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The Patent Litigation Explosion

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Abstract: This paper provides the first look at patent litigation hazards for public firms during the 80s and 90s. Public firms face dramatically increased hazards of litigation as plaintiffs and even more rapidly increasing hazards as defendants. The increase cannot be explained by patenting rates, R&D, firm value or industry composition, leaving legal changes as the most likely explanation. Firms that spend more on R&D are more likely to be sued and firms that acquire more patents are more likely to sue. The sharp increase in the probability of being sued per R&D dollar implies an increase in the "tax" that litigation imposes on innovation. Small firms face much higher marginal enforcement costs and marginal taxes on R&D.

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Introduction

The annual number of patent lawsuits filed in the U.S. doubled during the 1990s (see Figure 1).[1] Is this cause for concern?

Other research suggests that patent litigation can affect innovation incentives. Economic historian Zorina Khan (2004) argues that the introduction of the patent examination system during the 19th century reduced the relative number of patent lawsuits and that this substantially spurred inventive activity. Josh Lerner (1995) finds that the threat of litigation deters biotech firms from innovating in some technology fields. Lanjouw and Lerner (2001) find that the use of preliminary injunctions by large firms discourages R&D by small firms. Does the recent jump in patent litigation impose a "tax" on innovation that discourages innovation?

This paper provides the first comprehensive estimates of the incidence of patent litigation on public firms. We examine how firm and patent characteristics affect firm litigation hazards and how these hazards vary across different types of firms and industries. We also look at the extent to which observable characteristics can explain the increase in litigation rates.

In addition, we explore three arguments that might lead to a conclusion that the explosion in patent litigation is not a major problem:

1.) Patent grants have also doubled, so perhaps patent litigation rates rose simply because more inventions were patented. If this were so, then more frequent patent litigation might not represent a significantly increased burden on innovators.

2.) Perhaps the number of highly valuable patents has increased and these are the ones that tend to get litigated. If true, then perhaps the ratio of litigation cost to patent value has not increased, and the incentive to innovate has not been adversely affected.

3.) In some industries, firms build large portfolios of patents that they cross-license to each other. Perhaps this kind of patent "trading" promotes settlement and thus the recent surge in patenting may lead to lower future rates of litigation.

Our analysis differs from most previous research in that we use the firm as the unit of analysis. With the important exception of Rosemarie Ziedonis's study of semiconductor industry patent litigation (2003), most studies have either looked at the rate of litigation per patent (Lanjouw and Schankerman 2004, Allison et al. 2004) or have looked at aggregate litigation rates

[1] As discussed below, this figure represents case filings reported by the US 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.

(Landes and Posner 2003, Merz and Pace 1994). Aggregate litigation rates reveal little about the impact of litigation. Litigation rates per patent provide an incomplete picture at best because they do not address the costs that litigation imposes on defendants.

To analyze the effects of litigation on R&D, we begin by developing a model to explain why one firm files a patent lawsuit against another. From this we can then aggregate over all firms to analyze the total litigation hazards (as plaintiff and as defendant) that firms face. We show that these hazards determine the marginal costs of patenting and of R&D, affecting R&D incentives in two ways.

Much of the theoretical literature on litigation takes the existence of a dispute as given and then asks what factors determine whether the disputants will settle or proceed to trial , (see Hay and Spier (1998) for a recent survey, Meurer (1989) and Crampes and Laginier (2002)). Since we wish to explain the filing of lawsuits, not the occurrence of trials, our model needs to address those factors that affect firms' decisions to engage in patent disputes as well as those factors that may induce bargaining to break down prior to filing.

Our key assumption is that patent validity and infringement are uncertain. Firms A and B do not know with certainty *a priori* whether firm B infringes a valid patent held by firm A. They can only know a probability that firm A will be found to have a valid patent that firm B infringes if the matter were pursued through to trial.

Moreover, firms can take actions that influence their prospects for a successful outcome should a dispute be taken to trial. For example, a prospective plaintiff may build a larger patent portfolio in order have greater prospects of success at trial. Or a prospective defendant may build a larger "defensive" patent portfolio in order to have a credible threat of counter-suit. On the other hand, the more R&D a firm spends, the more it may increase its risk of infringement, given that the firm cannot feasibly determine all possible patents it may need to avoid.

