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Jean O Lanjouw and Mark Schankerman

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Centre for Economic Policy Research
90–98 Goswell Rd
London EC1V 7DB
Tel: (44 171) 878 2900
Fax: (44 171) 878 2999
Email: cepr@cepr.org

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ABSTRACT

Patent Suits: Do They Distort Research Incentives?*

This paper shows that the process of enforcing patent rights both dilutes and distorts Research and Development (R&D) incentives. We examine the characteristics of litigated patents by combining, for the first time, information about patent case filings from the US district courts with detailed data from the US Patent and Trademark Office. By comparing filed cases to a random sample of US patents from the same cohorts and technology areas, we show that case filings are much more common in some technology areas than in others, and also when (i) innovations are more valuable, (ii) they appear to form the basis of a sequence of technologically-linked innovations held by the patentee, (iii) there is domestic ownership, and (iv) they are owned by individuals, except in cases where others are active in the same technology area making reputation important. We use this empirical evidence to examine hypotheses about the determinants of patent suits.

JEL Classification: K41, O31, O34
Keywords: patents, litigation, R&D incentives

Jean O Lanjouw
Department of Economics
Yale University
PO Box 208264
New Haven CT 06520–8264
USA
Tel: (1 203) 432 3568
Fax: (1 203) 432 6323
Email: lanjouw@econ.yale.edu

Mark Schankerman
Department of Economics
London School of Economics
Houghton Streeet
London EC2A 2AE
UK
Tel: (44 171) 955 7518
Fax: (44 171) 831 1840
Email: schankem@ebrd.com

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NON-TECHNICAL SUMMARY

Litigation is an expensive way to resolve disputes. Concern that civil litigation imposes significant costs on business has led to institutional reforms to mitigate these costs, such as the introduction of damage award ceilings, mediation requirements and rules to shift legal fees that facilitate settlement. And there have been market responses too, such as the emergence of patent litigation insurance and the development of investment vehicles to finance intellectual property rights litigation.

The central question in this paper is whether patent suits seriously dilute or distort the incentives provided by the patent system. There is substantial evidence from studies using patent renewal and application data that, while patent rights provide significant Research and Development (R&D) incentives, the implied 'subsidy' rates are only on the order of 15% to 30%. Firm-level surveys have confirmed that companies rely heavily on other mechanisms to appropriate the returns to innovation. It is important to understand why the main policy instrument to encourage R&D investment is not more effective than these studies suggest. Part of the reason may be that the costs of enforcing patent rights significantly reduce the private benefit of owning patents. In order to evaluate the implications of enforcement costs, policy-makers need three types of information: first, the probability of patent suits, and how it varies with characteristics of patents and patent owners; second, the pattern of outcomes of patent suits; and third, the cost of settling and/or litigating patent suits. This paper analyses the frequency and pattern of patent infringement and invalidity suits, as a first step toward a broader assessment of how enforcement costs undermine R&D incentives.

In addition to reducing R&D incentives, the threat of costly patent litigation can distort firms' product location, contracting and other decisions as they adapt their strategies to the prevailing incentives. Beyond these microeconomic distortions, costly enforcement of intellectual (or indeed other forms) of property rights can have broader implications for growth. Existing models of endogenous growth assume that firms can costlessly enforce their property rights and appropriate their innovative rents. Any dilution or distortion of R&D incentives arising from the enforcement of patent rights will have implications for those models. For example, if litigation is more frequent in new technology areas and more burdensome for small, capital-constrained firms for whom intellectual property is typically their *key* asset, then enforcement costs may weaken their incentives for R&D and entry.

This paper presents new stylized facts about the determinants of patent suits. We bring together, for the first time, data on patent suits (case filings) and the

detailed information about inventions and their owners found in patent documents. This data set is very rich, and has important advantages for analysing legal cases that distinguish it from previous studies of litigation. First, to study the determinants of suits requires information *both about the litigants and about the population from which potential litigants are drawn.* As in other areas of law, court data contain (at best) information on law suits, but no information on the potential population. Matching court data to patent information allows us to construct a randomly drawn control group of patents. The analysis in this paper is conducted by comparing the characteristics of the patent and the patent owner in the litigated and control groups.

Further, these data allow us to construct a set of proxies for the following key determinants of suits: (i) the number of *potential disputes* – measured by the number of claims in the patent, the diversity of technology classes into which the patent falls and the technological similarity of future patents that cite the original one; (ii) the *size of the stakes* – measured by the number of future citations the patent receives, and the extent of self-citation (as an indicator of the firm's cumulative investment in that technology); and (iii) the *cost of prosecuting a suit* and *asymmetric information* – which we will infer from whether the patent ownership is individual or corporate and domestic or foreign. The data has extensive coverage, including about three-quarters of all patent suits filed in the US during the period 1975–91.

To summarize the key findings: Overall, there are about 11 suits per 1000 patents. While the average frequency is low, this fact conceals important differences across different types of patents and patent owners. Suits occur when the stakes are high. Litigated patents have more claims and more valuable claims. While not surprising, this is the first evidence that there is a systematic link between the value of patent rights and the expected legal cost of enforcing them. Patentees are also more likely to prosecute for infringement when they hold subsequent inventions in similar technology areas (measured by greater self-citation in similar technology classes). Taken together, these two findings suggest that cumulative technology increases the value of the earlier, base patents and is consistent with the theoretical literature that emphasizes the link between patent rights and bargaining in contractual arrangements between first and second-generation innovators.

There are also sharp differences across technology fields in the likelihood of being engaged in a court case, with nearly twice as high a rate in pharmaceuticals. Still, these rates are much lower than those found in the emerging field of biotechnology. This comparison supports the idea that the threat of litigation is of particular concern in new technology areas, where small firms are likely to be active. Individual owners are at least as likely to be involved in a suit as corporate owners. This is surprising, since corporations

are likely to have lower costs of litigation. It suggests that corporations have even greater advantages in settling disputes out of court, such as cross licensing and patent pooling arrangements which encourage cooperation. On the other hand, when building a reputation for aggressively defending property rights is useful, corporate owners are more likely to turn to the courts. We find that corporate (but not individual) patentees are more likely to sue for infringement when subsequent patent citations come from firms working in closely related technological areas.

Litigation is an expensive way to resolve disputes. Concern that civil litigation imposes significant costs on business has led to institutional reforms to mitigate these costs, such as the introduction of damage award ceilings, mediation requirements (Farber and White, 1991), and rules to shift legal fees which facilitate settlement (Kaplow, 1993; Spier, 1994). And there have been market responses too, such as the emergence of patent litigation insurance and the development of investment vehicles to finance intellectual property rights litigation (*Business Insurance*, 1995).

The central question in this paper is whether patent suits seriously dilute or distort the incentives provided by the patent system. There is substantial evidence from studies using patent renewal and application data that, while patent rights provide significant R&D incentives, the implied 'subsidy' rates are only on the order of 15 to 30 percent (see Lanjouw, Pakes and Putnam, 1998, for a review). Firm-level surveys have confirmed that companies rely heavily on other mechanisms to appropriate the returns to innovation (Levin, Klevorik, Nelson and Winter, 1987; Cohen, Nelson and Walsh, 1996). It is important to understand why the main policy instrument to encourage R&D investment is not more effective than these studies suggest. Part of the reason may be that the costs of enforcing patent rights significantly reduce the private benefit of owning patents. In order to evaluate the implications of enforcement costs, policymakers need three types of information: first, the probability of patent suits, and how it varies with characteristics of patents and patent owners; second, the pattern of outcomes of patent suits; and third, the cost of settling and/or litigating patent suits. This paper analyses the frequency and pattern of patent infringement and invalidity suits, as a first step toward a broader assessment of how enforcement costs undermine R&D incentives.

