THE ENFORCEMENT OF INTELLECTUAL PROPERTY RIGHTS: A SURVEY OF THE EMPIRICAL LITERATURE

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Working Paper **6296**

NBER WORKING PAPER SERIES

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Working Paper 6296
http://www.nber.org/papers/w6296

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
December 1997

We would like to thank Joel Waldfogel and an anonymous referee for useful comments on an earlier draft. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

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NBER Working Paper No. 6296
December 1997
JEL Nos. K41, O32, O34

ABSTRACT

This paper examines several recent avenues of empirical research into the enforcement of intellectual property rights. To frame these issues, we start with a stylized model of the patent litigation process. The bulk of the paper is devoted to linking the empirical literature on patent litigation to the parameters of this model. The four major areas we consider are (i) how the propensity to litigate patents varies with the expected benefits of litigation, (ii) the ways in which the cost of litigation affects the willingness to enforce patents, (iii) how the cost of enforcing patents changes the private value of patent rights, and (iv) the impact of intellectual property litigation on the innovation process itself.

Jean O. Lanjouw
Economics Department
Yale University
37 Hillhouse Avenue
New Haven, CT 06511
and NBER
LANJOUW@ECON.YALE.EDU

Josh Lerner
Harvard Business School
Morgan Hall, Room 395
Soldiers Field Road
Boston, MA 02163
and NBER
jlerner@hbs.edu

The enforcement of intellectual property rights (IPRs)--and the threat of enforcement--are of primary importance to those engaged in innovative activities. Understanding enforcement issues is thus crucial to the design of patent law. Only recently, however, has the legal environment entered into analyses of the patent system and of the relationship between IPRs and economic decisions regarding levels of research and development (R&D) spending, trade, foreign direct investment, and so on. This paper surveys the currently available empirical literature on patent litigation.

Patent owners often turn to the courts to resolve disputes. Lanjouw and Schankerman (1997) estimate that U.S. patents from the early 1980's will, by the time they expire, generate more than one suit for every hundred patents. The legal costs incurred by patentees in defending their rights through the courts appear to be substantial and increasing. Indicative are the several new financial products that seek to address patent litigation costs. Refac Corporation (New York, New York) and the Intellectual Property Reserve Corporation (Lexington, Kentucky), for instance, allow investors to buy part-ownership in patents solely for the purpose of litigating them. There is also a nascent patent enforcement insurance market (Hofmann, 1995). These markets to date, however, have not been well developed. It is likely that their development is handicapped by the severe information asymmetries (and consequent moral hazard problems) that characterize intellectual property: the party that develops the patent is likely to have far greater knowledge of the relevant prior art than the firm that purchases a part-interest in the patent or sells an insurance policy.

This is an important set of issues. As we discuss below, the need to defend patents through costly litigation can have a significant impact on their value. For firms whose primary assets are their intangible knowledge capital, the shift in value can be substantial. Perhaps the most direct evidence is from event studies of the change in firm value upon the filing of litigation. Bhagat, Brickley, and Coles (1994) examine the market reaction to the filing of 20 patent infringement suits reported in *The Wall Street Journal* during the 1981-1983 period. They find that in the two-day window ending on the day the story appears in the *Journal*, the combined market-adjusted value of the firms fell by an average of -3.1% (significant at the 0.01 level). Lerner (1995a), using data on 26 patent suits between biotechnology firms, finds an average fall of -2.0% (again significant at the 0.01 level). This represents a median loss of shareholder wealth of $20 million. There is also evidence that the cost of litigation falls most heavily on small firms. If a defendant is unable to raise capital to finance the litigation through the external capital markets, he may be forced to settle the dispute, no matter what the ultimate merits of its case. This asymmetry is particularly troublesome in the context of patent litigation, where studies suggest that small firms are disproportionately innovative (Acs and Audretsch, 1988).

A rapidly growing theoretical literature in law and economics examines the process of dispute resolution through the courts. This literature highlights several features as affecting the probability of litigation. Among these are: the size of, and asymmetries in, the returns to the parties from litigation, or the 'stakes'; uncertainty, or asymmetric information, about case quality; and the costs of litigation and settlement. In order to give a framework to our discussion of the empirical studies, we begin in Section I by outlining a simple model based on this literature and then extend it to capture features specific to patent litigation. In Section II, we discuss the empirical studies of patent litigation and link the results of these studies to the model parameters. Section III presents empirical simulation results, which show the size of the effect of various legal policy reforms on the incentives generated by the patent system. In Section IV we look at evidence of how patent enforcement concerns shape R&D and foreign investment decisions. Section V concludes.

I. The Dispute Process

We begin by outlining a very stylized model, which allows us to characterize those filed cases which will settle and those which will go to trial. We then consider a potential plaintiff's decision whether to file a suit and the potential defendant's decision of whether to avoid harm. The purpose of this modelling is to bring together the various empirical results in a unified way.

Consider a situation where a plaintiff claims to have been damaged by a defendant and has filed a suit to obtain compensation. Whether the parties end up in court depends on the returns that they expect from litigating (the trial value of the game) relative to those they can obtain from cooperation. We specify each in turn. The plaintiff's threat point in pre-trial bargaining is his expected payoff should he go to trial. This is composed of his expected returns, which are equal to the income he can attain given the damage he has incurred, Y, plus the value of the court-awarded judgment, J, times his expectation of winning the case, W.[1] It is net of the legal costs associated with a trial, L:[2]

$$Y + WJ - L. \tag{1}$$

(Throughout, plaintiff values shall be denoted by uppercase letters, defendant values by lowercase letters.) The threat point for the defendant is similarly the payoff that he expects should he be taken to trial. It is determined by the level of income he expects given the harm that he has imposed on the plaintiff, y, minus the amount that he expects to pay if the plaintiff wins, j, times the defendant's expectation of paying, w, and again net of legal costs, l:

$$y - wj - l. \tag{2}$$

The sum of these two threat values represents the trial (non-cooperative) value of the game.

We assume that the costs associated with settlement are negligible. Suppose first that all that is at issue in the dispute is the amount of a transfer to be given by the defendant to the plaintiff (the stakes in the case are symmetric, $J = j$). The settlement (cooperative) value of the game is simply $Y + y$ plus the size of the net transfer, which here is zero. The perceived surplus available from settling rather than going to court is then:

$$-j(W - w) + (L + l). \tag{3}$$

If the parties reach a settlement whenever the surplus is positive, it follows that they settle whenever

[1] Expected income may represent net profit, if the party is a firm, or, if the party is an individual, personal income. More generally it is the expected utility of the party in monetary units.

