcs/software	0.108	8.4	0.103	1.3
Retail/wholesale	0.021	5.9	0.111	10.9
Other non-manufacturing	0.141	8.0	0.152	2.1

Note: 20,522 observations from 1984–99 for firms with positive patent portfolio size and positive R&D. R&D figures are deflated by the GDP deflator. Raw hazard rates have been adjusted for underreporting (divided by .64).

Table 3. Lawsuits by Technological Closeness and Industry Overlap

Technological Closeness	No industry overlap	Weakly overlapping industries	Same primary industry	Total
Distant	24%	28%	11%	63%
Close	4%	15%	18%	37%
Total	28%	43%	29%	100%

Note: For 680 lawsuits where parties on both sides are public firms. Firms in the retail and wholesale industries have been excluded. "Same primary industry" means both parties' primary business is in the same four-digit SIC industry. "Weakly overlapping industries" means the parties had a business segment in the same three-digit SIC industry. "Distant" and "close" refer to a closeness measure >=.5 and <.5 respectively.

Table 4. Logit Regression of Probability of Suit

	1	2	3	4	5
Patentee litigant					
Log patents/employee	0.40 (0.07)	0.38 (0.07)		0.45 (0.09)	0.41 (0.07)
Ln patent/emp * distant			0.35 (0.08)		
Ln patent/emp * close			0.43 (0.08)		
Zero patents dummy	-1.62 (0.62)	-1.31 (0.62)	-1.30 (0.63)	-1.57 (0.62)	-1.92 (0.75)
Log employment	0.54 (0.03)	0.46 (0.04)	0.47 (0.04)	0.53 (0.03)	0.56 (0.04)
Log R&D/employee	0.00 (0.09)	-0.07 (0.09)	-0.07 (0.09)		-0.12 (0.09)
No R&D dummy	0.25 (0.41)	0.28 (0.42)	0.27 (0.42)		
Log Mkt. Value/employee					0.26 (0.09)
Log capital/employee					-0.23 (0.13)
Alleged Infringer					
Log patents/employee	-0.08 (0.06)	-0.16 (0.06)		0.00 (0.11)	-0.04 (0.06)
Ln patent/emp * distant			-0.08 (0.07)		
Ln patent/emp * close			-0.23 (0.07)		
Zero patents dummy	-0.92 (0.29)	-0.71 (0.30)	-0.65 (0.30)	-0.93 (0.29)	-1.07 (0.33)
Log R&D/employee	0.25 (0.08)	0.18 (0.08)	0.18 (0.08)	0.25 (0.08)	0.13 (0.10)
No R&D dummy	0.12 (0.38)	0.15 (0.39)	0.19 (0.39)	0.17 (0.38)	0.32 (0.39)
Log employment	0.39 (0.04)	0.28 (0.04)	0.28 (0.04)	0.39 (0.04)	0.13 (0.09)
Log Mkt. Value/employee					0.30 (0.09)
Log capital/employee					-0.26 (0.13)
Interaction terms					
plaintiff ln pat/emp*defendant ln pat/emp				-0.03 (0.03)	
Technological closeness		2.35 (0.24)	2.47 (0.38)		
Number of obs	1,240,580	1,240,580	1,240,580	1,240,580	994,148
Log likelihood =	-1568.9	-1522.8	-1521.3	-1568.6	-1400.4

Note: Logit regressions with industry and year dummies not shown. Asymptotic standard errors in parentheses. Patents are the portfolio size, that is, the number of patents granted the previous eight years. Dummy variables report zero patents and zero R&D. R&D and market value are deflated by the GDP deflator, capital is property, plant and equipment deflated by the NIPA capital goods deflator and employment is in thousands. Technological closeness measure is described in text.