We specify a model where factors such as these are included as right hand side arguments and we test this model using a sample of pairs of public firms whose primary businesses are in the same industry. We find that the plaintiff's portfolio size, the defendant's R&D spending and the firms' technological closeness all significantly increase the probability of suit. The defendant's portfolio size also tends to decrease the probability of suit, but this effect is weak and not always statistically significant.

We then build aggregate models for the number of suits a public firm can expect in a year as a plaintiff and as a defendant. Consistent with the analysis of matched pairs, we find that a firm's hazard of being a plaintiff increases with the size of the firm's patent portfolio and the firm's hazard of being a defendant increases with the size of its R&D expenditures.

Our model indicates that these two hazards affect R&D incentives directly and indirectly: the risk of being a defendant increases the effective marginal cost of performing R&D; the risk of having to enforce a patent through costly litigation increases the marginal cost of patenting, inducing firms to patent less, and, hence, earn smaller returns on R&D. Combining this analysis with our measured trends, we find that the marginal cost of enforcing patents has not risen much, but that the marginal litigation "tax" on R&D has risen sharply.

We also find that observable factors, including firm patent portfolio sizes, R&D, market value and other characteristics do not explain most of the increase in both litigation hazards.

Model and Specification

Litigation and R&D

How does patent litigation affect the incentives for firms to patent and to invest in R&D? Here is a simple model that generates useful insights. Let $\pi = \pi(P, R, P_{-1}, R_{-1})$ be the profits of the firm gross of patenting cost, R&D cost and the costs of litigation, letting *P* represent the firm's patent portfolio size, *R* represent the firm's R&D spending. This captures the idea that patents serve to increase the profits of the firm, either by excluding rivals from the market or by generating licensing revenues. Also, let P_{-1} and R_{-1} be the patent portfolios and R&D spending of other firms, respectively. These arguments capture the possible strategic effects other firms may have. We assume that π is increasing and concave in *P* and *R*.

Then the net profits of the firm are

(1) $$\pi(P, R, P_{-1}, R_{-1}) - cP - wR - h^p L^p - h^d L^d$$

where *c* is the cost of patenting, *w* is the cost of performing R&D, h^p and h^d are the expected number of suits (the hazards) the firms faces as a plaintiff (*p*) or as a defendant (*d*), and L^p and L^d are the respective litigation costs, including the opportunity costs of lost business, management distraction, etc.

The firm will then choose *P* and *R* according to these first order conditions:

(2) $$\frac{\partial \pi}{\partial P} = c + \frac{\partial h^p}{\partial P} L^p + \frac{\partial h^d}{\partial P} L^d, \qquad \frac{\partial \pi}{\partial R} = w + \frac{\partial h^p}{\partial R} L^p + \frac{\partial h^d}{\partial R} L^d.$$

Thus, generally, the marginal hazards of litigation with respect to *P* increase the marginal cost of patenting. Similarly, the marginal hazards of litigation with respect to *R* act as a "tax" on R&D, increasing the marginal cost. Note that this is not sufficient to determine the final effect on R&D: an increase in the marginal cost of performing R&D does not necessarily lead to less R&D in equilibrium, although one might expect it to under typical conditions. Nor is this a normative analysis. A decrease in R&D could increase social welfare if there is already too much R&D. Nevertheless, this partial analysis provides a straightforward way of interpreting the effect of the marginal litigation hazards: they simply act to increase the marginal costs of patenting and performing R&D.

Specification

Our strategy is to specify general functional forms for h^p and h^d, and then to estimate these equations. The estimates provide a basis to understand what has been driving the changes in litigation hazards and whether these changes are likely to affect the marginal costs of patenting and performing R&D.