[2] Throughout, we assume that legal costs are exogenous. In a richer model, the choice of investment in legal services by each party would be determined in a final stage of the game. The levels chosen would depend on the function mapping expenditures by each party to court rulings (see Cooter and Rubinfeld, 1989).

$$j(W - w) \leq (L + l). \quad (4)$$

Equation (4) highlights the importance of similarity in the views that the parties hold regarding likely court outcomes. In particular, if the subjective assessments of the probability that the plaintiff will win coincide, as they would with perfect information, parties will *always* settle. It follows that one explanation for trials is that parties sometimes have divergent views about the quality of the case being brought and, in particular, the plaintiff may view his case more favorably than the defendant does, i.e., $W > w$. If the plaintiff is sufficiently more optimistic about his chances, the cooperative surplus will disappear and the parties will go to the court.[3] Equation (4) also highlights the importance of the size of the stakes and the size of legal costs in determining litigation. As stakes increase, and costs fall, the likelihood of litigation increases.

Trials may also arise because the stakes in the case are not symmetric (a feature discussed further below). Suppose that $J = \alpha j$. The parties will settle then if:

$$j(\alpha W - w) \leq (L + l). \quad (5)$$

If α is sufficiently greater than one, so that the plaintiff views the returns to winning a trial as very high relative to the judgment paid by the defendant, the cooperative surplus may disappear even when the parties agree about the quality of the case (i.e., when $w = W$).[4]

When the parties have asymmetric information, equilibrium strategies may entail positive probabilities of trial even where the cooperative surplus is positive. For example, Bebchuk (1984) and Png (1983) show that, when there is asymmetric information, the parties may make unacceptable settlement

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[3]There is a long tradition in the law and economics literature exploring selection in dispute resolution, beginning with Priest and Klein (1984). In their model, imperfect assessments of case quality by both parties lead to divergent expectations about win probabilities and, as a result, trials occur (see below).

[4]α may be less than one. This means that the defendant is "paying" more than the plaintiff receives. This may be in actual costs if there is a third party to the transfer. It may also be because the defendant is more sensitive than the plaintiff to reputational concerns (see below).

offers with positive probability as a signalling device, and this probability (and thus the likelihood of trial) rises with the degree of asymmetry. Spier and Spulber (1993) show that when the plaintiff has private information about case quality and the defendant about damages, the likelihood of trial falls in the accuracy of information.

Finally, there may not be a cooperative surplus in patent disputes for a reason more specific to intellectual property. The purpose of patent protection is to restrict output in order to generate (monopoly) profits, say V_1, to reward inventors. An important feature of patent litigation is that the subject of the dispute, industry profits, changes value depending on whether the parties settle, and, if they go to trial, on what the outcome is (this point is noted in Meurer, 1989). Licensing limitations (because of antitrust policy or transactions costs) may prevent the patentee plaintiff and the infringer from restricting output in a settlement agreement to the monopoly level. Thus industry profits with a settlement, V_s, may be less than V_1. Litigation often involves attempts on the part of the infringing firm to have the patent sharply narrowed or revoked entirely. If successful, both firms may use the innovation without restraint and total profits fall to the duopoly level, V_2, again less than V_1.

To see how this special feature of patent litigation affects the decision to file cases and to litigate, we consider the threat points of the parties (equations 1 and 2) and the cooperative surplus (3) in this more specific setting. We make the following set of restrictive assumptions to more easily illustrate the point. A trial takes one year and the disputed patent remains valuable for m years after the trial if the patentee wins. Further, assume that if both parties use the innovation in the absence of a settlement, they each obtain $(1/2)V_2$. Let $W = w$ and assume that the discount rate is zero. j is the damage payment from the infringer to the patentee if the patentee wins the suit. Then the threat points may be written:

$$(1/2)V_2 + m[wV_1 + (1-w)(1/2)V_2] + wj - L \tag{6}$$

for the patentee and

$$(1/2)V_2 + (1-w)m(1/2)V_2 - wj - l. \tag{7}$$

for the infringer. The first two terms in (6) and (7) are expected income, Y and y, respectively. They are the parties' profits during the year of the trial plus expected returns over the m years after the trial. The sum of (6) and (7) is the non-cooperative value of the game.

The cooperative (settlement) value to the two parties is simply $(1+m)V_s$. Thus the cooperative surplus, the difference between the value with settlement and that with trial, is:

$$(V_s - V_2) + m\{ V_s - [(1-w)V_2 + wV_1]\} + (L+l). \tag{8}$$

The first term is the benefit of cooperation during the year of trial and it is always non-negative, as is the savings in legal costs. The second term, however, may be negative. If monopoly profits are substantially greater than those which may be obtained through licensing, and, in particular, if there is a long future, patentees may go to trial in order to maintain output restrictions.

To complete the story, we return to a general setting and move back a step in the dispute process, extending the model to consider when a *potential* plaintiff will decide to file a suit, and, moving back even further, the extent to which *potential* defendants will invest in avoiding harm in the first place. Suppose that if a suit is filed and a settlement is reached, the share of the cooperative surplus obtained by the plaintiff is θ and that obtained by the defendant, $1-\theta$.[5] Then the payoff that the potential plaintiff expects from filing a claim is:

$$(Y + W\alpha j - L) + Max\{ 0, \theta[(L + l)-j(W\alpha - w)] \}. \tag{9}$$

If the cooperative surplus (the term in square brackets) is negative, the case will go to trial and the plaintiff expects a threat point payoff (the first term only). If the cooperative surplus is positive, the case will settle and he receives, in addition, a share of the surplus.[6] Similarly, the expected payoff to the defendant if a claim is filed is:

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[5]For example, with a Nash bargaining solution $\theta = 1/2$. If one of the parties can make a take-it-or-leave-it settlement offer, that party obtains the full cooperative surplus (θ= 1 or 0), leaving the other with a threat point payoff.