Table 5. Poisson Regressions of the Number of Suits Per Year

	1		2		3		4	
Suits as patentee litigant								
Log portfolio size	0.39	(0.02)	0.37	(0.02)	0.36	(0.02)	0.40	(0.03)
Portfolio=0 dummy	-1.46	(0.14)	-1.41	(0.15)	-1.20	(0.21)		
Portfolio size missing	-0.98	(0.19)	-0.89	(0.19)	-0.91	(0.20)		
Log R&D/emp.			0.10	(0.03)	-0.06	(0.03)	0.09	(0.03)
R&D not reported			-0.30	(0.11)	-0.39	(0.11)	0.04	(0.12)
Log employment	0.47	(0.01)	0.49	(0.01)	0.51	(0.02)	0.51	(0.02)
Log capital/emp.			-0.23	(0.03)	-0.40	(0.04)	-0.33	(0.05)
Log mkt. Value/emp.					0.39	(0.04)		
Log other firms' patents					-0.02	(0.11)		
Log other firms' R&D					0.06	(0.11)		
Adj. Cites rec'd/patent							0.017	(0.003)
Chemicals/pharmaceuticals	1.18	(0.19)	0.86	(0.19)	0.82	(0.20)	0.73	(0.22)
Machinery/computers	0.88	(0.18)	0.46	(0.19)	0.57	(0.20)	0.31	(0.22)
Electronics	0.95	(0.18)	0.55	(0.19)	0.66	(0.20)	0.34	(0.22)
Instruments	1.20	(0.19)	0.74	(0.20)	0.82	(0.21)	0.59	(0.24)
Other manufacturing	0.63	(0.17)	0.42	(0.17)	0.47	(0.17)	0.28	(0.20)
Business svcs/software	0.52	(0.21)	-0.05	(0.23)	0.00	(0.23)	-0.12	(0.29)
Retail/wholesale	-0.80	(0.26)	-1.05	(0.27)	-0.81	(0.28)	-0.64	(0.40)
Residual growth (sample: 5.5%)	4.0%		4.7%		3.7%		6.1%	
Log likelihood =	-9751.1		-9645.3		-9035.3		-7187.8	

Table 5, continued

Suits as alleged infringer

Log portfolio size	0.10	(0.02)	0.11	(0.02)	0.11	(0.02)	0.17	(0.02)
Portfolio=0 dummy	-0.75	(0.09)	-0.76	(0.09)	-0.60	(0.11)		
Portfolio size missing	-1.23	(0.12)	-1.19	(0.12)	-1.13	(0.12)		
Log R&D/emp.	0.26	(0.02)	0.28	(0.02)	0.15	(0.03)	0.25	(0.03)
R&D not reported	-0.23	(0.09)	-0.22	(0.09)	-0.29	(0.09)	0.11	(0.11)
Log employment	0.48	(0.01)	0.50	(0.01)	0.53	(0.01)	0.53	(0.01)
Log capital/emp.			-0.12	(0.02)	-0.30	(0.03)	-0.23	(0.04)
Log mkt. Value/emp.					0.35	(0.03)		
Log other firms' patents					0.12	(0.09)		
Log other firms' R&D					-0.10	(0.10)		
Adj. Cites rec'd/patent							0.014	(0.003)
Chemicals/pharmaceuticals	0.65	(0.13)	0.53	(0.13)	0.49	(0.13)	0.18	(0.14)
Machinery/computers	0.55	(0.12)	0.36	(0.13)	0.48	(0.13)	-0.02	(0.14)
Electronics	0.79	(0.12)	0.61	(0.12)	0.70	(0.13)	0.18	(0.14)
Instruments	1.04	(0.13)	0.84	(0.13)	0.89	(0.14)	0.40	(0.14)
Other manufacturing	0.43	(0.10)	0.30	(0.10)	0.34	(0.11)	-0.09	(0.12)
Business svcs/software	0.01	(0.15)	-0.26	(0.16)	-0.26	(0.16)	-0.49	(0.22)
Retail/wholesale	0.85	(0.11)	0.61	(0.12)	0.75	(0.12)	0.70	(0.22)
Residual growth (sample: 8.4%)	6.7%		7.2%		6.3%		8.5%	
Number of obs	93,333		87,856		76,843		15,811	
Log likelihood =	-10253.4		-10153.9		-9318.8		-6014.5	

Note: Regressions are Poisson regressions with year dummies and independent variables lagged one year. Standard errors are heteroscedastic robust. R&D and market value are deflated by the GDP deflator, capital is property, plant and equipment deflated by the NIPA capital goods deflator and employment is in thousands. Cites received is adjusted for mean for patent class. Residual growth is annual growth rate of time dummies.