In addition to reducing R&D incentives, the threat of costly patent litigation can distort firms' product location, contracting and other decisions as they adapt their strategies to the prevailing incentives. For example, there is evidence that small firms rely more heavily on trade secrets rather than patents for protection (Baldwin, 1996; Lerner, 1995a), and that the strength of patent rights affects the way firms

structure their contracts for technology transfer (Anand and Khanna, 1996). Further, Lerner (1995b) provides evidence consistent with the idea that litigation costs induce small biotechnology firms to design their R&D strategies to avoid conflict with larger firms (for related theoretical analysis, Waterson, 1990).

In addition to these microeconomic distortions, costly enforcement of intellectual (or indeed other forms) of property rights can have broader implications for growth. Existing models of Schumpeterian growth, which require the appropriation of innovative rents, assume costless enforcement of these property rights (Aghion and Howitt, 1998). Any dilution or distortion of R&D incentives arising from the enforcement of patent rights will have implications for those models. For example, if litigation is more frequent in new technology areas and more burdensome for small, capital-constrained firms, then the entry process in Schumpeterian models may be impeded. It is common that intellectual property is the *key* asset of start-up firms and, in such cases, high costs of enforcement will weaken their incentives for R&D and entry.

This paper presents new stylized facts about the determinants of patent suits. We bring together, for the first time, data on patent suits (case filings) and the detailed information about inventions and their owners found in patent documents. This data set is very rich, and has three important advantages for analyzing legal cases that distinguish it from previous studies of litigation. First, to study the determinants of suits one requires information *both about the litigants and about the population from which potential litigants are drawn.* As in other areas of law, court data contain (at best) information on lawsuits, but no information on the potential population. Matching court data to patent information allows us to construct a randomly drawn control group of patents. The analysis in this paper is conducted by comparing the characteristics of the patent and the patent owner in the litigated and control groups.

The second advantage is that these data allow us to construct a set of proxies for the following key determinants of suits:[2] (i) the number of *potential disputes* - measured by the number of claims in the patent, the diversity of technology classes into which the patent falls, and the technological similarity of future patents that cite the original one; (ii) the *size of the stakes* - measured by the number of future citations the patent receives, and the extent of self-citation (as an indicator of the firm's cumulative investment in that technology); and (iii) the *cost of prosecuting a suit* and *asymmetric information* - which we will infer from whether the patent ownership is individual or corporate, and domestic or foreign. The third advantage is the extensive coverage of the data set, which includes about three-quarters of all patent suits filed in the U.S. during the period 1975-1991.

For convenience we summarize the key findings. Overall, there are about 11 suits per 1000 patents. While the average frequency is low, this fact conceals important differences across different types of patents and patent owners. Suits occur when the stakes are high. Litigated patents have both more claims and more valuable claims. While not surprising, this is the first evidence that there is a systematic link between the value of patent rights and the expected legal cost of enforcing them. Patentees are also more likely to prosecute for infringement when they hold subsequent inventions in similar technology areas (measured by greater self-citation in similar technology classes). Taken together, these two findings suggest that cumulative technology increases the value of the earlier, base patents, and is consistent with the theoretical literature that emphasizes the link between patent rights and bargaining in contractual arrangements between first and second-generation innovators (Scotchmer, 1991; Green and Scotchmer, 1995).

There are also sharp differences across technology fields in the likelihood of being engaged in a court case, with nearly twice as high a rate in pharmaceuticals. Nonetheless, these rates are much lower

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[2] There are some studies using proxy variables for these variables in other areas of litigation. For example, see Siegelman and Waldfogel (1996) and Fournier and Zuehlke (1989) on civil suits, and Hughes and

than those found by Lerner (1995a) in the emerging field of biotechnology. This comparison supports the idea that the threat of litigation is of particular concern in new technology areas, where small firms are likely to be active. We find that individual owners are at least as likely to be involved in a suit as corporate owners. This *is* surprising, since corporations are likely to have lower costs of litigation. It suggests that corporations have even greater advantages in settling disputes out of court, such as cross licensing and patent pooling arrangements which encourage cooperation. On the other hand, in cases where building a reputation for aggressively defending property rights is useful, corporate owners are more likely to turn to the courts. In particular, corporate (but not individual) patentees are more likely to sue for infringement when subsequent patent citations come from firms working in closely related technological areas. Finally, domestic patentees are far more likely to prosecute for infringement, with 16.4 versus 3.5 filed cases per thousand patents. We examine alternative explanations for this finding and conclude that it is because they have lower fixed costs of litigating per patent.

The paper is organized as follows. Section 1 states the hypotheses about the determinants of litigation, derived from existing theoretical literature. These are used as a reference for interpreting the stylized facts of patent suits developed in the subsequent empirical discussion. Section 2 describes the construction of the new data set. In Section 3 we develop the key stylized facts, and discuss which hypotheses in the literature are consistent with the evidence and which can be ruled out. While these are not definitive tests, our paper provides the first empirical evidence to investigate many of these hypotheses in the area of intellectual property. In this section, we combine information on patent infringement and patent invalidity (or, challenge) suits because there are no important qualitative differences in the results. Section 4 presents an econometric analysis of the determinants of infringement and challenge suits, treated separately. In addition to quantifying the importance of the factors identified in Section 3, we present a striking finding which is consistent with the idea that the plaintiff appropriates only part of the benefits

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Snyder (1989) and Farber and White (1991) on medical malpractice.

arising from a successful invalidity suit. In brief concluding remarks, we summarize directions for future research.

1. Determinants of Litigation Activity

Existing theoretical models identify the following four key determinants of litigation. (For an excellent survey see Cooter and Rubinfeld, 1989.)

A. *The probability of litigation increases in the likelihood of a potentially litigious situation, or 'event', occurring and being detected by the plaintiff. In our context, an event is any action which could be considered an infringement of patent rights.*

B. *The probability of litigation is increasing in the asymmetry information or the divergence in parties' expectations regarding the outcome of a trial. In our context this is more likely in emerging technology areas (e.g., biotechnology); where patent protection is new (e.g., computer software); or where legal procedure itself is changing.*[3]

C. *The probability of litigation rises in the size of the stakes. In our context, this includes the value of the patent right and any indirect benefits to filing a case (e.g., to strengthen reputation and bargaining power in subsequent interactions).*[4]

D. *The probability of litigation declines in the cost of trial relative to the cost of settlement. In our context differences are likely to arise between domestic and foreign patentees, and corporate versus individual patentees.*[5]

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[3] Strategic models of litigation show that the likelihood of litigation depends delicately on the information available to parties and the sequence of offers (for example, Bebchuk, 1984; Png, 1983; and Spier and Spulber, 1993). For a detailed discussion of the evolution of legal rules for software patenting, and the uncertainty it created, see Samuelson, Davis, Kapon and Reichman (1994).

[4] An important example of indirect returns to litigation arises when invention is cumulative, in the sense that subsequent innovations rely on earlier inventions. In such cases, it may be critical for a firm to enforce patent protection on its early patent in order to extract rents from its own or others' subsequent inventions (Scotchmer, 1991; Merges and Nelson, 1990).

These four generic factors influence the probability of both patent infringement and challenge suits. But there is one important difference between these two types of litigation: successful patent challenges generate positive externalities while infringement suits do not. If the plaintiff in a challenge suit is active in related R&D, it may be well placed to benefit if the disputed patent is declared invalid or is restricted in scope. But other R&D-performing firms may also innovate in any technology space opened up, and all firms would be able to use the original innovation freely. By contrast, the gains from a successful patent infringement suit accrue primarily, if not exclusively, to the patentee. Besides making infringements suits more frequent than challenges, this argument implies that the four factors listed above should increase the probability of infringement suits (at the margin) more than patent challenges (for a formal test see Section 4).