[6] Settlement may occur before a case is actually filed.

$$(y - wj - l) + Max\{ 0, (1 - \theta)[(L + l)-j(W\alpha - w)] \} \qquad (10)$$

These equations determine the extent to which the potential defendant will expend resources to avoid harm. If the plaintiff's return to filing a suit (equation 9) is negative, then the defendant can act without fear of being taken to court. If the plaintiff will respond to being harmed, the defendant must balance his expected payoff if he harms the plaintiff (equation 10) with his payoff if he avoids conflict, including the costs of care.[7]

II. Empirical Evidence

This section brings together empirical evidence from patent litigation regarding the various features of dispute resolution highlighted above. The first set of studies gives some insights into the magnitude of parameters that affect the expected benefits of litigation. The second set is concerned primarily with the economic effects of litigation costs, in particular, the fact that large legal costs may be an obstacle to the success of small, high-tech companies.

Evidence Regarding the Expected Benefits of Litigation

Following Priest and Klein (1984), Siegelman and Waldfogel (1996) model the subjective win probabilities, W and w, as follows (see also Waldfogel, 1995). Consider first the plaintiff. He has an assessment of the quality of his case, say q, which is equal to the true quality of the case, q^*, plus a normally distributed, mean zero, error term: $q = q^* + \varepsilon$. The case will win at trial if the true case quality is greater than some threshold decision standard, D. Thus,

$$W = Prob(q^* > D \mid q)$$

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[7]In the case of patent disputes, the cost of avoiding harm would include maintaining an awareness of patenting activity by others and tailoring production or research activities to prevent conflicts (see below). Ordover (1978), Png (1987), and Hylton (1990) are some of the studies of deterrence and the costs of care in other settings.

or $$W = \Phi[(q - D)/\sigma_\varepsilon],\qquad (11)$$

where $\Phi[]$ represents a cumulative standard normal distribution. w is determined analogously. To estimate the model, they assume, first, that legal fees are a constant proportion of the size of the case: $[(L + l)/j] = (1/3)$; second, that true case qualities are normally distributed $\phi(0,1)$; and, finally, that the assessment errors, ε, of the plaintiff and defendant are independent. The value of a case, j, plays no role in explaining trials in this model because the first assumption ensures that differences in legal costs exactly offset any differences in value.

They estimate the model using data on cases initiated in the District Court for the Southern District of New York after 1979 and resolved by 1989. The estimation is done separately for six types of civil cases: IPRs (which includes patent, trademarks, copyright), civil rights, contracts, labor, prisoner, and torts. They find that IPR cases have the lowest uncertainty parameter, σ_ε. That is, the parties in IPR cases have a relatively precise assessment of the quality of their cases. There are a number of reasons to expect such a finding. Compared to other types of cases, IPR disputes are fairly homogeneous. Patents cases are tried by a specialized bar. In addition, in 1982 a new U.S. Court of Appeals for the Federal Circuit, CAFC, was established to hear all patent appeals precisely in order to make rulings in these complex cases more consistent and predictable.

Although uncertainty seems to be lower in patent disputes than in other types of civil disputes, more detailed data suggests that there is variation among types of patents. One might expect more uncertainty about case quality in new technology areas where there is little precedence to guide assessments of infringement and patent validity. Comparing the litigation rate for patents protecting innovations in the relatively new area of biotechnology with the litigation rates for patents in other areas of technology, the results are consistent with the idea that uncertainty impedes settlement. Based on a sample of 530 new biotechnology firms, Lerner (1995b) estimates that as many as six cases will be generated per hundred U.S. corporate biotechnology patents. This figure was obtained by dividing the number of patent suits in which the sampled firms were involved in Massechusetts during January 1990-June 1994 by the number of patents they were awarded during that period. In constrast, as noted in the introduction, Lanjouw and Schankerman (1997) estimate that there will be about one case generated per hundred U.S. patents from the early 1980's. By technology group, their litigation rates varied from a low of 0.5 cases per hundred for chemical patents to a high of two cases per hundred for drug and health patents. These estimates are based on comprehensive data on Federal Court filings available from the Inter-university Consortium for Political and Social Research (Federal Judicial Center, 1991) matched to patent data using the Patent History CD-ROM produced by Derwent. The estimate is calculated using actual case filings for the cohorts in question. Even allowing for differences in data and in the estimation method across the two studies, the litigation rate appears to be substantially higher in the area of biotechnology, and area with relatively little prior litigation to help guide expectations.

Turning to the decision standard, D, Siegelman and Waldfogel (1996) find that IPR cases are subject to the second lowest decision standard among their six types of civil suits, higher only than contracts. Their estimate of $D = 0.38$ implies a relatively high win probability of 35% for the plaintiff in filed cases. Their estimate is for the entire period, 1979 through 1989. Anecdotal evidence, however, suggests also that the decision standard fell over the past decade. With the establishment of the specialized federal appeals court, courts have become more "pro-patent," enforcing the statutory presumption that "a patent is born valid and remains valid until a challenger proves it was stillborn or had birth defects" (Judge Markey, *Roper Corp.* vs. *Litton Systems, Inc.*, 757 F2d 1266 Federal Circuit 1993).[8]

The model outlined above implies that, if there was, in fact, a fall in the stringency of the decision standard, D, applied in patent cases, there should be a larger proportion of filed cases going to trial and a higher observed win rate in later years.[9] Further, given a dispute, patentees should have become increasingly likely to file cases because of an increase in their expected probability of winning, W (equations 9 and 11). These predictions seem to have been borne out. Plaintiff win rates at trial increased from an average of 61% in the years just before the establishment of the new court to 75% by 1987 (in conjunction with a 50% increase in the number of cases tried). Between 1953 and 1978, circuit courts affirmed 62% of district court decisions holding patents to be valid and infringed, and reversed 12% of the decisions holding patents to be invalid or not infringed (Koenig, 1980). In the years 1982-1990, the CAFC

[8]Other important policy changes include instituting renewal fees for patents in 1982 and, as a result of the TRIPs agreement of GATT, a lengthening of the average statutory patent term from 17 years following the date of issue to 20 years from the date of filing.