Table 6. Separate Litigation Poisson Regressions Dependent Variable: Number of Lawsuits as Patentee Litigants or Alleged Infringers

	Industry Group		Firm Employment Size		Year	
Lagged independent variables	Chemicals & pharma-ceuticals	Thicket Industries	<500	≥500	84 – 91	92 – 99
Patentee Litigants						
Log portfolio size	0.23 (0.06)	0.38 (0.03)	0.28 (0.06)	0.41 (0.03)	0.41 (0.04)	0.35 (0.03)
Portfolio=0 dummy	0.14 (0.35)	-1.39 (0.21)	-1.13 (0.26)	-2.00 (0.23)	-1.24 (0.23)	-1.53 (0.19)
Portfolio size missing	-0.91 (0.48)	-0.96 (0.32)	-1.03 (0.26)	-0.69 (0.28)	-1.14 (0.32)	-0.73 (0.24)
Log R&D/emp.	0.41 (0.07)	-0.04 (0.04)	-0.12 (0.05)	0.22 (0.04)	0.11 (0.05)	0.09 (0.04)
R&D not reported	-0.33 (0.56)	-0.29 (0.18)	-0.80 (0.27)	-0.08 (0.12)	-0.27 (0.17)	-0.39 (0.15)
Log capital/emp.	-0.43 (0.09)	-0.02 (0.05)	-0.20 (0.09)	-0.28 (0.04)	-0.25 (0.06)	-0.20 (0.04)
Log employment	0.74 (0.04)	0.45 (0.02)	0.49 (0.07)	0.47 (0.02)	0.48 (0.02)	0.50 (0.02)
Newly public firm	-0.45 (0.23)	0.28 (0.13)	0.28 (0.14)	0.28 (0.15)	-0.01 (0.16)	0.27 (0.12)
No. Observations	5345	26684	43464	44458	40518	47404
Log likelihood	-1451	-4692	-2480	-7007	-3827	-5798
Alleged Infringers						
Log portfolio size	0.04 (0.06)	0.18 (0.02)	0.02 (0.05)	0.14 (0.02)	0.12 (0.03)	0.11 (0.02)
Portfolio=0 dummy	-0.43 (0.35)	-0.59 (0.13)	-0.56 (0.21)	-1.06 (0.11)	-0.96 (0.14)	-0.66 (0.11)
Portfolio size missing	-0.41 (0.46)	-1.32 (0.22)	-1.42 (0.20)	-1.08 (0.14)	-1.27 (0.19)	-1.16 (0.14)
Log R&D/emp.	0.36 (0.06)	0.20 (0.03)	0.20 (0.05)	0.31 (0.03)	0.27 (0.04)	0.28 (0.03)
R&D not reported	-1.68 (0.61)	0.04 (0.15)	-0.30 (0.26)	-0.07 (0.09)	-0.21 (0.14)	-0.17 (0.11)
Log capital/emp.	-0.25 (0.09)	0.07 (0.04)	-0.06 (0.06)	-0.15 (0.03)	-0.15 (0.04)	-0.10 (0.03)
Log employment	0.60 (0.03)	0.47 (0.02)	0.40 (0.06)	0.51 (0.02)	0.50 (0.02)	0.51 (0.01)
Newly public firm	0.02 (0.23)	0.03 (0.09)	0.31 (0.11)	0.10 (0.09)	0.16 (0.11)	0.14 (0.08)
No. Observations	5345	26684	43464	44458	40518	47404
Log likelihood	-1209	-4497	-2415	-7684	-3804	-6352

Note: Regressions are Poisson regressions with year dummies, industry dummies and independent variables lagged one year. Standard errors are heteroscedastic robust. R&D, cashflow and market value are deflated by the GDP deflator, capital is property, plant and equipment deflated by the NIPA capital goods deflator and employment is in thousands. The "new firm" dummy is equal to one for the first five years a firm appears in Compustat. Thicket industries are SIC 35, 36, 38 and 73.