Before proceeding to the empirical analysis, one clarifying remark is in order. Here we analyze the incidence and characteristics of patent case filings rather than just those that proceed to trial. Often the factors listed above are used to explain whether disputes fail to settle in the negotiations *after* case filing, but this is only one stage in a more complex strategic game. Strategic models of litigation emphasize that this stage is preceded by the decision to file suit when there is a dispute (Shavell, 1982; P'ng, 1983; Eisenberg and Farber, 1995; Hughes and Snyder, 1989). In these models, the decision to file a suit is based on the expected benefits net of litigation costs, relative to settlement, which in sub-game perfect equilibrium depends on the four generic factors discussed in this section. Thus, in addition to being consistent with litigation models, our focus on the determinants of patent suits is appropriate from a policy perspective. The vast majority of patent cases filed do not reach the trial stage. Therefore, in order to assess the implications

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[5] Legal costs are probably higher for foreign firms. Even if they engage domestic legal representation, they incur higher costs in communications and in translating business documents into a form that will be understood by a U.S. court. Legal expenses are also likely to be higher for smaller firms and individuals

of the costs of enforcing patent rights on the net value of patent protection, the decision to file patent suits is at least as important as the decision to go to trial.

2. Description of the Data

The data source used to identify litigated patents is the Patent History CD-ROM produced by Derwent. This database is constructed from information collected by the U.S. Patent and Trademark Office (PTO). The data include 5,452 patent cases during the period 1975-1991, involving 3,887 U.S. patents. Although the U.S. Federal courts are required to report to the PTO whenever a case is filed which involves a U.S. patent, they often fail to do so. This means that the PTO data is a subset of all patent cases. We calculated the number of missing cases by linking the information from the PTO to comprehensive data on court activity available from the Inter-university Consortium for Political and Social Research (Federal Judicial Center, 1991). Only 22 percent of patent disputes recorded by the Federal courts (code 830) were reported to the PTO during the years 1977-79. This had increased to 85 percent of all cases by the years 1985-87, with the most substantial improvement in reporting occurring between 1983 and 1984. The incomplete reporting by the courts to the PTO seems to be mainly a clerical issue (reporting rates differ by districts). We checked for selection bias by comparing characteristics of federal cases reported to the PTO to those of unreported cases, and found no discernible differences between the two groups in a range of variables in the federal database.[6]

To create a control group, we generated a 'matched' set of patents from the population of all U.S. patents (both litigated and unlitigated). For each litigated patent, a patent was chosen at random from the set of all U.S. patents with the same application month and a common 4-digit International Patent Classification

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because of higher financing costs and their greater reliance on external legal counsel (Lanjouw and Lerner, 1996).

(IPC) sub-class assignment, described below. By constructing the population sample in this way, the comparisons we present between litigated patents and matched patents control both for technology and cohort effects. We obtained information on a range of characteristics for each litigated and matched patent, which we now briefly describe.

Number of Claims: A patent is comprised of a set of claims which delineate the boundaries of the property rights provided by the patent. The principal claims define the essential novel features of the invention in their broadest form and the subordinate claims are more restricted and may describe detailed features of the innovation claimed. The patentee has an incentive to claim as much as possible in the application, but the patent examiner may require that the claims be narrowed before granting.

IPC Assignments: Each patent is assigned by the patent examiner to 9-digit categories of the IPC system. Our data contain assignments at the more aggregated, widely used, 4-digit sub-class level (614 sub-classes). The IPC is a technology-based classification system and patents may be assigned to more than one sub-class. In the empirical analysis, we use the set of all 4-digit IPC sub-classes to which each patent was assigned.

Citations: An inventor must cite all related prior U.S. patents in the patent application. A patent examiner who is an expert in the field is responsible for insuring that all appropriate patents have been cited. Like claims, the citations in the patent document help to define the property rights of the patentee. For each patent in the litigated and matched data, we obtained the number of prior patents cited in the application (backward citations) and their IPC sub-class assignments. We obtained the same information on all subsequent patents that had cited a given patent in their own applications, as of 1994 (forward citations). For recent patents there is substantial truncation in the number of forward citations, since citation lags can be long (Jaffe and Trajtenberg, 1996), and we adjust for this fact in the analysis. For older patents there is

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[6] The variables included the method of disposition of the case, the type of judgement, the percentage of large (greater than ten million dollars) monetary judgements received, and the party favored in cases

considerable missing information on the IPC sub-class assignments of backward citations, as comprehensive IPC data are only available from about 1970, but the number of backward citations is complete for all patents.

Ownership: We construct a variable for the nationality and the type of ownership (corporate or individual) of each patent as follows. First, we classify the inventor as domestic, Japanese or other foreign, based on the address of the inventor. The nationality of the assignee of the patent is defined in the same way. Not all inventors assign their patent rights to others: 66 percent of litigated and 73 percent of matched patents have an assignee. The nationality of patent ownership is defined as that of the assignee, if there is one, and otherwise as the nationality of the inventor. With few exceptions, assignees are firms, whereas inventors are individuals. Thus we identify a patent as corporate-owned if there is an assignee.

Case Type: We have no direct information on whether a filed case is an infringement suit or a patent challenge. However, we checked whether the patent owner is the plaintiff or defendant and are able identify one of the litigants as the patent owner for about two-thirds of the suits in the data set. Among these, the patent owner was the plaintiff 84 percent of the time, which we interpret as infringement suits. The other cases, where the patent owner was the defendant, are almost surely suits for patent invalidation brought by competitors.

3. The Stylized Facts

3.1 Prevalence of Litigation

Panel A of Table 1 provides estimates of the number of cases which have been or will be filed per thousand patents applied for during the period 1980-1984, broken down by technology field and ownership. For example, the aggregate figure of 10.7 means that for every thousand granted patents applied for during

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were a final judgement was rendered.

the years 1980-84, they will eventually become the subject of 10.7 filed cases.[7] It is an estimate because of the need to adjust both for the under-reporting of cases (discussed in Section 2) and for truncation.[8]

We need to make two calculations in order to construct patent litigation rates by ownership (Panel B in Table 1). As in the aggregate data we must adjust for truncation. The case filings involving foreign-owned patents (including Japanese) tend to occur later than for domestic-owned patents. Following the procedure in footnote eight, this leads to a truncation adjustment of 48 percent for foreign-owned patents and 41 percent for domestic-owned patents. Second, to compute total patents in the denominator, we must impute the country of ownership from information on the country of first application (priority country). Inventions are often patented in multiple locations but, with few exceptions, the priority country is the country of the inventor.[9] Most exceptions involve cases where a foreign patentee chooses the U.S. as the priority country. Thus the share of total patents with domestic owners is slightly over-estimated and, as a result, the filing rate is understated for domestic patentees and overstated for foreign owners.

Despite this bias, domestic-owned patents are far more frequently involved in litigation. The aggregate litigation rate is nearly five times as large for domestic patentees, and this finding holds (with some variation) in all five technology areas. However, although domestic-owned patents are more likely to be litigated, they are *not* more likely to be litigated more than once. Among litigated patents the mean

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[7] Because some patents are litigated more than once, the number of cases per thousand patents is larger than the number of individual patents that are litigated. The latter statistics, adjusted for truncation in *first* filings, are 6.3 (total), 9.1 (domestic), and 2.0 (foreign). That is, for every thousand patents, 6.3 will be litigated and they will generate 10.7 cases.