It is helpful to first specify the probability that one firm sues another, given the characteristics of the two firms. We do this because some models of litigation emphasize the interaction between firms (e.g., defensive patenting) and these can be directly explored at this micro-level. We define a general logit regression equation:

(3)
$$y_{ABt} \equiv P[\text{firm A sues firm B in year t}] = \frac{e^{z+\delta_t}}{1+e^{z+\delta_t}}$$
$$z \equiv \alpha X_{At} + \beta X_{Bt} + \gamma X'_{At} X_{Bt} + \varepsilon$$

where X_{it} is a vector of firm characteristics for firm *i* at time *t* and δ_t is a time dummy. In general, characteristics that affect the outcome of a suit, should it be pursued all the way through trial, are also likely to affect the probability of filing a suit, all else equal. Such characteristics might include:

- Firm A's patent portfolio size; the more patents A has, the more likely it is to win a suit against firm B, so it may also be more likely to file suit against B.
- Firm B's R&D spending; the more R&D that B performs, the greater the risk that B uses a technology that firm A can successfully sue on.
- Technological closeness; if firms A and B use similar technologies, they are more likely to sue one another.

- If defensive patenting matters, then firm B's patent portfolio should affect the likelihood of filing a suit. With the threat of a retaliatory counter-suit, firm B may encourage settlement. Also, firm A's capital and R&D investments may make firm A more likely to settle in this case.

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 probabilities:

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

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

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

$$\ln h^p_{At} \approx \phi X_{At} + \mu_t + \varepsilon$$

(4) $$\phi = \alpha + \gamma \overline{X}$$

$$\mu_t = \delta_t + \ln(N-1) + \beta \overline{X}_t + \gamma(\overline{X}_t - \overline{X})$$

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,

(5) $$\ln h^d_{Bt} \approx \psi X_{Bt} + \eta_t + \varepsilon .$$

Finally, note that if there are no interaction terms in (3), that is, if $\gamma = 0$, then $\phi = \alpha$ and $\psi = \beta$. In words, the coefficients of the Poisson regressions, (4) and (5), should match those of the corresponding variables in the logit pairs regression, (3).

With estimates of (4) and (5) in hand, we will compute the marginal hazard rates in (2).

Data Description

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 USPTO made available by the 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 (AIPLA, 2003) and opportunity costs experienced by the firm (e.g., postponed business) may also be quite large. Talks with patent lawyers suggest that perhaps half of all patent disputes are resolved prior to filing a lawsuit. 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 (Lanjouw and Schankerman, 2004, Ziedonis, 2003). Federal courts are required to report all lawsuits filed that involve patents to the U.S. Patent and Trademark Office (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 90 days of a given suit that involved the same parties. Finally, we removed filings where the current PTO 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.[2]

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 they consistently report a larger number of filings. Two potential problems arise from under-reporting: a possible change in the reporting ratio over time, leading to spurious trends in the Derwent data, and possible selection bias. After de-duplicating Federal Judicial Center 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

[2] In a small percentage of cases Derwent did not report a patent or listed a design patent. We included these because Derwent's patent information appeared to be unreliable (see Moore ??).

64.1% from 1991-99. There thus appears to be no significant trend in this reporting ratio.[3] Also, using an extensive match between the two files, Lanjouw and Schankerman (2004) find no difference between reported and unreported cases over a range of variables, providing no suggestion of selection bias. 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 US 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).[4]

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 (2004).[5] At least one party was identified as a publicly traded US 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).

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[3] Lanjouw and Schankerman (2004) report that their comparable ratio was stable during the 90s. 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.

[4] 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.

[5] 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.

To obtain information about each firm's non-litigated patents, we also matched Compustat firms to the NBER patent database (Hall et al., 2001). To match the USPTO assignee name to the Compustat firm name, we began with the match file provided by the NBER. To this we added matches on subsidiaries developed by Bessen and Hunt (2004), we manually matched names for large patenters and R&D-performers, and we matched a large number of additional firms using a name-matching program.[6] In addition, using data on mergers and acquisitions from SDC, 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.[7] This matched group of firms includes 10,736 patent assignees matched to one of 8,444 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 US 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.[8]

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 does 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

[6] 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.

[7] 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.

suit, 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.[9] 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.[10] This classification then allowed us to create two new variables, 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 the number of suits per year for which the firm was an "alleged infringer" (the reverse).[11] Below when we speak of one firm "suing" another, we mean that firm is a patentee litigant and the other firm 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.

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 which have recently gone public, and these are largely young firms.

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),

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

[9] These numbers are quite similar to findings by Moore (2002) and Lanjouw and Schankerman (2004).

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

[11] 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.

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 (1986). 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).

