In Defense of the Patent Friendly Court Hypothesis: Theory and Evidence

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Abstract: This paper studies the puzzle of what caused the surge in US patenting in the 1980s. I first argue that, under the standard view of patents, where value depends only on the appropriable rents created by the patent's exclusive property rights over related technologies and product markets, this puzzle cannot be solved. I then adopt an alternative theory, based on a growing legal literature, where patents confer additional value by minimizing asymmetric information between patentees and observers. Under this view, which has yet to be analyzed by economists, the puzzle can be solved. I relate statistics on patent applications to statistics on patent litigation to describe the puzzle and frame my inquiry. There is strong evidence that these statistics are associated. Time series of US patent applications, new patent litigations and patent litigation outcomes have significant, synchronized structural breaks, and the 1982-83 break dates provide evidence that supports the "Friendly Court Hypothesis," the contention that the establishment of the Court of Appeals for the Federal Circuit (CAFC), in 1982, is the source of the surge in patenting. Also, statistics on US patent litigation rates by foreign inventors explain why some foreign inventors' US applications growth did not surge, providing the "missing piece" of the puzzle. Under the alternative theory of patent value, I show that such a pattern is a predictable outcome of a surge in patent strength. Under the standard view, it is not possible.

JEL Classification: F23, K3, L0, O31, O34

I. Introduction

Patenting activity in the United States surged in the 1980s. In the time series of (log) US patent applications from 1951-2000 (Figure 1), I identify, using a sup-Wald test, a structural break in trend growth in 1982 and find an increase, from 1.4% to 6.2% annual growth, that is statistically significant. Given the nature of structural break testing, this is strong evidence that an exogenous event in or around 1982 triggered increased growth in US patent applications.

The Court of Appeals for the Federal Circuit (CAFC), which was established by law in 1982 as the sole appeals court in US patent infringement suits, has been substantially more favorable to patentees on the issue of patent validity than its predecessors. In an annual time series of the aggregate Appeals Court rate of affirmation of District Court rulings of "invalid" (Figure 2), I identify a statistically significant structural decrease in the mean, from 84% to 57%, in 1983.[1] Thus, the likelihood of overturning a District Court ruling of invalid nearly tripled, from a little more than 1 in 7 to about 3 in 7. Numerous legal scholars, including Goldstein (1993) and Merges (1997), have noted the CAFC's "pro patent" tendencies.

Patent litigation activity also surged in the 1980s. In a time series of new patent litigation filings for 1971-91 (Figure 3), Merz and Pace (1994) identify, using a variant of the sup-Wald test, statistically significant structural increases in both the mean and trend of the series in September 1982. I confirm their findings true.

Thus, there were exogenous increases in patent application counts, patent strength and patent litigation filings in 1982-83. The timing and synchronicity of these three statistical phenomena, each of which I prove in section II, strongly suggests that the establishment of the CAFC had significant effects on the behavior of inventors and

[1] This result is also reported in Henry and Turner (2004), who analyze a broad spectrum of time series of US patent litigation outcomes for 1953-2002.

patentees. Namely, inventors became more inclined to file patent applications and patentees became more inclined to pursue patent infringement cases against their rivals. Thus, the establishment of the CAFC is a possible explanation for the contemporaneous surges in patenting and patent litigation.

Other empirical regularities cast doubt on it, however. Kortum and Lerner (1998, 2003), in particular, show that patenting in the US in the late 1980s and early 1990s by inventors from the four foreign countries with the most US patents (Japan, Germany, Great Britain and France) was not significantly different from the pre-1982 pattern. Namely, growth did not accelerate. In addition, Kortum and Lerner show that US inventors' domestic *and international* patenting surged after 1982. Based on these findings, Kortum and Lerner conclude that the US improved as a "source" for patents but not as a "target" and reject what they call the "Friendly Court Hypothesis" for the surge in US patenting in the 1980s. Instead, they argue that increased R&D productivity explains the surge. For expositional simplicity, I refer to this alternative explanation as the R&D Productivity Hypothesis.

While Kortum and Lerner are correct that US inventors' international patenting surged after 1982, they overstate the extent to which this is evidence against the Friendly Court Hypothesis. Many structural aspects of multi-jurisdictional patenting tend to make domestic and foreign filings positively correlated in general. In particular, the marginal cost of a patent in a second country is generally lower than it is in the first. By patenting, the inventor places his invention in the public domain forever, thereby paying the full opportunity cost of surrendering its secrecy. For a second (or further) patent, however, the inventor pays only the filing fees. Hence, there are scale economies - the decision of whether to pursue patent protection is implicitly a decision of whether to pursue either zero or a plurality of patents. Thus, we should expect that when inventors file more patent applications in their own country, they file more applications abroad no matter what the reason for the original increase in home-country patenting. Most importantly, a friendly court could cause this pattern of patenting activity.

