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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. Consistent with our model, litigation is more likely when prospective defendants spend more on R&D, when prospective plaintiffs acquire more patents and when firms are larger and technologically close. 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 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 reduce the incentives firms have to innovate?

We attempt to answer this question with a model of firm patent disputes that may help us understand what is driving the increase in litigation and what effect this has on firm incentives. At root, most patent disputes arise because patent validity and infringement are uncertain. Although patents are often called "intellectual property," they differ in this respect 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 (Moore 2005).

If patents worked like real property rights, they would be largely self-policing and there would be few disputes and little litigation. That is, firms would avoid investing in any technology covered by patent claims (or they would obtain an *ex ante* license from the patent holder) and no patent holder would attempt to assert a patent against any firm whose technology fell outside the scope of the patent. But when patents have uncertain validity and their boundaries are poorly defined, then disputes arise that affect firm R&D incentives. Some firms "stumble" and make unauthorized use of patented technology. This might occur because of inadequate investigation of issued patents, but also because the relevant patent had not yet issued, or the scope of the patent rights was unclear, or because the details of the technology were not fully known when funds were committed to development. Furthermore, some patent holders overreach, asserting patent claims against non-infringing firms. The disputes that arise in these cases yield litigation or licensing under the threat of litigation, and sap rents from innovative firms. The reduction in rents

[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.

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.

All else equal, the annual expected cost of patent disputes to a firm varies proportionally with the firm's hazard rate of entering disputes. Although we observe only those disputes where a lawsuit is filed, under reasonable conditions, trends in the hazard of filing should reflect trends in the total hazard of disputes. Thus firm litigation hazards provide a baseline indicator of the changing effect of litigation on innovation.

Of course, a rising cost of disputes may be accompanied by offsetting benefits. For example, firm dispute hazards might be driven by the number of inventions that a firm has. Then more inventions might lead to more patents and more disputes, but the greater cost of disputes may be offset by greater returns from the larger pool of inventions. To evaluate the possibility of such offsetting benefits, we want a comprehensive understanding of the factors driving the changes in litigation hazards, including, among other things, the number of patents a firm has and, perhaps, measures that capture the value of its inventions.

What drives changes in firm litigation rates? We conduct an empirical analysis at two levels to explore this question. 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. These include the possibility that firm behavior affects litigation risk—for example, acquisition of "defensive" patent portfolios or even the conduct of R&D itself may affect a firm's exposure to litigation risk.

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 paper differs from previous research in two principal ways, one theoretical, the other empirical. First, our model of litigation addresses the origin of patent disputes, not just dispute settlement. Most 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.[2] But the rate of lawsuit filing depends as much on the frequency of disputes as the frequency of

[2] See Hay and Spier (1998) and Lanjouw and Lerner (1998) for recent surveys. Models of patent settlement used in empirical research are found in Harhoff and Reitzig (2004) and Somaya (2003).

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 (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 (Landes and Posner 2003, Merz and Pace 1994). 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 next section describes our model of patent disputes, some hypotheses from this model, and the specification of equations we estimate. The second section describes our data and the third reports our empirical results. The fourth section discusses the interpretation of these results and the fifth section concludes.

Model and Specification

Dispute, Filing and Settlement

We model how a dispute might arise between a patent owner and a potential defendant, and whether the parties will resolve the dispute before filing a lawsuit. Our model contains features of Meurer (1989) and is similar in spirit to Crampes and Langinier (2002). The latter model shows how disputes might arise because of costly monitoring for infringement. In equilibrium, Crampes and Langinier show that firms will sometimes gamble and adopt an infringing technology on the hope that they will not be detected. Our model accommodates costly monitoring, but we also show how disputes might arise because the scope and validity of patents is uncertain. The details of the model can be found in our companion paper, (Bessen and Meurer 2005); here we provide a brief overview and summary of relevant results.