[8] Based on the comprehensive ICPSR data, the number of cases reported to the patent office by 1991 is assumed to be three-quarters of the true number of cases involving these patents by that date. Because the litigation data end in 1991, there is truncation at seven to eleven years after application. Some of the patents from cohorts 1980-84 which appear as unlitigated in 1991, will become the subject of a dispute late in life. To estimate the size of the truncation effect we examine the first few cohorts in the data (1975-77), where one would expect truncation to be minimal, and find that 45 percent of all case filings occur within seven years of the application date of the patent, and 75 percent within eleven years. We use the midpoint of this range, and the estimated 25 percent under-reporting, and gross up the litigation rates accordingly.

[9] Putnam (1996) calculates that 98 % of U.S. inventors have their residence as priority country. Figures for other leading OECD countries include: France, 84 %; Germany, 88 %; the U.K., 83 %; and Japan, 87 %.

number of cases per patent is 1.39 (0.02) for domestic owners, 1.30 (0.10) for Japanese owners and 1.53 (0.10) for non-Japanese foreign owners. (Throughout the paper, figures in parentheses are standard errors.) These means are not statistically different from each other at the 0.01 level. Thus, the nationality of the patent owner influences the *probability* of litigation, but not the *number of times* that a given patent is litigated. This finding is consistent with there being a fixed cost to litigating a given patent, which is higher for foreign firms, but it is not consistent with the idea that foreign firms are at a disadvantage in detecting infringements in the U.S. market since, if that were true, we would also expect the number of cases per litigated patent to be lower for foreign firms.[10]

There are also sharp differences in litigation rates across technology fields, holding ownership constant. The most notable are the very low litigation rate for chemical patents and the high rate for drugs and health. There is a cased filed for every fifty drug patents. This may reflect the fact that patents are relied upon more frequently to protect pharmaceutical innovations, as confirmed by survey evidence (Levin, *et. al.*, 1987; Cohen, *et. al.*, 1996). In addition, some of differences in litigation rates may be associated with variation in the value of patent protection. (See Lanjouw 1998, Schankerman 1998, for evidence of differences in the value of patent rights across technology areas.)

The litigation rates in Table 1 are much lower than those for the relatively young field of biotechnology, as presented by Lerner (1995a). Based on a sample of 530 biotechnology firms, he estimates that there are about sixty cases per thousand U.S. corporate biotechnology patents. In other words, in biotechnology the rate of litigation is at least four times as large as it is for patents as a whole, and more than twice as high as for drugs and health. These sharp differences highlight the importance, for avoiding

[10] An alternative to the fixed-cost interpretation is that there are two types of foreign patent owners, those with low costs of detecting infringement and litigation (for example, owners with a domestic presence by virtue of a local subsidiary) and those with high costs. If most foreign patent owners are of the first type, the probability of litigation will be low. But the low-cost type will be highly represented among the foreign patent owners who do get involved in litigation, so the frequency of cases, conditional on a first filing, may be high.

litigation, of experience with disputes and the existence of established legal precedent to guide disputants in assessing their cases.

Finally, there are sharp differences between litigation rates for individual and corporate owners (not shown in the table). Litigation rates for domestic and non-Japanese foreign individuals are 16 percent *higher* than corporate owners in those countries, and the difference is even more striking for Japanese inventors, where individuals are more than three times as likely as corporations to file suits involving their U.S. patents.[11] This suggests that, while corporate owners may have lower litigation costs, they must have even greater advantages in reaching settlement agreements. The econometric evidence in Section 4 shows that the effect of ownership is less pronounced, but still significant, when one controls for other patent characteristics.

Panel B in Table 1 provides information on the type of litigation occurring in each technology group and ownership category. We defined infringement (challenge) suits as those where the patent owner is the plaintiff (defendant).[12] In each technology group, infringements account for the bulk of litigation; about 60 percent if unclassified cases are excluded, and 90 percent if they are treated as infringement suits. This is consistent with plaintiffs being better able to appropriate the gains from successful infringement suits, as compared to patent challenges.

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[11] This understates the difference between individual and corporate behavior. When neither litigant is identified as the patentee, it means that a third party (invariably a firm) is involved in the suit even though it does not own the patent. Third parties may be parent companies, exclusive licensees or joint venture partners. There are third party litigants for 26 percent of corporate-owned patents and 53 percent of patents owned by individuals. This measure understates the extent of third party involvement because even in the 47 percent of cases where an individual owner *is* identified as one of the litigants, firms act as co-litigants in roughly half the cases. Thus, individuals are actually litigating in only about 25 percent of cases which involve individual ownership.

[12] The unclassified category refers to cases where the patent owner is neither the plaintiff nor defendant. Under U.S. patent law, an exclusive licensee (but not a non-exclusive licensee) can sue for infringement on behalf of the patentee, but the defendant in a challenge suit must be the patent owner. Thus we conclude

3.2 Patent Citations

Future citations received by a patent (forward citations) are one indication that an innovation has contributed to the development of subsequent inventions. For this reason, citations have been used a measure of the value of an invention (Trajtenberg, 1990a and 1990b) and to trace and measure the effects of R&D spillovers (Jaffe, Henderson and Trajtenberg, 1993; Caballero and Jaffe, 1993). We use citations to investigate whether the value of patents is systematically related to litigation.

The link between citations and litigation in these data is striking. Litigated patents are *much* more frequently cited than a randomly chosen patent. The mean number of citations among the litigated patents is 11.9 (0.2), but only 5.8 (0.1) for matched patents. This is partly because domestic-owned patents tend to be more heavily cited and also form the bulk of the litigated sample. In the matched sample, domestic-owned patents are cited 6.3 (0.16) times on average, compared to 4.8 (0.19) citations for non-Japanese foreign-owned patents and 5.8 (0.32) for Japanese-owned patents. However, litigated patents are more heavily cited even when we control for ownership (Table 2). We can easily reject the null hypothesis that litigated and matched patents have the same distribution of the number of citations, both for domestic-owned patents ($\chi^2/6 = 190.8$, p-value < 0.01) and foreign-owned patents ($\chi^2/6 = 492.9$, p-value < 0.01). Considering Japanese-owned patents separately does not appreciably effect the results. Table 2 clearly shows that litigation is much more likely to be a feature of maintaining property rights for more valuable (heavily cited) inventions.

In Section 3.1 we argued that the lower litigation rate observed for foreign-owned patents was consistent with higher litigation costs per patent for foreign patentees, but not with higher detection costs for foreign owners. The findings in Table 2 on citations allow us to rule out another explanation for the lower litigation rate: lower value of foreign-owned patents. Studies of the private value of patent rights in

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that the unclassified category is primarily infringement suits brought by an exclusive licensee or the parent company of the patent owner.

different countries have found that foreign-owned patents are typically more valuable than those owned by domestic patentees (Pakes and Simpson, 1989; Lanjouw, 1992; Putnam, 1996. Schankerman, 1998, provides mixed evidence).[13] Since foreign-owned patents are less heavily cited in the population, we can infer that they receive fewer U.S. citations per unit of value. But among *litigated* patents, those with a foreign owner are just as heavily cited as those with a U.S. owner. Using the same breakdown of citations categories shown in Table 2, we can not reject equality of the distributions in columns (2) and (4) ($\chi^2/ 6 = 2.45$, p-value = 0.88). This implies that litigated patents owned by foreigners are *more* valuable than their domestic counterparts. This conclusion is consistent with the hypothesis that foreign patentees face higher legal costs and thus litigate only their more valuable patents. As with our finding in Section 3.1, this evidence does *not* support the hypothesis that foreigners have more difficulty detecting infringements, since there is no reason to expect the latter to have a selective (value-related) effect.