The Kortum-Lerner data on patenting in the US are quite puzzling, however. If the CAFC caused the surge in US patenting by domestic inventors, it is surprising that it had no statistically significant effect on the US patenting behavior of Japanese, German, British and French inventors. On the other hand, if some other force (such as increased R&D productivity) was behind the surge in patenting, one must conclude that it is merely coincidental that patenting surged at the exact time when both patent litigation and patent strength increased. In addition, the CAFC must have had no effect on patenting, either because it was not sufficiently "friendly" or because friendlier courts do not have a major effect on patenting.

Since Kortum and Lerner (1998), the economics literature has yet to settle on which explanation is more compelling. Hall and Ziedonis (2001) show that R&D managers in the US semiconductor industry believe that the increases in patent strength led to more patenting, while Hall (2004) estimates that patent values of US startup companies increased substantially from 1980-84 to 1985-89. Each of these findings is consistent with the Friendly Court Hypothesis. Kim and Marschke (2004) argue that R&D spending accounts for most (about 70%) of the surge in patenting and that "legal factors" may account for about 20% of the surge. In surveys, Jaffe (2000) and Gallini (2002) conclude that the puzzle remains unsolved.

Until now, the discussion of this set of events has been framed entirely within the standard economic view of patents. Under this view, the value of a patent stems from only the appropriable rents created by the patent's exclusive property rights over related technologies and product markets. As consequence, the fraction of inventions for which patent protection is sought, which I call the marginal propensity to patent (MPP), must depend on the prevailing legal strength of patents. Unfortunately, within this framework, each of the proposed explanations for the surge in US patenting in the 1980s is contradicted by one or more empirical regularities.

For the Friendly Court Hypothesis, the Kortum-Lerner finding that Japanese, German, British and French inventors' US patenting did not accelerate in the 1980s is the contradiction. For this hypothesis to be correct, it must be that the CAFC had no effect on the MPP of these inventor countries but a significant effect on the MPP of the domestic US inventors.[2] Under the standard view, such an explanation is impossible.

The R&D Productivity Hypothesis is contradicted by several empirical regularities. To see this, note that if it is true, then US patenting by domestic inventors surged only because the stock of inventions surged. Under the standard view, one must conclude that the CAFC had little or no effect on the MPP of *both foreign and domestic inventors*. That is, the CAFC has not been a friendly court. In addition to being at odds with the comments of numerous patent attorneys and legal scholars, this conclusion is contradicted directly by statistics on patent validity (which I buttress in Section II), by the survey responses reported by Hall and Ziedonis (2001) and by the measures of firm value by Hall (2004), each of which show that the CAFC was friendly and did affect the MPP of domestic inventors. It is also contradicted indirectly by historical evidence from the 1930s, which gives a precedent for an association between patent strength and patent counts in the US.[3]

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[2] The MPP is a determinant of the *growth rate* of patent applications because of the cumulative nature of patenting. When inventions are patented, they become publicly known and form the basis for future inventions from the full population of inventors.

[3] Schmookler (1966) argues that when US courts weakened patents as part of sweeping economic reforms in the 1930s, one clear result was that US patent application counts fell sharply. Scherer et al.

Thus, under the standard view, the Kortum-Lerner argument refutes the Friendly Court Hypothesis, but any evidence that the CAFC was friendly refutes any alternative explanation. Fundamentally, it is impossible to jointly explain the two observations that there was a friendly court but that some inventors did not respond to it.[4] Thus, within the standard view, there is little room for a solution.

I depart from the standard view. Instead, I appeal to recent work in the legal literature by Lemley (2000, 2001), Long (2002) and Heald (2004) and argue in favor of a broader theory of patent value. In contrast to the standard view, these authors contend that some, perhaps a lot, of a patent's value obtains independently of its legal strength. Economists have not yet studied the implications of this broader theory. I show here that if it is correct, it is possible to explain the surge in US patenting in the 1980s.