Our model has three stages and two players, firm 1, who owns patents and is a potential plaintiff, and firm 2, who invests in technologies that might possibly infringe and who is, therefore, a potential defendant. The game has symmetric information and we characterize the unique subgame perfect Nash equilibrium. In the model there is one set of related inventions and each firm has only one product (the "product" might be a patent license); we relax these assumptions in the empirical specification. In stage one, firm 1 chooses an investment, P_1, in patent "refinement." We assume firm 1 has exogenously given inventions, and chooses a level of patent protection that determines the probability (actually a distribution of probabilities) of successfully suing firm 2 for patent infringement. Firm 1 can improve its probability distribution by obtaining multiple patents, delaying the issuance of some of its patents through continuation practice, crafting multiple claims, investing in high quality claims and disclosures, conducting a careful prior art search, and so on. We call these activities "refinement" and assume a constant marginal and average cost of refinement, ρ. In stage two, firms 1 and 2 simultaneously choose development investments, x_1 and x_2.[3] We assume a constant marginal and average cost of development, δ. In stage three, the firms decide whether to dispute infringement and if so, they then decide whether to enter a license agreement or file a lawsuit.

Between stages two and three, the firms observe the probability α that firm 1 could win an infringement suit against firm 2. At the earlier stages the firms know that α is distributed over [0, 1] according to the distribution function $G(\alpha; P_1, x_2, n)$, where n is the "nearness" between the two firms in product or technology space.[4] For convenience we assume n, P_1, and x_2 induce shifts of G that satisfy first order stochastic dominance. It is natural to assume that P_1 and x_2 influence the distribution α. A patent dispute only arises when firm 2 adopts a technology that arguably falls within the scope of at least one of firm 1's patents. Firm 1 can improve its prospect at trial by investing more in patent refinement which shifts the distribution to the right, and firm 2 can affect its prospect at trial through its development investment. Possibly, firm 2 increases its exposure to a lawsuit by increasing it development investment; alternatively, firm 2 might reduce the probability of a successful suit by designing a technology that a court is likely to find outside the scope of firm 1's patents ("inventing around"). For now, we leave open the possibility that x_2 shifts the distribution either right or left. Finally, we assume that as the two firms move nearer to each other, so that n grows, the distribution shifts to the right.

The third stage of the model is a hybrid of strategic and cooperative bargaining. Initially, firm 2 can choose whether to abandon its newly adopted technology or not. If firm 2 abandons its

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[3] Patent law allows firms to get patents long before development is completed and without evidence of commercial value. We therefore assume that the majority of R&D spending, what we call development investment, occurs after some patents are filed for.

[4] We assume that n is exogenous perhaps determined by each firm's expertise or competency. Later, some research projects will be endogenously abandoned because of potential infringement.

development project, it simply does not produce the product ("deterrence").[5] If it does not abandon, then firm 1 first chooses whether to assert its patents or not. If it does assert them, it can choose to negotiate a license with firm 2 or to file suit against firm 2. We assume the firms equally split the surplus achieved from the license. Filing may create greater joint profit than licensing, and when it does, the parties choose filing over licensing. We show that there are four possible solution regions depending on critical values of α:

For the smallest values of α, $\alpha \in [0, \alpha_A)$, firm 1 lacks a credible threat of suit—its expected profits from filing a lawsuit are less than the profits from no suit. In this case, firm 1 "acquiesces" and allows firm 2 to enter the market without restriction.[6]

For $\alpha \in [\alpha_A, \alpha_F]$, both parties have a credible threat of suit, and their joint profits are greatest under a settlement license.

For $\alpha \in (\alpha_F, \alpha_D]$, both parties have a credible threat of suit, and their joint profits are greatest when firm 1 files a lawsuit.

For $\alpha \in (\alpha_D, 1]$, the alleged infringer lacks a credible threat of suit and drops out ("deterrence"). Although firm 2 has sunk development investments, it does not bring the product to market.

Figure 2 shows the equilibrium outcomes for different values of α. We will say there is a patent dispute when both firms have a credible threat of litigation. This occurs when $\alpha_A \leq \alpha \leq \alpha_D$. Filing occurs in a subset of these cases when $\alpha_F \leq \alpha \leq \alpha_D$. *Ex ante*, the probability of filing which we denote y equals $G(\alpha_D) - G(\alpha_F)$.