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 4-digit SIC level) are included twice (A sues B and B sues A), 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 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.[12] 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, many defendants are retailers). 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 prosecution (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. That is, all the patents owned by firms that sue are cited more often and not just their litigated patents, 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 (Lanjouw and Schankerman 1999, Allison et al. 2004) may involve causality that runs in both directions.

[12] 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.

Empirical Results

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 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.[13] In contrast to previous research, however, this estimate reflects the effective patent term.[14] We estimate a hazard of 1.18% of lawsuits per patent. By comparison, Lanjouw and Schankerman (2004) report a rate of 1.04% lawsuits per patent for a sample of public firms. 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 patent did not change much during the 90s. 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.[15] In general,

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[13] 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.

[14] The effective patent term may be shorter than the statutory term of 20 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.

[15] If the rate of litigation per $billion 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).

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. Note that this increase cannot yet be interpreted as an increased tax on R&D; the taxing effect depends on the marginal risk of litigation per R&D dollar, not the average risk. Below, we show that an increase in the average hazard per R&D dollar corresponds to an increase in the marginal effect.

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, 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 similarly 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 business services have low litigation rates by both measures. Chemicals including pharmaceuticals has 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 rate per R&D dollar (see similar numbers from Ziedonis, 2003 for semiconductors).

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" (ALMT 2004). But this explanation by itself seems unable to account for the above average rate of litigation relative to R&D spending in semiconductors.

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.

Fully 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.[16]

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 are not direct market competitors but have a closeness of 0.53. The first row 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 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 occurs 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.

[16] 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.

Regression analysis of pairs

To analyze the trends in litigation hazards, 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. All continuous variables are scaled by firm employment. Firm employment size is clearly significant for both parties with a coefficient of .53 for the patentee litigant and .39 for the alleged infringer. Although both coefficients are significantly greater than zero, both are also significantly less than one. Moreover, this finding that the coefficients on scale variables are less than one seems robust across various specifications and, as we shall see below, this turns out to have important consequences.

One might suppose that these coefficients should be about one, meaning, say, that the likelihood of a suit should increase proportionally with firm size. But, in fact, there is good reason to expect the probability of suit to scale less than proportionally. The probability of filing a suit might well be proportional to the patentee litigant's probability of winning a suit, all else equal. This will increase with the number of patents owned by the plaintiff because more patents increase the probability that the defendant will be found to have infringed. But this increase faces diminishing returns (see Bessen 2004 and Wagner and Parchomovsky 2004). This is because only one successful patent claim is sufficient to enjoin the defendant from the market and to justify damages based on lost profits. Additional successful claims for a given product do nothing to further benefit the plaintiff. So the probability of suit will scale less than proportionally to firm portfolio size.[17] Similarly, greater R&D or production use of technologies by the defendant also has a diminishing effect on the defendant's exposure to successful patent claims.

The coefficients on the patentee litigant's log portfolio size per employee and the alleged infringer's log deflated R&D per employee are both positive and significant. This consistent with the interpretation that the plaintiff's portfolio size increases its prospects for winning a trial

[17] Moreover, portfolio size is the main factor responsible for the effect of employment size—the coefficient on log patents/employee is about three quarters of the coefficient on log employment. So diminishing returns in portfolio size will translate to diminishing returns in employment.

and/or increases the potential targets it can sue and that the defendant's R&D increases its exposure to successful legal action.

The evidence that defensive patenting avoids litigation is, at best, weak. The coefficient on the alleged infringer's patent portfolio per employee is negative, consistent with a defensive patenting explanation, but it is small and not significantly different from zero.

Column two explores this further. The patentee litigant's log deflated R&D per employee and log capital per employee both have negative coefficients, but these, too, are not significantly different from zero. Both of these might be indicators of the patentee litigant's exposure to a counter-suit, so the negative signs are indicative of possible strategic patenting effects. Similarly the alleged infringer's capital per employee has a weak negative coefficient, suggesting that greater capital intensity increases the firm's risk of holdup from litigation. This column also includes measures of firm market value per employee. This captures, among other things, the value of the plaintiff's technology (hence the value of exclusion) and the value of the defendant's technology (the realized value of the R&D).