Long (2002), who gives the most comprehensive analysis of this alternative theory of patent value, contends that by reducing information asymmetries between patentees and observers, patents allow patentees to credibly convey information to observers at a lower cost. To get a patent, an inventor must detail the specifications of his invention, its preferred embodiment, its' improvements over the prior art, etc., and prove his invention is novel, useful and non-obvious. In addition, an inventor faces penalties for misrepresenting his invention. Thus, if the invention is patented, observers gain substantial information about the nature and veracity of the invention merely by reading the patent. Relative to trade secrets, this reduces transactions costs associated with selling, mortgaging, contracting on or organizing a partnership around the

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(1959) show that companies forced to license their patents for unfavorable royalties dramatically curtailed their patenting.

[4] It is also impossible to explain sector-specific explanations for the surge in US patenting. This includes Kortum and Lerner's Fertile Technology Hypothesis (which they reject).

invention. Clearly, this reduction in costs obtains independent of the legal strength of patents.

In addition, Long writes, patents may signal positive firm attributes, such as high inventive aptitude, product quality or commitment to entering a particular market. Thus, firms may obtain patents, in part, to distinguish themselves from firms without these characteristics. Long appeals to the corporate finance literature to motivate this "signaling" function of patents, arguing that patent ownership improves a firm's chances to attract investors. Although signaling for these reasons has not yet been applied to patenting in the economics literature, Long's argument is well grounded in the economic theory of signaling. It is well known, from classical economics papers such as Spence (1973) and Milgrom and Roberts (1982), that for an action to credibly signal a characteristic (e.g. only high quality firms undertake the action), it must be sufficiently costly.[5] But the action need not, in and of itself, create anything intrinsically valuable. For instance, Milgrom and Roberts (1986) show that "uninformative advertising," an intrinsically wasteful expenditure, may signal firm quality and thus exist as a complement to price in an equilibrium strategy.[6] Thus, as Long maintains, even intrinsically "worthless" patents may have value as signals. Moreover, given that patent counts are correlated with positive firm attributes empirically, firms have the incentive to use patents to signal these qualities. Lemley (2000, 2001) for instance, notes that venture capitalists correlate patent applications with good company management and tend to finance companies when they have more patents.

[5] Spence (1973) models an individual's choice of how much (costly) education to pursue as a signal of "ability" in a model of hiring. High ability workers choose high levels of education. In the Milgrom and Roberts (1982) "limit pricing" model, a low-cost firm may signal that it is such with a low price in the first period (which lowers its first-period profit), convincing a potential entrant to stay out of the market.

[6] The low quality firm is unwilling to undertake the uninformative advertising in a "separating" equilibrium, so the high-quality firm distinguishes itself.

Heald (2004) argues that patents promote "affirmative asset partitioning," which reduces the transactions costs associated with team production problems and technology sales. In turn, this enhances a firm's ability to conduct long-term planning and attract investors. These costs are distinct from, though similar to, the information costs discussed by Long.

When patents are sought for the reasons these authors discuss, changes to patent legal strength need not affect the value of all patents. In particular, it will affect the value of only those patents that are credibly worth litigating. As I show, when this holds an inventor's MPP need not depend on patent legal strength. Thus, it is possible to jointly explain the presence of both a friendly court and of some inventors who did not respond to it in the 1980s.

The keys to my analysis, and the major contributions of this paper, are empirical and theoretical analyses of patent litigation and its relationship to the sensitivity of inventors (i.e. how the MPP depends on legal strength). These are necessary both to assess the "pro patent" tendencies of the CAFC and to characterize the determinants of an inventor's MPP. Yet, surprisingly, no paper in the economics literature has studied patent litigation in the context of the 1980s surge in patenting.

First, in addition to revisiting statistics on patenting and new patent litigations in the 1980s, I directly analyze the CAFC. From its very first case, the CAFC has enforced a presumption of patent validity far stronger than its predecessor courts. The result has been a staggering increase in the likelihood of overturning district court rulings of "invalid." I measure this difference using a time series analysis of a new data set of decisions in US patent cases from 1953-2002.

Second, I analyze empirical patent litigation rates of inventors from foreign countries. Allison and Lemley (1998) and Lanjouw and Schankerman (2001) have shown that domestic inventors are substantially more likely to litigate their patents. I confirm this for data drawn from my 1953-2002 data set. I also show that, among the 10 countries accounting for the most US patenting from 1950-76, my measure of their empirical US litigation rates explains a significant amount of their US patent application growth rates after 1982. Namely, holding constant average applications growth from 1960-82, "inventor countries" with lower rates of (pre-CAFC) patent litigation of their 1950-76 patents experienced lower average applications growth after 1982. This analysis shows that the determinants of patent litigation rates explain a significant percentage of the variation in post-1982 applications growth among these 10 inventor countries. I also show that Canada, which had the second-highest litigation rate (behind the US), experienced a surge in US patenting very similar to that of domestic US inventors.