Figure 2 also shows profit for firms 1 and 2 as a function of α. Naturally, firm 1's profit increases in α and firm 2's profit decreases. Outside the dispute region, the firms' profits are invariant to α because the threat of filing is not credible. Within the settlement region, the firms do not file, but the expected profits from filing determine the threat points of the bargaining problem. A higher probability of success for firm 1 from filing translates into higher expected profit from filing, and a stronger bargaining position given settlement.

Figure 2 helps us think about the origins of patent disputes and possible explanations for an increase in the filing of lawsuits. The set of disputes depends on whether the parties have

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[5] Equivalently, firm 2 could obtain an *ex post* license that cedes its profits to firm 1, our analysis would not change. In a variant of the model, firm 2 negotiates an *ex ante* license when the distribution of α puts a lot of mass toward the right side of the [0, 1] interval. Allowing *ex ante* licensing in the model reinforces the results we discuss below.

[6] We assume that antitrust considerations and transaction costs prevent the firms from collusive licensing in this case.

credible threats to sue. Factors that shift α_A to the left and α_D to the right increase the set of disputes. For example, higher stakes and lower litigation costs make it easier for both parties to satisfy the credibility constraint. In addition, a larger patent premium makes it easier for firm 1 to satisfy its credibility constraint. The boundary between settlement and filing depends on the joint profit from those two choices. Relaxed antitrust rules and other changes that reduce settlement cost increase the attractiveness of settlement, while reduced litigation cost and a larger patent premium increase the attractiveness of filing. Besides factors that shift these boundaries we also need to think about the distribution of α.

In an ideal (though not necessarily optimal) patent system in which validity and scope are clear, potential patent lawsuits would result in either a certain win or a certain loss for the patent owner, i.e., the distribution *G* would concentrate all mass at $\alpha = 0$, or $\alpha = 1$. Then there would not be any patent disputes or filing. Introducing a small chance of error in court could, for example, spread the mass of the distribution a little to the right of $\alpha = 0$ and a little to the left of $\alpha = 1$. There would still not be any patent disputes, and profits and investment incentives would not be affected.[7] As uncertainty about trial outcome grows and *G* gives a positive probability to values of $\alpha \in [\alpha_A, \alpha_D]$, then disputes and lawsuits arise, and profits and investment incentives are affected. Note that in the dispute region firm 1 earns less profit than in the deter region. Similarly, firm 2 earns less in the dispute region than in the acquiesce region. These differences reflect the relative cost of patent disputes.

The distribution of trial outcome probabilities is affected by the endogenous patenting and development choices of the firms, and also by a variety of exogenous factors of interest to us. For example, patent refinement investment shifts the distribution of α to the right as the patentee takes care to strengthen its case for validity and the scope of its patent rights. Similarly, legal changes that expand the scope of patent rights or reduce the stringency of patent standards would shift the distribution to the right. Whether the probability of disputes (filing) increases, of course, depends on whether the change shifts more of the mass of the distribution into the dispute (filing) interval.

Hypotheses

The stage 3 profits of each firm depend on the size of the market opportunity, the market structure, including monopoly profits, duopoly profits, etc., and the nature of the dispute

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[7] This account assumes no monitoring costs. If infringement monitoring were costly, then some firms might infringe, some of these might get caught, and some of these might fall in the dispute range. Interpreting *G* as the probability that firm 1 *detects* infringement *and* wins at trial incorporates these considerations into the model.

resolution, which is a function of α, e.g., expected profits from litigation in the filing zone. Let $\pi_i(\alpha)$ denote the profit to firm *i* at stage 3 (shown in Figure 2). Then the profits for firms 1 and 2 at stages one and two are:

(3)
$$W_1(x_1, x_2, P_1; S, n) = \int_0^1 \pi_1(\alpha; x_1, x_2, S) dG(\alpha; x_2, P_1, n) - \delta_1 x_1 - \rho P_1$$
$$W_2(x_1, x_2, P_1; S, n) = \int_0^1 \pi_2(\alpha; x_1, x_2, S) dG(\alpha; x_2, P_1, n) - \delta_2 x_2$$

where *S* represents the exogenous scale of the profits at stake. At stage two the firms simultaneously choose (x_1, x_2) given P_1 and at stage one, firm 1 chooses P_1 looking ahead to the subgames at stages two and three. We impose plausible conditions and show there is a unique Nash equilibrium and derive comparative static results (see Bessen & Meurer 2005).

Our theoretical model concerns firms developing individual products, and is best interpreted as a model of business units. However, our data are at the firm level. We assume that firm variables are correlated with business unit variables, e.g., larger firms have larger product markets. We also assume that in cross-section, the (*ex post*) distribution of α's is heavily weighted toward 0 and the probability density decreases monotonically with α. In other words, most randomly selected pairs of firms do not have active disputes. Given these assumptions, we are able to frame the following hypotheses:

H1: 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: The probability of litigation between two firms increases with the size of the stakes, all else equal.

Research finds that patents that receive more citations are more likely to be litigated (Lanjouw and Schankerman (2004) and Allison et al. (2004)). Our model predicts this relationship if we assume that highly cited patents are associated with more valuable innovations which increase the stakes for both firms from litigation. Greater stakes relaxes the credibility constraints, and makes filing more attractive relative to settlement. Thus, the size of the filing region grows. We investigate whether other measures of the private value of the innovation are also correlated with filing.

In addition, we investigate factors that are likely to affect the size of the stakes for one firm but not the other. For example, the size of firm *i* is likely to affect the stakes for firm *i* but perhaps not firm *j*. The model does not generate a clean prediction about the effect of firm-specific changes in the size of the stakes. The values of α_A and α_D change in a predictable fashion, with α_A moving to the left and α_D moving to the right, but the change in α_F is ambiguous. We will explain below that we do find evidence of firm-specific stake effects, and these effects have interesting implications for interpreting some of our other findings.

> *H3a. The probability that firm 1 sues firm 2 increases with the patent portfolio size of firm 1, all else equal.*

This captures the notion that greater effort at patent refinement in the form of a higher patent propensity (after controlling for scale and R&D) increases expected α, corresponding to a greater likelihood of falling in the litigation region. 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. A larger portfolio size implies a larger probability that firm 1 will win a suit against firm 2, α, and this increases the likelihood of litigation. But α may exhibit diminishing returns with portfolio size, e.g., if each patent has an independent probability of being found infringed.

> *H3b. 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 reduce the probability of filing and increase the probability of settlement.

The next hypotheses concern the relationship between development investment and the probability of filing. The nature of the relationship depends on the sensitivity of the stakes in patent litigation to the development investments of the two firms. It also depends on how development investment by firm 2 influences the distribution of α.

> *H4a. If development investment by firm 1 has a stronger positive effect on firm 1's filing payoff than on the joint settlement payoff, then the probability of litigation should increase with firm 1's development investment, all else equal.*

Referring to Figure 2, the critical question is whether an increase of x_1 causes α_F to move to the left. Such an effect is most likely to appear in the pharmaceutical and similar industries, where the share of innovation rents attributable to patents is large, output share of R&D is high, technologies are discrete, and products are few. On the other hand, in the electronics or computer industries, where different conditions apply, development investment by firm 1 might have little effect on the litigation stakes or the value of α_F.

H4b. If the development investment by firm 2 has a weak effect on the stakes in patent litigation and firm 2 uses development investment mainly 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 in inventing around will be less likely to be found to infringe firm 1's patents. Those firms that simply imitate without expending resources to invent around will be more likely to be sued. In terms of Figure 2, the assumption that the stakes are not very sensitive to x_2 means that α_F and α_D do not move very much. The assumption that inventing around is important means that an increase in x_2 shifts the distribution of α to the left.[8]

H4c. If development investment by firm 2 has a stronger positive effect on firm 2's filing payoff than on the joint settlement payoff and if development investment by firm 2 has little effect on the distribution of α, then the probability of litigation should increase with firm 2's development investment, all else equal.