[9] The trial rate increases until $D = 0$. It decreases as D falls further.

affirmed 90% of district court decisions holding patents to be valid and infringed, and reversed 28% of the judgments of invalidity or non-infringement (Merges, 1992). Aggregate evidence regarding the proportion of patent disputes leading to filed cases is not available.[10] Again, however, anecdotal evidence suggests that filings are becoming more frequent. For example, several firms have begun aggressively litigating patents awarded in the late 1970s, filing cases for infringement disputes that the patent-holders previously did not consider worth the time and costs of prosecution. Several companies, including Texas Instruments, Intel, Wang Laboratories, and Digital Equipment, have established groups that approach rivals to demand royalties on old patent awards. In many cases, they have been successful in extracting license agreements and/or past royalties. Texas Instruments, for instance, is estimated to have netted $257 million in 1991 from patent licenses and settlements because of its general counsel's aggressive enforcement policy (Rosen, 1992).

It should be emphasized that the probability that the patentee will prevail in 35% of the IPR cases, implied by the estimate of $D = 0.38$, is *unconditional* on the case going to trial but *conditional* on filing. Waldfogel (1996) presents empirical evidence using data on U.S. patent litigation which suggests that the probability of plaintiff success *unconditional* on filing is substantially higher. He makes use of the idea that win proportions will more closely reflect the underlying win probability if there is a great deal of uncertainty and approach 50% as uncertainty is resolved (Priest and Klein, 1984). He finds that when adjudication occurs within three months, the win proportion in favor of the patentee is 84%, whereas it is only 61% for cases completed after more than a year.[11] If the timing of adjudication is exogenous and parties gain information over time, the outcomes of cases adjudicated early more closely reflect the average probability of plaintiff success among all patent disputes.

Another finding in the study by Siegelman and Waldfogel (1996) is that IPR cases are characterized by a substantial degree of stake asymmetry. Their estimate of the asymmetry parameter is $\alpha = 1.77$. What are the possible sources of systematically higher stakes for the plaintiff? One explanation is that disputes

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[10] Certainly, patent applications and awards to U.S. applicants have increased dramatically. For an analysis, see Kortum and Lerner (1997).

[11] Adjudication includes decisions made on pre-trial motions.

are not one-off events. Either party may anticipate other potential conflicts. Winning a case may generate reputational benefits in addition to net current payments. If plaintiffs are more likely than defendants to be repeat players, their stakes will be higher. Siegelman and Waldfogel present two indicators of the extent to which reputation might be important to the plaintiff. The first is the ratio of the percentage of cases with an institutional (non-individual) plaintiff to the percentage with an institutional defendant. Since most IPR cases involve firms, the ratio is close to one. Only contract cases have a higher representation of institutional plaintiffs. Lanjouw and Lerner (1996) find a similar ratio, 0.92, in data from a later period (see below). The second indicator is the average number of previous cases that the plaintiff had been involved in relative to the average number of cases for the defendant. They find plaintiffs involved on average in 50% more cases. For both indicators IPR ranks at the top, suggesting that stake asymmetry, and hence trials, may be more closely associated with reputational concerns in patent disputes.

The statistics above reflect the relative importance of the reputations of the agents. In the case of patent litigation one can also consider reputation with respect to an individual patent. Patents vary in terms of their breadth. Some protect narrowly defined innovations with specific uses. Others protect broadly defined innovations with many possible applications. In the latter case, the patentee is likely to be licensing in multiple markets and therefore generating more potential disputes. In these situations, winning a trial against one infringer has the additional benefit of dissuading infringers in other markets.

Not only may a patent which is broad in scope be more likely to create a situation where the plaintiff has a greater stake than the defendant in the outcome of the trial, evidence suggests that broad patents are also likely to be more valuable (see below). For both reasons--greater α and greater j--one would expect broader patents to go to trial more often.

This hypothesis is explored in Lerner (1994). He constructs a proxy for patent scope based on the International Patent Classification (IPC). While the best way to measure patent scope might be through subjective assessments, this approach is a practical way to develop a sample of sufficient size for an empirical analysis. His proxy for patent scope is the number of subclasses into which the U.S. Patent and Trademark Office assigns a patent. Patent classifications are determined carefully, and extensively cross-checked by patent office officials. Patent examiners simultaneously assign firms to U.S. and IPC subclasses. The IPC system, which had its origin in the Council of Europe's 1954 European Convention, has several advantages which make it preferable for these purposes, including its nested structure. He uses the first four digits only: e.g., a patent assigned to classes C12M 1/12, C12N 1/14, and C12N 9/60 was counted as falling into two classes, C12M and C12N.

Lerner examines patenting by firms in biotechnology, an industry that relies heavily on patents to protect discoveries. He first explores the economic value of patent scope by examining the relationship between the stock of intellectual property and the valuation of firms. Because many factors other than the stock of intellectual property may affect the valuation of a biotechnology firm, particularly as the company's product approaches the marketplace and the strength of the firm's marketing and distribution arrangements become apparent, he focuses on valuations during the venture capital investment process. Venture capitalists typically invest in privately held firms. In each financing round, the venture capitalists and the entrepreneur negotiate a valuation of the firm. Intellectual property is a young biotechnology company's most valuable asset, so if a relationship between intellectual property and valuation exists, this is a natural place to observe it. He identifies the dates of venture financings through the records of two database providers, Venture Economics and Recombinant Capital, as well as other sources. The final sample consists of 962 financing rounds at 350 firms between 1978 and September 1992; for 535 financing rounds at 173 firms, he identifies the valuation of the firm at the time of the investment.

The results suggest that patent scope has an economically and statistically significant impact on the valuation of firms. A one standard deviation increase in average patent scope at the mean of the independent variables translates into a 21% increase in value. This implies that the stakes, j, are greater in disputes over broader patents.