We have interpreted the empirical association between citations and case filings as reflecting the role of the size of the stakes. Another interpretation is that forward citations indicate that many firms are innovating in the same area and, because of this, they make competing claims. We test this hypothesis by noting that, when many inventors are operating in the same area, their patents will tend to fall in technology classes more closely related to the patents they cite and those patents that cite them. To measure the technological "similarity" between a patent and one of its citing patents, we calculate the percentage of 4-digit IPC assignments of the citing patent which overlap with those of the patent itself. Our similarity index is the mean degree of similarity taken over a group of citations. Similarity between a patent and its backward citations is measured analogously. Similarity measures the technological closeness of a patent to

[13] This reflects self-selection in the patent application process - given the substantial cost of applying for and maintaining patent protection, foreign patentees are less likely to take out patent protection in other countries for low-valued inventions. There may also be differences across nationalities in the underlying value of their inventions, but studies of patent systems *in different countries* tend to find foreign-owned patents are higher valued, suggesting that it is more to do with selection. From the point of view of the argument in the text, the reason for the value difference does not matter.

its children and its parents. We treat self-citations separately since, when a firm cites its own past patents, they are more likely to be technologically similar because they arise from the same research program.

For backward citations, we cannot reject the hypothesis that the similarity index is the same for litigated and matched patents (Table 3). However, for forward citations, the similarity index for litigated patents is significantly higher than for matched patents. Both conclusions hold for self-cites and citations by others, and for domestic and foreign patentees. This evidence supports the idea that crowdedness in a research area contributes to litigation by increasing the number of potential disputes and, thereby, the importance of reputation.

Patentees are more likely to litigate when they have subsequent inventions in the same technology area. There is significantly greater technological similarity between patents and their future *self*-citations among litigated patents than among the matched patents - 0.67 versus 0.58 for domestic owners, 0.72 versus 0.63 for foreign owners. One interesting explanation for this finding is that greater similarity of future self-citations is an indication of cumulative or sequential invention. In such cases, the ability to appropriate returns from later inventions may depend on having effective proprietary control over the earlier invention. This can arise because stronger control of earlier inventions changes the bargaining position for subsequent licensing agreements (Scotchmer, 1991 and 1996; Scotchmer and Green, 1995). This gives a firm trying to control a technology as it develops a strong incentive to prosecute infringers of the early patents. Not only does this increase the stakes of the dispute, but equally important in explaining suits, it is also likely to cause an *asymmetry* in the stakes. Protecting the early patent in a cumulative chain generates benefits for the other patents in the chain that can only be enjoyed by the patent owner.

We have argued that citations (as a measure of value) lead to patent suits. One might be concerned that the causality runs in the reverse direction: publicity generated by a patent suit leads to more citations. To test for the presence of a 'publicity effect,' we compute the mean number of citations received by litigated patents at various lags after the patent application date (Table 4). The first column in the table

presents the mean number of citations at various lags for patents that have not yet had a first case filing by the time of the citation (e.g., for patents which will eventually be litigated but have not yet been by age six, the mean number of citations in that year is 0.96). The second column gives the mean number of citations T years after application for patents which had a first case filing T-1 years after application; the other columns refer to patents where the first case filing date is progressively further from the year of citation. If there is a publicity effect, we expect citations to be relatively more frequent in the years shortly after a case filing. The final row in the table gives clear evidence that there is a 'publicity effect': the mean number of citations for given lags is significantly higher in the two years following a case filing, but the effect dissipates out after four years. However, while there *is* a publicity effect, it is much too small to explain the higher number of citations for litigated patents. The publicity effect raises the number of citations by an average of 0.5, or half a citation, which is less than ten percent of the observed difference in citation rates for litigated and matched patents.

3.3 Patent Claims

The number of claims is another, underutilized, indicator of the 'bits of information' contained in a patent, and therefore its value. Supporting evidence for the relationship between claims and value is found in the fact that claims are positively correlated with forward and backward citation in all technology areas in these data (Lanjouw and Schankerman, 1998), and also with R&D expenditures at the economy-wide level (Tong and Frame, 1994). Panel A in Table 5 shows that technologies fall into two distinct groups: drugs and health, chemical, and electronic inventions have more claims per patent, while patents protecting mechanical and other types of inventions have fewer claims. We easily reject that the distribution of claims across technology is the same ($\chi^2/20 = 4.56$, p-value < 0.01, based on the claims categories 1-5, 6-10, 11-15, 16-20, 21-50 and > 50). The mean number of claims per patent also differs significantly across

ownership types: the mean for domestic owners is 13.2 (0.2), it is 10.7 (0.2) for non-Japanese foreign owners, and 9.0 (0.3) for Japanese owners. This conclusion holds within each technology field.

The mean number of claims per patent has increased over time (Panel B in Table 5). It was stable prior to 1983, averaging 12.2 (0.15) over the period 1975-1982. But in 1983 the mean number of claims began to drift upward after 1982, averaging 13.5 (0.24) for the 1983-1991 cohorts. This time series evidence also supports the idea that the number of claims is related to the private value of a patent, since in 1982 the PTO raised application and issuance fees and introduced the requirement that patentees pay renewal fees to keep their patents in force. This increase in the cost of protection should have led inventors to cease applying for patent protection on less valuable inventions, and the observed rise in the number of claims per patent is consistent with such self-selection.[14]

In addition to being an indicator of patent value, the number of claims may be associated with the technology or product "space" being protected by the patent. A patentee making more claims runs a larger risk of conflict with competitors. For both reasons, we expect litigation to be more likely for such patents, and it is. Litigated patents have far more claims than matched patents, both when they are domestic-owned and foreign-owned. The differences are large and statistically significant, and are also evident in the median and mode (Table 6). Not only is the mean number of claims larger for litigated patents, but the number of forward citations per claim is also higher (controlling for ownership). Thus litigated patents have both more claims, and more valuable claims. Moreover, we cannot reject the hypothesis that, *among litigated patents*, domestic and foreign-owned patents have the same number of citations per claim. As in our earlier analysis of citations per patent, this highlights the self-selection at work among foreign-owned, litigated patents.

In Table 6 we also examine the number of prior patents cited per claim in the patent documents of litigated and matched patents (backward citations). Controlling for ownership, we find that a litigated

patent is likely to cite *fewer* prior patents per claim than a randomly selected patent. A small number of backward citations may indicate that the invention is in a relatively new technology area. In this situation there is little information available to either the patentee or his competitors about how the courts will view the claims made in the patent, increasing the likelihood of divergent expectations and, as a result, litigation.[15]

3.4 Technology Classifications

Lerner (1994) argues that patents with uses in many areas - "broad" patents - are faced with more potential infringers and are thus more likely to be litigated. He proposes a measure of breadth: a simple count of the number of 4-digit IPC sub-classes to which a patent is assigned by the patent examiner. Using a sample of biotechnology patents he finds a large, statistically significant positive relationship between the probability that a patent is litigated and its breadth. We constructed his measure of breadth on our more comprehensive data and tested the hypothesis that the distribution of the number of IPC sub-classes to which litigated and matched patents are assigned is the same (Table 7). We also found some significant differences in breadth, but they go the "wrong" way. It is the *narrower* patents that tend to be litigated more often. We interpret this finding as indicating that it is more difficult for a patentee to detect infringement

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[14] This increase is all the more striking because, during this period, the new specialised appeals court liberally interpreted the doctrine of "means and functions claims," which allows patentees to widen the coverage of individual claims. We thank Robert Merges for pointing this out.