The third 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 fourth column includes terms for log deflated market value per employee and also the closeness of the two firms. The latter has a large and highly significant coefficient—even in a sample of firms within the same industry, technological closeness makes a big difference. Note that the coefficient on the alleged infringer's portfolio size is more negative in this regression and is, in fact, statistically significant at the 5% level. Portfolio size is correlated with technological closeness. Firms that are close may acquire larger, "defensive" patent portfolios. This may help explain why the effect of defensive patenting seems weak—firms may jointly decide which technologies to pursue and how heavily to patent them. Firms may choose to invest in technologies that expose them to a greater risk of infringement suits (e.g., technologies close to those of another firm), but they may also attempt to inoculate against this risk by acquiring more patents. These two choices may counteract each other, so that in equilibrium, prospective defendants with larger portfolios might not have lower probabilities of being sued even though their portfolio may encourage settlement.

To pursue this idea, column 5 repeats the regression, but interacts the coefficients of both parties' portfolio sizes with dummy variables, one for closeness less than 0.5, one for closeness greater than or equal to 0.5. The magnitudes of the coefficients on the close coefficients are both larger, providing some support for this interpretation.

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 .53 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 suggested 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 greater defensive patenting among firms that are 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. 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 coefficient on the patentee litigant's R&D and the coefficients on capital intensity may reflect evidence of strategic patenting. In column 3, where firm market value is included, the coefficients on all three are negative and those for capital intensity are significant, suggesting that firms sue less when they are at greater risk of retaliation. Also, capital intensive firms may settle more readily when sued because they are subject to possible holdup. The distance weighted measures do not appear to have significant effects, perhaps because other variables already capture the effect of close competitors.

Table 5 also shows the coefficients on industry dummies ("Other non-manufacturing" is the excluded category).[18] 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. 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 capture changes in technological density.

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

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.[19] 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. Firms that anticipate that they will become involved in litigation may prosecute their patents more intensively by making more citations. And patents that are litigated may receive more subsequent citations *because* they are identified as being particularly dangerous prior art. As discussed above, Table 1 provides some limited evidence for these conjectures.

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 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 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 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

[19] 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.

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 for in the residual hazard for instrument firms as patentee litigants.

Interpretation

The effect of litigation on R&D

Summarizing the coefficient estimates from Tables 5 and 6, the more patents a firm holds, the more likely it is to sue. Also, the more R&D a firm performs, the more likely it is to be sued. The coefficient of the plaintiff's R&D and the coefficient on the defendant's patent portfolio are either positive or not significantly different from zero. For simplicity of exposition, consider these latter two coefficients equal to zero (making them positive does not alter the conclusions significantly). Then, taking the relevant estimates from the tables, (4) and (5) can be substituted into (2) to yield

(6) $$\frac{\partial \pi}{\partial P} = c + \alpha \frac{h^p}{P} L^p \ , \quad \frac{\partial \pi}{\partial R} = w + \beta \frac{h^d}{R} L^d \ .$$

In words, the marginal cost of enforcement of patents is proportional to the rate of litigation as patentee litigant per patent. Likewise, the marginal tax on R&D is proportional to the rate of litigation as alleged infringer per R&D dollar.

As shown in Table 2, the first ratio did not change much over the 90s because the greater rate of litigation as patentee litigant was largely offset by a higher rate of patenting. This implies that the marginal enforcement cost of litigation did not increase much. However, the rate of litigation per R&D dollar grew rapidly—although R&D spending increased, it did not increase nearly as fast as the hazard of being sued. This means that the marginal tax imposed by litigation on R&D also grew rapidly over the 90s.

The effect of firm size

The data in Table 2 also imply that litigation imposes much larger marginal enforcement costs and marginal R&D taxes on small firms.

Lanjouw and Schankerman (2004) found evidence of large differences in litigation rates per patent. 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: patent trading where firms with large patent portfolios more easily cross-license and settle rather than litigate, and repeated interaction between large firms, also inducing more frequent settlement. 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 circumstantial evidence of such interaction between firms: a firm with greater R&D or capital 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, the net effect of firm interactions seems to work against this kind of explanation. A firm with more patents is *more* likely to be sued overall. The exception appears to be that such a firm may be slightly less likely to be sued by other firms in the same industry that are technologically close.