Lerner then investigates the effect of scope on the likelihood that a patent is litigated. To do this, he examines whether firms were more likely to resolve disputes involving broader patents through the costly and time-consuming process of litigation. Using data on 1678 patents awarded between 1973 and September 1992 to independent venture-backed biotechnology firms, he estimates the following probit regression. The dependent variable, *LIT*, equals one if the patent was involved in any litigation through the end of May 1993:

$$LIT = \underset{(0.23)}{2.90} + \underset{(0.02)}{0.10\,YEARS} + \underset{(0.08)}{0.17\,SCOPE}, \qquad (12)$$

Log likelihood = -136.36; χ^2-statistic = 20.18.

where *YEARS* is the number of years from the grant of the patent to May 31, 1993, and is included as a control for truncation (standard errors in parentheses). These results imply that, at the mean of the independent variables, a one standard deviation increase in patent scope increases the probability of litigation by 41% (from 1.3% to 1.8%). Again, this is consistent with the hypothesis that patents disputes where both the stakes (j) and the *asymmetry* of these stakes (α) are high will be more likely to end up in the courts.[12]

Further evidence of the importance in the size of stakes in determining litigation activity is presented in Lanjouw and Schankerman (1997). Using U.S. data on patents in all technology areas, they investigate the relationship between a range of measures of patent breadth and value and the likelihood of litigation. One measure of the value of a patent is the number of times that it is cited by future patentees as an important antecedent invention. Revolutionary new technologies with commercial value spawn further innovative efforts in the same area and hence the related patents are often cited. Lanjouw and Schankerman find that the number of citations to a patent is very strongly correlated with the probability of an infringement suit being filed.

Evidence Regarding the Expected Costs of Litigation

The amount of legal costs is another important consideration affecting both the decision whether to risk causing harm and, in the event of a dispute, the payoffs obtained when the court is used to resolve the

[12] Interestingly, the role of patent scope (as measured by the number of 4-digit IPC sub-classifications of a patent) in contributing to litigation is not confirmed in multivariate probits using comprehensive U.S. patent data. In fact, in regressions which control for value of the patent using other indicators, as well as controlling for the type of technology and ownership, Lanjouw and Schankerman (1997) find that scope *reduces* the likelihood of litigation.

dispute. It is clear from equations (3) and (8) that the probability of having a cooperative surplus, and therefore the proportion of filed cases which are settled, depends only on the *total* legal costs associated with going to trial ($L + l$). On the other hand, for each party, own costs have a greater (negative) effect on threat points than their (positive) effect on the shared cooperative surplus. The changes in payoffs are $-(1-\theta)dL$ and $-\theta dl$ for the plaintiff and defendant, respectively (equations 9 and 10). Thus, an increase in L makes a potential plaintiff less likely to file a claim when harm occurs, and an increase in l induces a potential defendant to invest more in avoiding harm. The payoffs to either party from a dispute are increasing in the other party's legal costs.

One implication is that it is in the interests of each party to increase the legal costs of the other when a case has been filed. This point is explored in Lanjouw and Lerner (1996) in a study of the use of preliminary injunctive relief in patent litigation. (The grant of a preliminary injunction prevents an infringing firm from using the innovation during the period of the trial.) They investigate the hypothesis that financially strong firms use this mechanism to prey upon weaker firms. The threat of higher legal costs and the possibility of a cessation of operations may lead defendants to settle on less favorable terms.

Lanjouw and Lerner extend the model presented in Section I to a two-stage game. In the first stage, the patentee may settle or proceed directly to trial, as above. In addition, however, he now has the option to request a preliminary injunction. If a preliminary injunction hearing is held, then there is a second stage where, again, the patentee may decide whether to continue to trial or to settle.

The primary implications of allowing patentees to request preliminary injunctions are best seen by examining the new threat point of the infringer if a preliminary injunction is certain to be granted:

$$(1-w)m(1/2)V_2 + (1-w)j^* - [k(1-\lambda) + \delta\lambda]l, \qquad (13)$$

and comparing it to the threat point of the infringer without this mechanism (equation 7). Note that it is now the infringer that bears the damages during the trial and obtains compensation, j^*, if the patentee is unsuccessful. The last term indicates that legal costs are increased by a preliminary injunction proceeding in two ways. The share of legal services required for the preliminary injunction proceeding, $1-\lambda$, is more costly by a factor $k \geq 1$ because it must be financed quickly. The remaining share of legal services required for a trial, λ, is also more costly by a factor $\delta \geq 1$ because the injunction may constrain the infringer's production.

A comparison highlights several reasons to expect small infringing firms to be worse off when faced with an injunction. First, it is likely that a financially weak infringing firm would not be able, or asked, to fully compensate the patentee for damage inflicted during a trial ($j << V_1 - 1/2V_2$). A preliminary injunction removes this advantage, lowers the small firms' threat point (13) relative to (7) and weakens their bargaining position. Second, evidence suggests that financing constraints are more of a concern to smaller firms. Empirical studies of capital constraints suggest that an inability to obtain external financing limits many forms of business investment (see Hubbard, 1996, for a review). Studies by Himmelberg and Petersen (1994) and Hall (1992) show that capital constraints appear to limit R&D expenditures, especially in smaller firms. These financial burdens are exacerbated by legal limits on the ability of firms to raise external funds to finance litigation. Many states have adopted champerty prohibitions from the common law, which prevent uninvolved third parties from investing in a lawsuit in return for compensation if it is successful. This restriction is particularly important in the context of patent litigation, where the large costs of litigation often preclude financing suits through contingency fee arrangements with attorneys. Because financing considerations relate to size, the model predicts that preliminary injunctions will be used primarily by large firms and, in particular, those with cases filed against smaller firms. As discussed in the introduction, this is of particular concern because it exacerbates the disadvantage that financially constrained firms already face in using the court system for dispute resolution.

Lanjouw and Lerner explore the predation hypothesis empirically, using data on 252 patent lawsuits filed between January 1990 and June 1991 in six Federal districts. Bringing together data from multiple sources, they obtain the characteristics of each legal suit, in particular whether a preliminary injunction was requested by the plaintiff, as well as two measures of the resources of each party: sales and employment.[13]

[13] Their primary source for lawsuits was the PACER databases compiled by the various Federal district courts which provide a detailed listing of the litigating parties and an item-by-item catalog of the docket entries. The Federal Judicial Center's Integrated Database was used to identify patent cases. They used four sources to identify the patents involved in these cases. At the time a patent suit is filed, the Clerk of the Court is required to submit a form to the Commissioner of the U.S. Patent and Trademark Office (USPTO) which indicates the district in which the suit was field, the docket number, and the patent(s) in dispute. This information is printed in the USPTO's *Official Gazette* and compiled in the "LIT/REEX" field in LEXIS's

Since uncertainty about how the court will rule in a case may play a role in decisions about use of the court (equation 11, parameter σ_ε), they use three measures of uncertainty as controls: previous litigation of the patent, reexaminations of the patent in the patent office, and the number of total patents granted in the subclass.