Table 7. Annual Growth Rate of Residual for Sub-samples

	linear trend 1987-99			
	As patentee litigant		As alleged infringer	
Chemicals/pharmaceuticals	2.9%	(2.4)%	7.4%	(1.9)%
Machinery/computers	5.7%	(1.9)%	8.3%	(1.7)%
Electronics	6.6%	(2.3)%	2.9%	(1.8)%
Instruments	9.3%	(1.9)%	7.2%	(1.9)%
Other manufacturing	6.2%	(1.5)%	7.7%	(1.3)%
Business services/software	2.3%	(4.7)%	9.2%	(4.0)%
Retail/wholesale	8.1%	(6.3)%	4.3%	(2.7)%
Other non-manufacturing	-1.1%	(4.2)%	6.8%	(2.6)%
New firms	7.8%	(2.2)%	5.4%	(1.7)%
Incumbent firms	3.9%	(1.0)%	6.3%	(0.7)%
Small firms	5.1%	(1.8)%	5.7%	(1.7)%
Large firms	4.4%	(1.0)%	6.4%	(0.7)%
ALL	4.3%	(0.9)%	6.1%	(0.7)%

Note: Regressions are Poisson regressions with linear year trend from 1987–99. Independent variables are lagged one year. Standard errors, in parentheses, are heteroscedasticity robust. New firms (incumbent firms) have been listed in Compustat for five years or fewer (more). Small firms (large firms) have fewer than 500 employees (more).

Figure 1. Patent Lawsuits Filed Annually (Derwent data from USPTO)

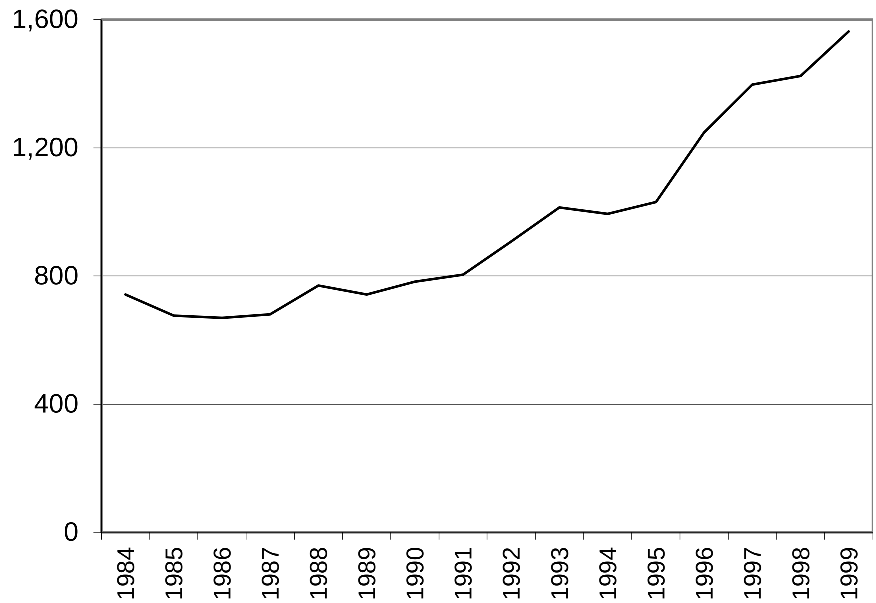

Figure 2. Residual Time Trends for Litigation Hazards from Table 5, Column 3.