[15] An alternative hypothesis is that a small number of backward citations just reflects a failure by the patentee to cite relevant patents, which leads to litigation. Under this hypothesis we expect to observe challenges to the new patent, not infringement suits by the patentee. To test the hypothesis, we group patents into those where the owner is the plaintiff (infringement suits) and those where the owner is the defendant (patent challenges). Under the "new area" hypothesis in the text, the number of backward citations per claim should not be significantly different for infringements and challenges, but under the "failure to cite" hypothesis, backward citations per claim should be larger for infringement suits. There was no significant difference in any of the three ownership categories. This evidence favors the "new area" hypothesis stated in the text. This finding is not surprising since, under U.S. patent law, "gross negligence" in citing prior art is sufficient grounds for invalidating a patent (Merges, 1997, Chapter 7).

when his patented invention is used in diverse technology areas.[16] Whatever the reason, it is clear that biotechnology is not representative in terms of the link between patent suits and breadth.

4. Econometric Analysis

Table 8 presents probit regressions relating the probability of infringement and challenge suits, separately, to the following regressors: the number of claims, forward citations per claim, backward citations per claim, the number of 4-digit IPC's to measure patent breadth, similarity indices for backward and forward citations to measure crowdedness, the percentage of backward and forward citation which is *self*-citation to capture cumulative technology, and a set of ownership dummy variables to allow for nationality and individual/corporate differences. In each regression, the sample includes the litigated patents of the indicated type plus all of the matched patents. Technology group dummies are included as controls since the 50:50 breakdown of litigated and matched patents by IPC group does not hold for these separate samples. The table presents both the parameter estimates and the corresponding marginal effects.[17]

Turning first to infringement suits, the results strongly confirm that the probability of litigation rises with the number of claims and forward citations per claim, and the effects are substantial. A ten-percent rise

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[16] To investigate this issue further, we developed a more refined measure of patent breadth, defined as one minus the maximum percentage of patent's 4-digit IPC sub-class assignments that fall into one of twenty-two 2-digit technology groups. This measure recognizes that 4-digit sub-classes may be closely related (a patent with three sub-class assignments all within chemicals is less broad by this measure than a patent with two sub-class assignments where one assignment is in chemicals and the other is in electronics). The point estimates again confirm that broader patents are *less* likely to be litigated, but the difference was not statistically significant in any technology group.

[17] Where there are quadratic terms, the reported marginal effect includes the full effect of a change in the variable. For the similarity of forward citation, the marginal effect indicated for the interaction is the full effect of a change in similarity for corporate owners. The marginal effects for ownership are calculated as follows: for ownership type i it is the difference between the probability of litigation given i and a weighted average of the probabilities of litigation given ownership type j, where the weights are the probability that a patent is type j given that it is not type i. Because the characteristics of patents (and their owners) involved in infringement and challenge suits differ, we evaluate the marginal effects at the *population means* for all covariates (see the appendix for details). Thus the reported marginal effects correspond to a randomly-drawn patent and can be compared between the infringement and challenge regressions.

in the number of claims (1.0 claim at the mean) implies a 1.4 percentage point increase in the probability of litigation. Because the number of claims is very skew, a one standard deviation increase in the number of claims increases the probability of litigation by 12.0 percentage points. One additional forward citation per claim raises the probability of an infringement suit by 8.1 percentage points (standard error of 0.57). A one standard deviation increase in forward citations per claim raises the probability of litigation by 13.1 percentage points. These findings confirm the importance of the value of a patent in determining infringement suits.

The point estimates suggest that the likelihood of an infringement suit declines with the number of backward citations per claim. This is consistent with the hypothesis, proposed in Section 3.3, that a small number of backward citations indicates patenting in a relatively new area and that the associated uncertainties lead to more frequent patent disputes. However, the effect is not significant.

There is no evidence that Lerner's index of patent breadth (NO4IPC) increases the probability of infringement litigation. On the contrary, the point estimate again indicates that "broader" patents are *less* likely to be litigated. But the effect is marginally significant and small: a one standard deviation increase in breadth lowers the litigation probability by only 1.1 percentage points (standard error of 0.6).

The similarity of forward citations by others (SIMFWD) significantly raises the probability of infringement litigation, and the effect is substantial. Moreover, the effect of the similarity index is almost twice as large for corporate owners as for individual owners: a one standard deviation increase in the similarity index raises the likelihood of infringement litigation by 3.6 percentage points for individual owners and 6.2 percent for corporate owners. Recall that greater similarity, conditional on the number of citations, is a measure of the "crowdedness" of a technology area. This causes litigation because it increases both the likelihood of disputes, as well as the importance of reputation in dealing with disputes. Our finding that similarity increases the probability of litigation *more sharply* for corporate owners indicates that reputation concerns may be an important factor in patent litigation.

In Section 3.2 we suggested that *forward self-citations* for a patent (given its total forward citations) may be an indicator that the patent owner is engaged in subsequent inventions that build on this earlier patent and that, as a result, he would have a greater incentive to protect his property rights in this area. This hypothesis is supported by the positive and significant coefficient on the variable FWDSELF, the percentage of citations which is self-citation. The point estimate implies that a one standard deviation increase in this variable raises the probability of an infringement suit by 4.0 percentage points. At the same time, we find that greater *backward self-citation* (BWDSELF) significantly reduces the likelihood of litigation: a one standard deviation rise in this variable lowers the litigation probability by 4.4 percentage points. Other things equal, greater backward self-citation in a patent indicates that an invention builds more extensively on one's own past research and is thus more likely to be a "derivative" invention. This evidence supports the idea that there are complementarities among technologically linked inventions in a firm's R&D portfolio, and that this raises the willingness to protect the property rights of inventions at the base of the chain.

In the simple comparisons in Section 3.1, we found that individual patentees litigated as often as corporate patentees. Since corporations are likely to have lower litigation costs, this finding suggested that corporations are better positioned to settle. The econometric results show that another factor is also at work - reputational concerns. When reputation is not at issue because no future citing patents come from the same technology area (SIMFWD=0), we again cannot reject the hypothesis that the litigation probability is the same for corporate and individual owners of a given nationality ($\chi^2/3=7.34$, p-value = 0.06). However, when reputation is potentially relevant (which we evaluate by calculating the effect of corporate ownership at SIMFWD equal to its mean value) we find that, among domestic patentees, corporate owners are much more likely to become engaged in a patent suit than individual owners ($\chi^2/1=4.34$, p-value=0.04). In short,

there is evidence that corporations have both lower settlement costs and strategic incentives to litigate, and that the latter effect dominates for domestic corporate patentees in the United States.

As in Section 3, we can easily reject that there are no nationality differences when we control for other factors ($\chi^2/4=375$, p-value<.01). Foreign individuals and corporations are less likely to engage in infringement suits than their domestic counterparts. For example, comparing the marginal effects of DINDOWN with FINDOWN and JINDOWN, we see that foreign owners are about 30 percentage points less likely to become engaged in litigation than domestic individual owners. A similar pattern is observed among corporate owners.