The regressions examine in probit regressions whether the plaintiff requested a preliminary injunction. The regressions use the level of the size variable, sales or employment, averaged across co-litigants if there is more than one, as well as the log of the size variable for the largest of the co-litigants. In both cases, the results are similar. Plaintiff size has a positive and significant effect on the likelihood that the plaintiff will request a preliminary injunction. Using the first set of estimates, at the mean of the independent variables, a one standard deviation increase in the plaintiff's sales increases the predicted probability of a preliminary injunction request from 15% to 24%. Defendant size has a negative but insignificant effect. In other regressions, the *difference* between plaintiff and defendant size was found to have a positive and significant effect. These results are consistent with the hypothesis that financially strong firms use preliminary injunctive relief to prey upon weaker firms by driving up their costs.

Other data on enforcement suggests that large and small firms make different use of the IPR system. Lerner (1995b) analyzes the patent and trade secret litigation of a sample of 530 manufacturing firms. His data includes all the litigation in which the sampled firms were involved in the federal and state judicial districts encompassing their headquarters over a four-and-a-half year period. He finds that trade secret disputes are commonplace, representing 43% of the intellectual property litigation. Cases litigated by smaller firms disproportionately involved trade secrets, suggesting that this source of intellectual property protection is more critical to these companies. This result is consistent with the view that less established firms employ trade secrecy because their direct and indirect costs of patenting are relatively high.

PATENTS database. They also used two other databases from: Research Publications, which prepares an annual listing of patent litigation based on the information provided by the clerks to the USPTO and on the firm's independent searches of activity in the district courts and the Intellectual Property Reserve Corporation, a provider of patent litigation insurance, which has compiled its own proprietary database of patent suits that the firm employs when designing policies. Finally, information was collected from the docket files.

Finally, direct survey evidence also supports the statistical results of studies of IPR litigation. In their 1994 survey of 1,478 managers of U.S. R&D units, Cohen, Nelson, and Walsh (1996) ask respondents to indicate the most important reasons, out of five possibilities, for *not* having patented a recent innovation: difficulty in demonstrating novelty, disclosure, ease of inventing around a patent, the cost of application, and the cost of enforcement. While enforcement costs are not rated highly overall as a concern, the breakdown of responses by firm size is suggestive. They report that none of the first three reasons for not patenting is correlated with firm size. However the Spearman correlation coefficient between firm size and whether enforcement cost is listed as a concern is -0.23 and that between size and application cost is -0.15 (both significant at the .01 level). Related results come from a smaller 1990 study of 376 U.S. firms (Koen, 1991). This survey finds that the time and expense of intellectual property litigation was a major factor in deciding to pursue an innovation for 55% of the enterprises with fewer than 500 employees, but only for 33% of larger businesses. In general, small firms believed that their patents were infringed more frequently, but were considerably less likely to litigate these perceived infringements.

III. Costs of Enforcement and the Value of Patents

The previous section surveyed the empirical evidence regarding the size of the various parameters that determine whether patent disputes will be litigated or settled. Various characteristics may affect the value of bringing suit, including the expectation of winning, W, and the size of the case, J. The empirical evidence--based primarily on differences in behavior across firms of varying size--also suggests that the legal costs associated with enforcement are an important aspect of the IPR system. Lanjouw (1996) presents simulation estimates of the size of the effect of recent changes to U.S. intellectual property law and legal policy on the average (private) value of patent protection received by inventors. She also considers a legal reform being discussed in the U.S. Congress: a move from the American Rule system of legal fee allocation to the British Rule, where the loser pays the legal costs of both parties.[14] Under the latter system, the expected legal costs for the patentee are $(1 - w)(L + l)$, while those for the infringing firm are $w(L + l)$.

[14]The relative merits of the American and British rules, and variants, has been studied extensively in the theoretical literature (see Meurer, 1989, Choi, 1994, and Aoki and Hu, 1996, for patents; see Shavell, 1982,

As noted in the introduction, the legal costs actually incurred by firms resolving patent disputes in the courts have been increasing. However, direct legal costs are only part of the story. Legal policy changes also influence the value of patents that are *not* litigated. When the expected benefit of recourse to the courts is low, infringement will be tolerated (equation 9). If, for example, the expected costs of litigation rise, the level of infringement tolerated increases and the value of patent protection is correspondingly diminished. Consequently, patents will be kept in force (through payment of renewal, or maintenance, fees) for a shorter period of time, and some inventors will not find it worthwhile to patent their innovations in the first place.

Lanjouw (1996) presents estimates of some of these less visible effects of legal reforms. The estimation joins two different lines of research by embedding an infringement/litigation game in a behavioral model of patent renewal (see Lanjouw, 1993, for details). The renewal model estimates are used to calculate the value of patent protection, and policy changes are simulated by altering the relevant legal policy variables. Although the choice of simulations relates to U.S. policy, the analysis is done using German data because the recent introduction of renewal fees in the United States precludes, for a few more years, this type of analysis for that country. However, the results regarding the relative magnitude of effects apply more generally.

The data set contains more than 20,000 German patents in four technology groups, randomly sampled from those which were applied for or in force during the period 1955-1988.[15] The size and distribution of patent value implied by the parameter estimates for computers are found in the first column of Table 1, under the heading "Base." The mean value of a computer patent is 24,329 1975 deutschemarks (DM); 6.5% of computer patents never generate any positive returns. The distribution of value is very skewed, with the bulk of the value of protection going to a small share of patentees.

Reinganum and Wilde, 1986, and Hylton, 1993, for examples in general civil litigation settings). However, empirical investigations of these alternatives are few (but see Hughes and Snyder, 1995).

[15] This data set was constructed by sampling from granted patents published in volumes of the *Patenteblatte* to obtain patent numbers and IPC classifications. Then renewal information for the early cohorts was obtained from cardfiles and, for the later cohorts, from a computerized database, both located at the German Patent Office, Munich.