If development investment by firm 2 has little effect on the distribution of α, then any change in the probability of filing is driven by changes in the filing interval [α_F , α_D.]. An investment that significantly increases firm 2's stake in litigation makes settlement less appealing and makes it easier for firm 2 to satisfy the credibility constraint, thus the probability of filing increases.

H4d. If development investment by firm 2 has a weak effect on the stakes in patent litigation and if development investment by firm 2 shifts the distribution of α to the right,, then the probability of litigation should increase with firm 2's development investment, all else equal.

This 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. Uncertain detection and trial outcome also contribute to the positive relationship between development investment and infringement exposure.

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.

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[8] Recall we also assume that g(α) is decreasing in α so that the loss in probability density at the α_F boundary is greater than the gain in density at the α_D boundary.

Specification

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

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

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), and 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 probabilities:

$$
\begin{aligned}
& h^p_{At} \equiv E[\text{number of suits filed by A in year t}] = \sum_{j \neq A} y_{Ajt} \\
& h^d_{Bt} \equiv E[\text{number of suits filed against B in year t}] = \sum_{j \neq B} y_{jBt}
\end{aligned}
$$

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

$$
\begin{aligned}
& \ln h^p_{At} \approx \phi X_{At} + \mu_t + \varepsilon \\
(5)\qquad & \phi = \alpha + \gamma \overline{X} \\
& \mu_t = \delta_t + \ln(N-1) + \beta \overline{X}_t + \gamma(\overline{X}_t - \overline{X})
\end{aligned}
$$

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,

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

Finally, note that if there are no interaction terms in (4), that is, if $\gamma = 0$, then $\phi = \alpha$ and $\psi = \beta$. In words, the coefficients of the Poisson regressions, (5) and (6), should match those of the corresponding variables in the logit pairs regression, (4).

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.[9]

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

[9] In a small percentage of cases Derwent did not report a patent or listed a design patent.

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 64.1% from 1991-99. There thus appears to be no significant trend in this reporting ratio.[10] 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).[11]

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).[12] 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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[10] 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.

[11] 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.

[12] 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.[13] 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.[14] 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.[15]

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

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[13] 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.

[14] 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.

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

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.[16] 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.[17] 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).[18] 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. 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 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), 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.

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

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

[18] 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.

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.[19] 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 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 (they will draw a higher α).

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.

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[19] 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 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.[20] In contrast to previous research, however, this estimate reflects the effective patent term.[21] 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.[22] In general, the hazard of a public firm being an alleged infringer has been slightly less than the hazard of the

[20] 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.

[21] 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.

[22] 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).

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, 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" (Allison et al. 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.[23]

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 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.

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

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[23] 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.

for plaintiffs and defendants because it is associated with larger stakes in litigation.[24] 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 3a. 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.

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 3b.

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 and significant. This pattern is consistent with Hypotheses 4c and 4d — higher R&D either increases litigation stakes, or increases a firm's exposure to being sued for patent infringement. These results are also inconsistent with the Hypothesis 4b, suggesting that defendants in patent lawsuits are not merely copying to avoid spending R&D or only spending as necessary to "invent around" patents.

Our results relating to number of employees help us interpret our results relating to R&D spending per employee. We find a positive relationship between number of employees of the patentee litigant and number of employees of the alleged infringer, and the probability of suit. Our model leads us to believe that these effects arise because firm size affects firm stakes; it does not seem plausible that firm size affects the distribution of α. The employee size data suggest that an increase in the patentee litigant firm-specific stakes has a greater impact on filing than an increase in the alleged infringer firm-specific stakes. Our results on R&D spending per employee by the patentee litigant suggest that R&D spending does not have the statistically significant effect on filing (via stakes) displayed by patentee litigant employee size. Thus, we doubt that R&D spending per employee by the alleged infringer has a significant effect on filing (via

[24] 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.

stakes). But we do observe a statistically significant effect of alleged infringer R&D intensity on filing. We interpret this effect as arising from an *exposure effect*; greater R&D intensity exposes a firm to a greater risk of suit, and in terms of the model, shift the distribution of α to the right. In other words, we favor the explanation described in Hypothesis 4d over that in 4c.