The empirical results for patent challenges are very similar to those for infringement suits, so we do not discuss them extensively. The new and striking finding is that the *marginal effects* of the covariates in the patent challenge regression are nearly proportional to those in the infringement regression. We cannot reject the hypothesis that the marginal effects are proportional to each other ($\chi^2/12=13.77$, p-value=0.33). We obtain a point estimate of 0.31 for the factor of proportionality (see the appendix for details of the test methodology).[18]

Clearly there is something to be explained. One interesting interpretation of this finding is that it reflects the positive externalities generated by a successful invalidity suit (since invalidation generates potential benefits for all competitors and users of that invention). Suppose, for argument's sake, that the probability of litigation is proportional to the expected benefits (as a reduced form of some underlying strategic litigation game.) If a firm successfully challenging a patent can only capture a fraction α of the benefits, then the marginal effect on the probability of litigation of an increase in patent value would only be α percent as large for patent challenges as for infringement suits. Under this interpretation, our point

[18] This finding is *not* an artifact of the data generation process - e.g., that patents tend to have three infringement suits and one challenge. In fact, very few patents in the data are involved in both infringement and challenge suits.

estimate of $\alpha = 0.31$ suggests that a plaintiff can appropriate about a third of the benefits from a successful patent challenge.[19]

5. Concluding Remarks

The goal of this line of research is to assess how the cost of enforcing property rights affects the structure of R&D incentives provided by the patent system. This paper shows that the frequency of involvement in court actions in the United States varies markedly with the characteristics of the patent and the patent owner. Case filings are much more common in some technology areas than others, when innovations are more valuable, when they appear to form the basis of a sequence of technologically-linked innovations held by the same patentees, when there is domestic ownership, and when they are owned by individuals, except in cases where others are active in the same technology area making reputation important. These findings indicate that the legal system both dilutes and distorts R&D incentives. We have analyzed the *incidence* of patent infringement and challenge suits. This is important information for policymaking, but for a complete assessment one would also need to know how the costs of settlement and litigation, and the *outcomes* of patent suits, depend on patent and patentee characteristics. Taken together, such evidence would allow policymakers to gauge how enforcement of property rights alters the expected net value of patent rights, and thus the effectiveness of the patent system in providing R&D incentives. This paper is a first step, and we are initiating the other studies.

Another contribution of this paper is that it illustrates the usefulness of combining detailed patent data, which has recently become available in computerized form, with other types of microeconomic data. Here we have linked court-based litigation data to the patent information. Company-level data on

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[19] An alternative interpretation is that the probability of winning a challenge suit (rather than the ability to capture profits) is lower, so that the expected benefit of litigation for any level of patent value is reduced. But this interpretation can explain the observed proportionality finding only if the probability of winning a challenge suit, relative to an infringement suit, does not itself depend on the value of the patent.

investment, sales, profits, and other characteristics could also be linked to these data, and to information on patent applications and renewals. This would make possible more detailed investigations, including estimation of structural models, in the microeconomics of innovation.

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Table 1
Litigation Rates and Composition

Panel A: Filed Cases per 1,000 Patents, 1980-1984

By Technology Group and Ownership[a,b]

	Total	Domestic	Foreign
Drugs and Health	20.1	26.6	6.5
Chemical	5.4	6.1	1.4
Electronic	9.6	12.7	3.3
Mechanical	11.8	20.1	3.4
Other	15.2	23.4	9.9
Total	10.7	16.4	3.5

Panel B: Composition of Litigation by Technology Group and Ownership

By Technology Group

	Infringements	Challenges	Unclassified
Drugs and Health	63.2	10.5	26.2
Chemical	57.0	11.5	31.5
Electronic	58.1	10.5	31.4
Mechanical	59.4	9.8	30.8
Other	57.9	8.1	34.0
By Ownership			
Domestic	60.7	10.1	29.2
Foreign	43.8	7.4	48.8
Total	58.7	9.8	31.5

Notes:
[a] The IPC categories included in each of these groups are: Drugs and Health: A61 and A01N; Chemical: A62, B31, C01-C20, D-; Electronic: G01-G21, H-; Mechanical: B21-B68 not incl. B31, C21-C30, E01-F40; Other: A- not incl. A61 or A01N, B01-B20, F41-F42, G21.
[b] Panel A is based on the sample of all filed cases. Panel B deletes cases where the patent owner is listed as both the plaintiff and defendant, which are almost surely misreported.

Table 2
The Distribution of Forward Citations (percent)

	Domestic		Non-Japanese Foreign		Japanese	
Number of Citations	Matched	Litigated	Matched	Litigated	Matched	Litigated
	(1)	(2)	(3)	(4)	(5)	(6)
0	9.1%	3.3%	17.9%	2.7%	9.1%	1.6%
1-5	60.4	36.0	70.7	37.0	62.9	32.8
6-15	31.1	39.8	24.0	39.8	29.5	37.7
16-50	8.2	22.2	5.6	19.0	7.6	27.8
>50	0.3	2.1	0.0	2.1	0.0	1.6
Mean Citations	6.3 (0.16)[a]	12.0 (0.24)	4.8 (0.19)	11.5 (0.78)	5.8 (0.32)	12.0 (1.55)
No. of Observations	2,573	3,440	899	373	396	61

Notes:
[a] Standard errors are in parentheses.

Table 3
Similarity Index for Backward and Forward Citations

	Backward Citations		*Forward Citations*	
	Matched	Litigated	Matched	Litigated
Domestic Owners				
Self-citations	0.57	0.62	0.58	0.67
	(.019)[a]	(.014)	(.017)	(.012)
Citations by others[b]	0.55	0.58	0.51	0.59
	(.010)	(.008)	(.008)	(.006)
Foreign Owners				
Self-citations	0.64	0.62	0.63	0.72
	(.026)	(.041)	(.024)	(.032)
Citations by others	0.57	0.60	0.54	0.62
	(.014)	(.025)	(.011)	(.017)

Notes:
[a] Standard errors are in parentheses.
[b] Citations by others includes all backward or forward citations where the owner of the citing or cited patent could not be directly matched to the owner of the patent. Because of entry errors in the original data and format differences, some self-citations are probably included.

Table 4
Publicity Effect of Case Filings on Forward Citations

Citation Lag	Not Yet Litigated	Litigated			
		1-yr Back	2-yrs Back	3-yrs Back	4-yrs Back
	(1)	(2)	(3)	(4)	(5)
6	0.96 (.05)[a]	1.22 (.11)	1.04 (.07)	0.95 (.08)	0.84 (.08)
7	0.96 (.06)	1.22 (.12)	1.17 (.09)	1.21 (.12)	0.96 (.09)
8	0.90 (.06)	1.15 (.17)	1.14 (.11)	0.90 (.08)	1.08 (.10)
9	0.87 (.07)	1.42 (.16)	1.08 (.13)	1.10 (.10)	0.73 (.06)
10	0.93 (.08)	1.37 (.13)	1.25 (.14)	0.84 (.09)	1.00 (.11)
11	1.22 (.11)	1.03 (.21)	1.24 (.19)	1.10 (.17)	0.89 (.10)
12	0.93 (.11)	1.46 (.15)	0.77 (.11)	1.38 (.17)	0.97 (.14)
13	1.25 (.18)	0.94 (.17)	0.88 (.14)	0.85 (.13)	0.89 (.13)
14	0.72 (.17)	1.20 (.16)	1.09 (.19)	0.84 (.11)	1.03 (.16)
15	0.67 (.26)	1.10 (.45)	1.36 (.22)	1.11 (.20)	0.79 (.14)
Mean[b]	0.94 (.04)	1.18 (.07)	1.10 (.05)	1.03 (.05)	0.95 (.04)

[a] Standard errors are in parentheses.
[b] These the overall mean numbers of annual citations taken over citation lags 6 through 15.

Table 5
Mean Claims per Patent

Panel A. Technology Class Differences

	Drugs & Health[a]	Chemicals	Electronic	Mechanical	Other
Mean Claims	13.6 (0.5)[b]	13.5 (0.5)	14.2 (0.3)	11.9 (0.2)	11.2 (0.2)

Panel B. Time Series Differences

	1975	1980	1983	1985	1990
Mean Claims	11.6 (0.4)	12.5 (0.5)	12.6 (0.4)	13.7 (0.7)	17.2 (1.6)

Notes:
[a] See notes to Table 1 for technology group definitions.
[b] Standard errors are in parentheses.