In any case, the dominant size effect appears to be driven by the individual size characteristics of the parties, not by their interaction. For example, a firm with more patents is more likely to sue, independently of characteristics of the prospective alleged infringer, but the effect of the plaintiff's patent portfolio size on the probability of suit faces diminishing returns (elasticity less than one). We argue that this result follows naturally because a plaintiff's probability of winning an injunction and damages against any particular opponent also faces diminishing returns, in line with theoretical models of patent portfolios (Bessen 2004; Wagner and Parchomovsky 2004). Moreover, our results show that the diminishing returns measured between individual pairs of firms in Table 4 correspond almost exactly to the diminishing returns observed in aggregate in Table 5. This means that the portfolio size effect appears to be driven by the concavity of the individual probability of litigation relative to portfolio size. A similar argument holds for the diminishing effect of an alleged infringer's R&D.

This interpretation has important implications. Researchers commonly assume that the value of individual patents is independent of the other patents owned by the firm and that patent propensity (the ratio of patents to R&D) is independent of firm size. This result raises questions about these assumptions.

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 patenting, either because of "innovative fertility" or because of greater patent propensity, the growth in R&D spending, the value of firm technology or growth in technological crowdedness.

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 sale 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 90s.

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 they 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 in other industries as 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 (2004), 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 (2003, Chapter 12) 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.

Our results are consistent with this view, especially greater "noise" regarding the interpretation of standards of patentability.

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 (2004) 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 (see also Henry and Turner, 2005).

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 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 90s cannot be explained by firm patenting rates, R&D spending, firm value or industry composition. Looking at a variety of explanations, we suggest that legal changes may be the dominant factor driving this increase.

Moreover, we argue that this increase in litigation hazards affects R&D. We find that the more R&D a firm performs, the more likely it is to be sued. This means that although the marginal enforcement cost of patents has not increased much, the marginal "tax" that litigation imposes on R&D has gone up sharply. For our sample of public firms, the marginal tax on R&D increased 70% from 1987 to 1999.

Also, as Lanjouw and Schankerman (2004) found, the risk of litigation falls disproportionately on small firms. We find that the marginal cost of enforcement and the marginal tax on R&D are four and six times larger, respectively, for small firms (under 500 employees) than for large firms.

Finally, we find that any optimism regarding the ability of "defensive" patenting to ameliorate these hazards is misplaced. Although we find circumstantial evidence that patent trading may be used to avoid litigation, this is apparently offset by a greater willingness of firms with large portfolios to risk infringement suits. Firms with larger patent portfolios are more likely to be sued in the end.

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 defendants falls by 2-3% on the filing of a patent lawsuit (Bhagat et al. 1994, Lerner 1995), suggesting that the economic burden on litigants may be substantial. So the recent doubling of litigation hazards may well impose substantial costs.

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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
Newfirm	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 4-digit SIC industry. “Weakly overlapping industries” means the parties had a business segment in the same 3-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	0.39	(0.06)	0.41	(0.07)	0.45	(0.09)	0.29	(0.07)		
Ln patent/emp * distant									0.27	(0.08)
Ln patent/emp * close									0.32	(0.08)
Zero patents dummy	-1.59	(0.62)	-1.92	(0.75)	-1.57	(0.62)	-1.67	(0.75)	-1.67	(0.75)
Log employment	0.53	(0.03)	0.56	(0.04)	0.53	(0.03)	0.46	(0.04)	0.46	(0.04)
Log R&D/employee			-0.12	(0.09)						
Log Mkt. Value/employee			0.26	(0.09)			0.11	(0.08)	0.11	(0.08)
Log capital/employee			-0.23	(0.13)						
Alleged Infringer										
Log patents/employee	-0.08	(0.06)	-0.04	(0.06)	0.00	(0.11)	-0.14	(0.06)		
Ln patent/emp * distant									-0.09	(0.08)
Ln patent/emp * close									-0.19	(0.07)
Zero patents dummy	-0.92	(0.29)	-1.07	(0.33)	-0.93	(0.29)	-0.86	(0.34)	-0.82	(0.34)
Log R&D/employee	0.25	(0.08)	0.13	(0.10)	0.25	(0.08)	0.01	(0.09)	0.01	(0.09)
No R&D dummy	0.14	(0.38)	0.32	(0.39)	0.17	(0.38)	0.25	(0.40)	0.27	(0.40)
Log employment	0.39	(0.04)	0.13	(0.09)	0.39	(0.04)	0.04	(0.10)	0.04	(0.10)
Log Mkt. Value/employee			0.30	(0.09)			0.25	(0.09)	0.24	(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							2.40	(0.25)	2.48	(0.40)
Number of obs	1,240,580		994,148		1,240,580		1,020,196		1,020,196	
Log likelihood =	-1569.1		-1400.4		-1568.6		-1363.1		-1362.5	