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 has 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.

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 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 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. 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.

Table 5 also shows the coefficients on industry dummies ("Other non-manufacturing" is the excluded category).[25] 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 3. 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.

The residual growth rates and the pattern shown in Figure 3 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.[26] 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

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

[26] 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.

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. Consistent with Hypothesis 4a, the larger R&D coefficients in pharma may suggest that rivals treat each others' R&D spending as strategic substitutes.

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

Interpretation

Drivers of litigation

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.

As the theoretical analysis makes clear, firm scale should be an important variable because it relates to the magnitude of what the firms have at stake in litigation. The importance of the prospective plaintiff's patent portfolio size underlines the importance of refinement—firms can improve their prospects in patent disputes by building a larger patent portfolio among other things.

The significance of prospective defendants' R&D spending emphasizes the costs that imperfect patents can impose on innovators. Firms do not appear to spend this R&D substantially to invent around others' patents. Instead, the act of performing R&D places a firm at greater risk of being sued for infringement, perhaps because poorly defined and uncertain patent boundaries make orderly processes of clearance and licensing too difficult.

All of these factors discussed so far affect both the hazard of patent disputes and the hazards of patent litigation. Capital intensity may only affect the choice between settlement and litigation. Firms with high capital fixed costs appear to be more reluctant to engage in litigation, perhaps because they are at greater risk of holdup.

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 (2004) find evidence of large differences in litigation rates per patent across size groups. 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 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 (see Bessen 2004 and Wagner and Parchomovsky 2004). 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.

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 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 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 outside of their own industry 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 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 (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 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 innovating firms may be unable to completely “clear” their technology for possible infringement in advance. 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 (2004) find, 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 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	0.40	(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 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)