Table 6
Claims per Patent and Citations per Claim

	Domestic		Non-Japanese Foreign		Japanese	
	Matched	Litigated	Matched	Litigated	Matched	Litigated
Claims						
Mean	11.2 (0.18)[a]	14.7 (0.22)	9.7 (0.23)	13.2 (0.60)	8.8 (0.31)	10.2 (1.41)
Median	9	11	8	10	7	8
Mode	3	8	4	7	4	4
Forward Cites per Claim[b]	1.04 (0.08)	1.57 (0.07)	0.84 (0.09)	1.88 (0.29)	1.20 (0.19)	1.61 (0.32)
Backward Cites per Claim	1.21 (0.04)	1.01 (0.03)	0.98 (0.04)	0.90 (0.06)	1.10 (0.07)	0.79 (0.08)

Notes:
[a] Standard errors are in parentheses.
[b] The forward citation statistic is calculated using cohorts 1975-77 only.

Table 7
Chi-Square Tests of Differences in the Breadth of Matched and Litigated Patents

Pooled Data	χ^2/df	Df	p-value	Mean Number Matched	Mean Number Litigated
Number of 4-digit IPC sub-classes	6.68	3	<0.001	1.243	1.197
				(.009)[a]	(.008)
By Technology Group					
Drugs and Health[b]	1.15	2	0.315	1.081	1.052
				(.018)	(.019)
Chemicals	2.41	3	0.065	1.327	1.365
				(.032)	(.040)
Electronics	1.31	3	0.270	1.207	1.182
				(.016)	(.017)
Mechanical	4.48	3	0.004	1.259	1.191
				(.014)	(.012)
Other	1.30	3	0.270	1.276	1.229
				(.019)	(.016)

Notes:
[a] Standard errors are in parentheses.
[b] In Drugs and Health the maximum number of 4-digit IPC assignments in the sample is three, so the test has two degrees of freedom.

Table 8
Probit Estimation for the Patent Infringements and Challenges[a,b]

	Infringement Suits		Challenge Suits	
	Parameters	Marginal Effects	Parameters[c]	Marginal Effects
	(1)	(2)	(3)	(4)
Log Claims	0.405**	0.136**	0.433**	0.058**
	(.030)	(.010)	(.050)	(.007)
FWD Cites/Claim	0.256**	0.081**	0.230**	0.029**
	(.019)	(.006)	(.027)	(.003)
FWD Cites/CLM^2	-0.0083**		-0.005**	
	(.0011)		(.001)	
BWD Cites/Claim	-0.033	-0.010	-0.043	-0.005
	(.023)	(.007)	(.040)	(.005)
BWD Cites/CLM^2	0.0012		0.003	
	(.0011)		(.002)	
NO4IPC	-0.062*	-0.021*	-0.052	-0.007
	(.036)	(.012)	(.057)	(.008)
SIMFWD	0.278**	0.093**	0.129	0.017
	(.087)	(.029)	(.144)	(.019)
SIMFWD*CORP	0.203**	0.162**	0.223	0.047**
	(.103)	(.020)	(.170)	(.013)
FWDSELF	0.674**	0.226**	0.585**	0.078**
	(.106)	(.036)	(.165)	(.022)
BWDSELF	-1.015**	-0.341**	-0.936**	-0.125**
	(.173)	(.058)	(.307)	(.041)
DINDOWN	-1.419**	0.103**	-2.320**	0.022
	(.126)	(.024)	(.205)	(.019)
FINDOWN	-2.321**	-0.214**	-2.911**	-0.059**
	(.158)	(.024)	(.250)	(.014)
JINDOWN	-2.305**	-0.195**	NE	NE
	(.349)	(.071)		
DCORPOWN	-1.562**	0.195**	-2.466**	0.060**
	(.123)	(.016)	(.200)	(.013)
FCORPOWN	-2.321**	-0.181**	-2.963**	-0.050**
	(.129)	(.016)	(.209)	(.011)
JCORPOWN	-2.893**	-0.287**	-3.510**	-0.084**
	(.156)	(.015)	(.266)	(.008)

Table 8 Continued

	Infringement Suits	Challenge Suits
No. Observations	6151	4227
Log-likelihood	-3506.6	-1222.5
Pseudo-R^2	0.141	0.115
χ^2 Tests (df)		
No Nationality	374.7 (4): p-value < 0.001	66.47 (3): p-value < 0.001
No Corp/Individual	7.3 (3): p-value = 0.062	1.7 (2): p-value = 0.42

Notes:
[a] Statistical significance at the 0.01 (0.05) level is denoted by ** (*).
[b] Marginal effects are calculated at the population means of the variables. For dummy variables the partial effect is calculated as the increase in the probability of a case filing with a change in the dummy variable from zero to one. See footnote 17 for details.
[c] NE denotes not estimable.

Appendix. Marginal Effects Calculations and the Chi-Square Test of Proportionality

The Definition and Estimated Covariance Matrix of the Marginal Effects

Let $m(\hat{\beta})$ be vector of the marginal effects of changes in the independent variables on the probability of litigation, implied by the coefficient estimates, $\hat{\beta}$, and evaluated at the population (matched sample) variable means, $\overline{X}$. For a representative continuous variable i, the marginal effect is:

$$m_i(\hat{\beta}) = \phi(\overline{X}'\hat{\beta})\,\hat{\beta}_i. \tag{A.1}$$

where $\phi(.)$ is a standard normal density function. In the case of a variable with linear and quadratic effects, say β_i and β_{i2},

$$m_i(\hat{\beta}) = \Phi(\overline{X}'\hat{\beta})(\hat{\beta}_i + 2\hat{\beta}_{i2}), \tag{A.2}$$

where $\Phi(.)$ is a normal distribution function. In the case of a variable with an ownership interaction term, again β_{i2}, the marginal effect when the ownership dummy variable is one is,

$$m_i(\hat{\beta}) = \Phi(\overline{X}'\hat{\beta})(\hat{\beta}_i + \hat{\beta}_{i2}). \tag{A.3}$$

There are six discrete variables indicating the six possible ownership types. For a representative discrete variable i, the marginal effect is a change in the dummy variable from zero to one. The probability of litigation when i is zero is taken to be a weighted average of the probability of litigation for each of the other ownership categories. Thus:

$$m_i(\hat{\beta}) = \Phi(\overline{X}_{-}'\hat{\beta}, i) - \Sigma_{j\neq i} Pr(j|i=0)\Phi(\overline{X}_{-}'\hat{\beta}, j), \tag{A.4}$$

where $\overline{X}_{-}$ is the vector of independent variable means but with ownership dummy variable mean values replaced by zeros except for those appropriate to the ownership category indicated by the second argument, which are one. $Pr(j|i=0)$ is the sample proportion of patents falling in ownership category j, given that they are not in category i. Taking a Taylor's expansion around $m(\beta)$, the estimated variance-covariance matrix of $m(\hat{\beta})$ is:

$$V(m(\hat{\beta})) = [\partial m(\hat{\beta})/\partial\hat{\beta}]'\, V(\hat{\beta})\, [\partial m(\hat{\beta})/\partial\hat{\beta}], \tag{A.5}$$

where $V(\hat{\beta})$ is the estimated covariance matrix of the parameters.

The Chi-Square Test of the Proportionality of the Marginal Effects

The chi-square statistic was calculated by minimizing the following chi-square statistic with respect to α:

$$\chi^2(\alpha) = [\alpha m(\hat{\beta}_I) - m(\hat{\beta}_{II})]'\,[\alpha^2 V(m(\hat{\beta}_I)) + V(m(\hat{\beta}_{II}))]\,[\alpha m(\hat{\beta}_I) - m(\hat{\beta}_{II})], \tag{A.6}$$

where $\hat{\beta}_I$ and $\hat{\beta}_{II}$ are vectors of parameter estimates from the infringement and challenge probit regressions, respectively. This two-step procedure makes the test of proportionality conservative because the β parameters are not allowed to adjust to improve the fit under the constraint.