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 8 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 expected number of suits per year

	1		2		3		4	
Expected 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	
Expected 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 & pharmaceuticals	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)

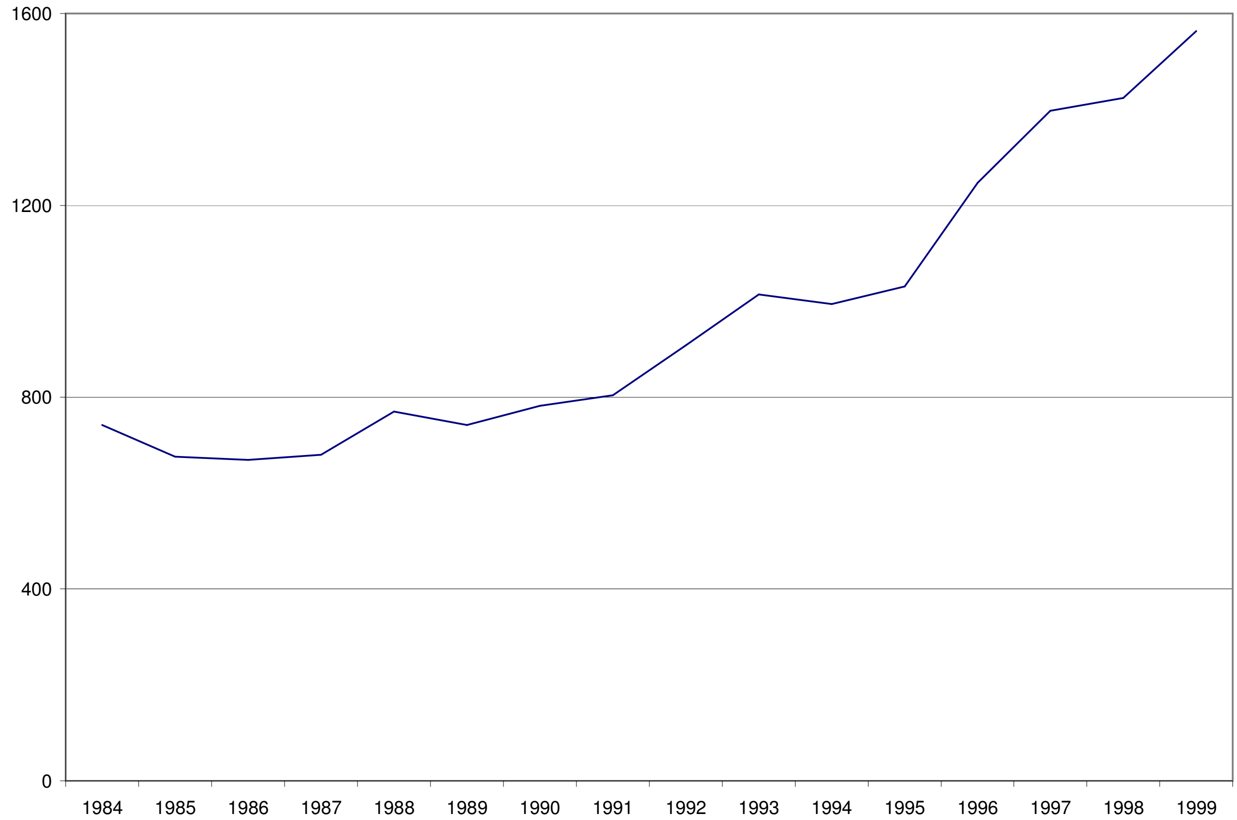

Figure 2. Residual Time Trends for Litigation Hazards from Table 5, Column 3.