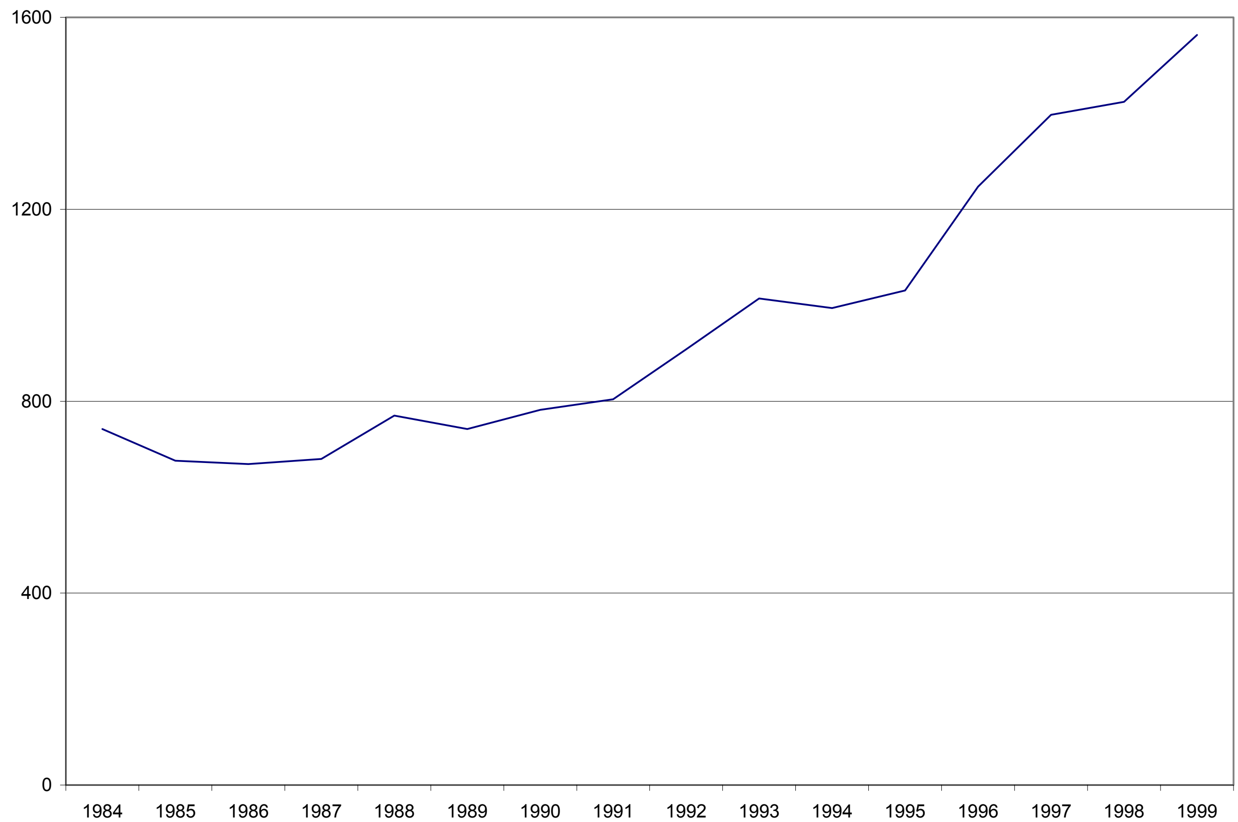

Figure 2. Equilibrium Regions

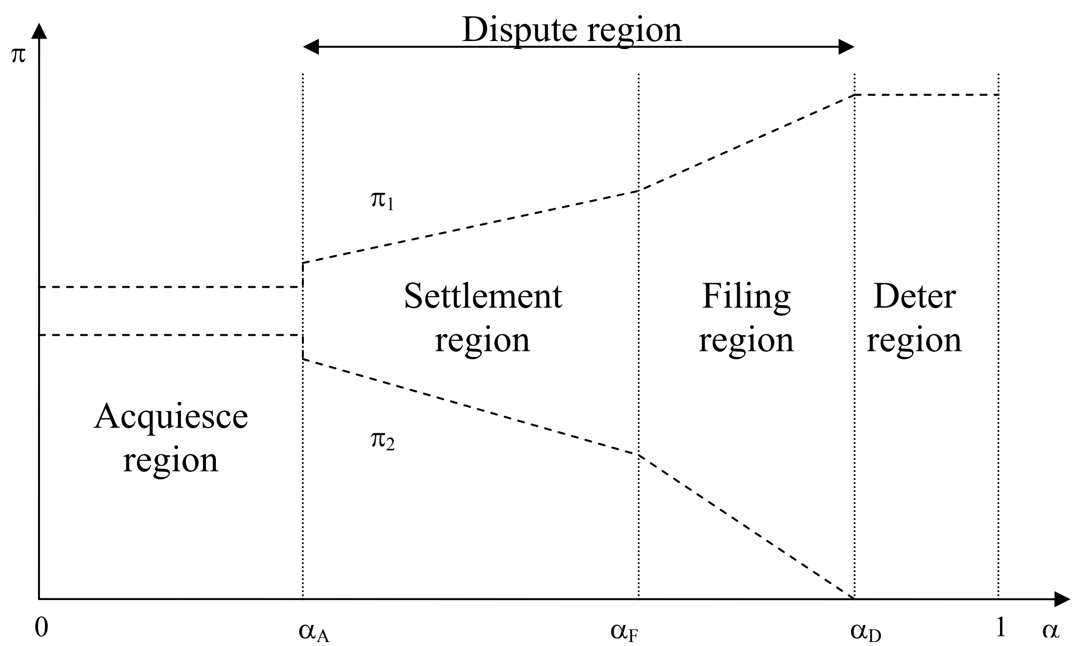

Figure 3. Residual Time Trends for Litigation Hazards from Table 5, Column 3.