The simulations are presented in columns (2)-(7), with the feature being changed highlighted in bold at the top of the columns. The bottom two rows of the table show the value generated by the patent system as a percentage of its value before the policy change, and the elasticity of value with respect to changes in the indicated policy parameter.[16]

Columns (2) and (3) demonstrate the effect on patent value of moving from the German system of fee allocation (British Rule) and the 20-year statutory term limit to the U.S. system (American Rule) and the 17-year term limit in place there until last year.[17] These policy differences have a very substantial effect on the incentives generated by the patent system. Moving from the British Rule to the American Rule cuts on average about 4,000 DM from the value of a patent, or 16%. This is *before* any actual increase in legal fees paid by patentees under the American Rule is netted out. The reason for the large effect is that patentees have a high expected probability of winning at trial and therefore benefit greatly from the British rule which says that losers pay costs. This expectation in turn means that they are slower to drop their patents simply because of an unwillingness to go to court. Moving from a 20- to a 17-year term limit has an even greater negative effect on the value of patents (column 3), causing an additional 22% loss of value.

Columns (4) and (6) demonstrate the impact of a favorable shift in the court's attitude toward patentees, under the U.S. system and the German system, respectively. This shift in attitude is reflected in an increase in patentees' expectation of winning at trial, W. The size of the increase used in the simulations corresponds to the actual change in W which occurred in the United States in the 1980s following the introduction of the new Federal Court of Appeals.[18] To explore the concurrent increase in legal costs, L,

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[16] Note that all distributions were calculated with the *same* simulated patents. This means that the standard errors for the mean and percentile estimates found in column (1) do not indicate anything about the significance of the differences across columns.

[17] The filing and granting dates are treated as simultaneous which overstates the difference in systems somewhat. The effective term of a U.S. patent is, typically, longer than 17 years because the granting period is additional.

[18] Its value was calculated as follows. As noted in Section I, U.S. patentees' *observed* win proportion was 61% in 1978-1980 and increased to 75% by 1987. In other words, the probability of the infringer prevailing (1-W) fell by 36% over the period. We take this latter figure and apply it to the estimated

columns (5) and (7) indicate the magnitude of response to a 25% increase in statutory legal fees, with the associated elasticities.

Under the U.S. system, the higher likelihood of a favorable ruling at trial increases the average value per patent by 300 DM, with an elasticity of response of 0.64 (column 4). Increasing legal fees work in the opposite direction, bringing down the value of protection. The elasticity of response to legal costs is somewhat less than the response to changes in the probability of winning (-0.45 versus 0.64). Turning to the results of the same set of simulations under the German system, we see that the elasticity of response to these policy changes is, with one exception, considerably lower. However, the relative importance across the two rules of changes in W and in legal costs is as expected. Under the British Rule, when W is high, as it is here, changes in legal costs have relatively little bite since patentees do not expect to pay them. Similarly, changes in W are relatively important because being liable for both parties' costs makes losses more painful. This relationship can be seen by noting that [column(4)/column(5)] < [column(6)/column(7)].

To put these changes in patent value in perspective it should be emphasized again that these effects are felt by all patents, whether litigated or not, so that even fairly small changes can represent substantial sums in the aggregate. For example, there were 21,515 patents granted in Germany in 1975 for all technology areas. The implicit subsidy to R&D generated by the system, calculated as the total value of protection relative to the R&D expenditure related to the underlying innovations, was on the order of 10% to 15% (Lanjouw, 1993). The simulation results show that moving from the German system of fee allocation and 20-year term to the U.S. system leads to a fall in the mean value per patent of about 10,000 DM, *even if no patents are ever actually prosecuted.* Taking the sampled technology groups as representative, for Germany this difference would be equivalent to a loss of 200 million DM *per year* in the value received by inventors from the patent system (and a fall in the implicit subsidy to R&D investment to 6% to 10%). The change in the value of U.S. intellectual property from these policy changes would be considerably larger, both because of the greater number of patents involved and because U.S. patents offer protection in a much larger market.

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unconditional (on filing) win probability, W. This results in $(1-W)$ falling from 0.09 to 0.06 with a new W of 0.94.

IV. Intellectual Property Litigation and Innovation

The previous section indicated how the value of patent protection is shaped by the legal environment and the threat of litigation. Changes in the implicit subsidy rate will affect, in turn, the level of investment in R&D by firms and the innovation rate. There is evidence which suggests, however, that enforcement concerns affect not only the level of resources invested in innovation, but also the location and type of research undertaken.

As noted in Section I, as the costs of becoming involved in a suit fall, the expenditure that potential defendants are willing to incur to avoid harm in the first place increases (equation 10). In the context of patents, one way of avoiding disputes with other patentees is to avoid innovating and producing in areas where others are present. In particular, if the threat of litigation is an important concern, one would expect that small firms would tailor their R&D programs so as to avoid conflict, especially with large firms that have lower legal costs and that would be likely to actively pursue infringements.

These hypotheses are explored in Lerner (1995a) using data on the U.S. patenting behavior of 419 new biotechnology firms. As discussed in Section II, all patents are classified in one of the more than 120,000 U.S. patent subclasses. Since virtually all biotechnology discoveries are patented, the patent subclass designations are a good indicator of the areas within biotechnology that are the focus of each firm's research efforts. The costs of litigation for each firm are proxied by the firm's previous experience in patent litigation and by its paid-in capital.

Lerner finds that there are two respects in which the patenting behavior of firms varies with litigation costs. First, firms with high litigation costs are less likely to patent in subclasses with many previous awards by rival biotechnology firms. The results indicate that firms with the highest litigation costs are twice as likely as others to patent in subclasses with no rival awards. When high-litigation-cost firms do patent in subclasses in which rival biotechnology firms have already patented, they tend to choose less crowded subclasses. Breaking the sample into high- and low-cost firms, when a patent is granted to a high-litigation-cost firm, the preceding award of a patent to a rival is, on average, 303 days earlier. For low-cost firms, an average interval of only 164 days separates the patent from the most recent, previous rival award. These results are summarized in Table 2.

Second, firms with high litigation costs are less likely to patent in subclasses where firms with low litigation costs have previously patented. In his data, a patent awarded to a firm with low litigation costs is followed by an award to a firm with high litigation costs 11% of the time; awards to other firms are followed by a patent to a firm with high litigation costs 21% of the time. The results are robust to control for a variety of sample selection biases, such as the changing mixture of firms over time and the different technological focuses of various vintages of firms.

At a more macro level, differences across countries in legal enforcement are just beginning to be incorporated in studies of the relationship between IPR incentives and trade, foreign direct investment, technology diffusion, and growth. Mansfield (1994) provides survey evidence of the importance of the strength of IPR systems in shaping the foreign investment decisions of firms. The study is based on a random sample of U.S. manufacturing firms in six industries. Each firm was asked the importance of the strong intellectual property protection in various investment decisions. Twenty percent of firms reported that the strength of IPRs was a major consideration in decisions to invest in rudimentary production facilities, but about 80% deemed it important for locating R&D facilities. Interestingly, interviewees gave three areas of concern in assessing the strength of IPRs in a country: the laws, the legal infrastructure, and the willingness of government to actively enforce patent rights.

Various non-survey indicators of IPR protection have been used in cross-country analyses. For example, dummy variables indicating whether certain features of patent laws exist in a country have been included as explanatory variables (see Ferrantino, 1993). Rapp and Rozek (1990) and Gould and Gruben (1996) construct an aggregate index of the "strength" of IPR protection, again based on laws and procedures. Countries differ widely, however, in the ways in which they enforce their IPR laws. Ginarte and Park (1997) extend this approach to incorporate patent enforcement issues. In constructing their aggregate indicator, in addition to features of the law, they add measures of the availability of three enforcement mechanisms: preliminary injunctive relief (see Section I), contributory infringement pleadings; and burden of proof reversals (accused must prove that he is not infringing a process patent). Given the wide range in the effectiveness of legal enforcement across countries, further development in this direction should make IPR indicators more useful in studies of trade and development.

IV. Conclusions

This paper has examined several recent avenues of empirical research in the enforcement of intellectual property rights. To frame these issues, we initially presented a stylized model of the patent litigation process. The bulk of the paper was devoted to linking the empirical literature on patent litigation to the parameters of this model.

We summarized four distinct avenues of research. First, we examined studies of how the propensity to litigate patents varies with the expected benefits of litigation. We then considered how the cost of litigation affects the willingness to enforce patents, particularly for young capital-constrained firms. The third section also analyzed the cost of enforcing patents, but focused on how these costs affected the private value of patent rights. Finally, we considered studies of the impact of intellectual property litigation on the innovation process itself.

This area appears to be one that is ripe for further empirical exploration. Studying intellectual property litigation--and the impact of changes in system on firm behavior--may help address some of the most difficult questions in the economics of technological change. For instance, the extent to which intellectual property protection has a real impact on R&D spending and the rate and direction of technological progress is still largely unclear. The recent strengthening of patent holders' rights in the U.S. courts and elsewhere may help illuminate this issue.

Second, patent litigation is an interesting arena for examining more general models of litigation and settlement. The patent system, with its detailed classification scheme, allows researchers to assess firm behavior even in cases where suits have not been filed. A problem with the examination of filed suits is that, in many cases, the disputants engage in extensive bargaining prior to the filing of a suit. If a potential plaintiff can credibly threaten to sue, many disputes should be settled before a formal filing. Any analysis of suits will consequently face selection biases, whose effects are difficult to predict. Because patents provide a detailed mapping of firm behavior, they should be a useful arena for researching the impact of litigation--and the threat of litigation--on firm behavior.

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Table 1

Simulated Value Distributions for West German Computer Patents

Simulation	(Base)	(2)	(3)	(4)	(5)	(6)	(7)
Variables - (Bold are changes from base case)							
Fee-shifting rule	BR	**AR**	**AR**	**AR**	**AR**	BR	BR
Patent life (years)	20	20	**17**	**17**	**17**	20	20
Win probability (*W*)	.91	.91	.91	**.94**	.91	**.94**	.91
Legal fees (*L*)	Base	Base	Base	Base	**1.25*Base**	Base	**1.25*Base**
Value Distributions							
Mean	24,329 DM (2,147)	20,503 DM	15,011 DM	15,326 DM	13,338 DM	25,292 DM	24,210 DM
Percentile:							
50% (median)	13,922 DM (1,295)	5,980 DM	5,096 DM	5,096 DM	5,096 DM	15,039 DM	13,802 DM
75	32,686 (2,881)	27,682	11,296	11,399	10,778	33,192	32,651
99.9	239,868 (19,944)	237,037	232,285	232,285	227,687	239,868	239,868
Percentage of Base Value	100%	84%	62%	63%	55%	104%	100%
Elasticity	-	-	-	0.64	-0.45	1.20	-.02

NOTE--The analysis looks at the distribution of values of computer industry patents under alternative litigation environments. "Base" refers to parameter values estimated from the renewal model and other data. The other cases are selected changes. Values, in 1975 DM, are net of annual renewal and administration fees, as well as application, examination and publication costs. Calculations use 10000 simulation draws. Estimated standard errors for the value (vper) estimates calculated using a Taylor approximation: vper($_N$) ≈ vper($\underline{\omega}_0$) + $\Gamma(\underline{\omega}_0)'(_N - \underline{\omega}_0)$. Gradient matrices $\Gamma(\underline{\omega}_0)$ are approximated with central finite difference gradients calculated at $_N$.

Table 2

Location of new biotechnology firm patents, by characteristics of patentee

Panel A: Patentees divided by the number of patent lawsuits prior to award

	% of patents with no rival in subclass	**Days since last patent in subclass**
Patentee involved in no previous patent suits	31.4	270.5
Patentee involved in 1-5 previous patent suits	14.9	182.9
Patentee involved in 6-10 previous patent suits	9.1	153.6
Patentee involved in 11 or more previous patent suits	6.6	192.2

Panel B: Patentees divided by paid-in capital at end of year prior to award

	% of patents with no rival in subclass	**Days since last patent in subclass**
Patentee's paid-in capital is in bottom quartile	40.6	302.5
Patentee's paid-in capital is in third quartile	25.6	251.6
Patentee's paid-in capital is in second quartile	19.7	216.4
Patentee's paid-in capital is in top quartile	11.0	164.1

NOTE--The sample consists of 2048 patent awards awarded to 419 new biotechnology firms between 1973 and 1992. Each subclass of these patents is used as a separate observation (a total of 14885 observations). The first column indicates the percentage of the firm's patents that are in subclasses with no earlier patents by rivals. The second column indicates, for those patents that are in subclasses where a rival has patented previously, the mean number of days since the previous award by a rival. Patentees are divided by two proxies for litigation costs at the time of the award, the number of previous patent lawsuits and paid-in capital (in millions of current dollars).