These results are important for a number of reasons. They indicate that, in failing to account for inventor heterogeneity with respect to patent litigation rates, the Kortum-Lerner test of the Friendly Court Hypothesis is biased to reject it. They also suggest that patent strength is more likely to have little or no effect on an inventor's MPP when that inventor infrequently litigates his patents. This hints at an explanation for why foreign inventors' patent applications growth did not generally accelerate in the 1980s, which is the only major "missing piece" of the puzzle for the Friendly Court Hypothesis. However, theory is needed to explain how this is the case.

Unfortunately, no existing theory links inventors' MPPs and their observed litigation rates, so the importance of patent legal strength (e.g. a friendly court) on both is unclear. To build a theory, I develop and analyze a simple, stylized, decision-theoretic model. It yields sharp predictions that bear directly on the received literature discussed earlier.

To focus on the MPP and patent litigation rates, I abstract from the R&D investment decision and take the stock of inventions as given.[7] In my model, the determinants of patent counts and patent litigation rates include the likelihood of patent issue, the cost of a patent application, the likelihood of infringement, the likelihood of successful litigation, the cost of litigation, and the relative value of the invention in its various states (unpatented, patented and uninfringed, and patented and infringed). My choices of determinants reflect recent contributions in both the economics and legal literatures. For instance, two prominent explanations have been advanced to explain why foreign inventors seldom litigate their patents. Lanjouw and Schankerman (2001) argue that foreign inventors face larger fixed costs of litigation, while Moore (2003) argues that foreign inventors face "xenophobic" US courts. My model permits the study of both of these explanations.

In modeling the relative value of an invention in its various states, I permit the possibility that some of the value of obtaining a patent is realized regardless of whether inventors are credibly willing to sue if the patent is infringed. Following Long (2002), I refer to this, for convenience, as "signaling" value. Since I am interested in assessing the *implications* of signaling value, I abstract from the complicated problem of modeling signaling as an equilibrium. Instead, for simplicity, I model it with a single parameter, μ, and, for comparison, nest the important case where patents have no signaling value ($\mu = \gamma$).

In the model, an inventor's litigation rate and his MPP are endogenous. Consistent with my simple empirical analysis, I show that an inventor with larger litigation costs (or poorer chances of winning in court) litigates a smaller percentage of his patents. I also show that inventors with sufficiently large litigation costs, who

[7] To apply my results to growth rates, however, I implicitly assume that one year's patents form the basis for next year's stock of inventions.

therefore have a sufficiently small litigation rate, are not "sensitive" to patent legal strength - that is, their MPP does not depend on it. However, a necessary condition for an inventor's MPP to be unaffected by a friendly court is that patents have positive signaling value ($\mu > \gamma$). In contrast, when all value is based on legal strength, all inventors' MPPs would increase with the establishment of a friendly court.

These results shed considerable light on the received empirical literature. If patents have signaling value, it is possible to explain why some countries' inventors were not sensitive to the CAFC while others' were, thereby bolstering the Friendly Court Hypothesis. If not, however, all inventors are sensitive to legal strength. If this holds, any explanation for why some inventors' patenting surged in the 1980s while others' did not must be predicated on the CAFC not being friendly. Since it is clear that the CAFC has been friendly, the results from the signaling case are more consistent with the known empirical regularities.

This is also true with respect to patent litigation rates. If patents have signaling value, it is possible to explain differences in observed litigation rates as *direct* consequences of either differences in litigation costs (Lanjouw and Schankerman, 2001) or xenophobia (Moore, 2003). If all value is based on legal strength, however, this is not possible. Differences in observed litigation rates depend on differences in litigation and/or xenophobia only *indirectly*, through different probabilities of infringement and/or settlement. Thus, if this case holds, the results of Lanjouw and Schankerman (2001) and Moore (2003) must be reinterpreted.

This paper is organized as follows. Section II discusses the establishment of the CAFC and analyzes the structural stability of time series of patent validity, US patent applications and new patent litigations. Section III analyzes the relationship between observed US patent litigation rates and US patent applications growth for 10 countries. Section IV presents the theoretical model. Section V concludes.

II. Contemporaneous Structural Breaks

In the introduction, I claim that there were contemporaneous increases in the exogenous components of time series of log US patent applications, of new patent litigations and of the likelihood of overturning a district court ruling of "invalid" in a patent infringement suit in 1982-83. In this section, I verify this claim. I also illustrate the key insight from Kortum and Lerner (1998) that foreign inventors' US applications did not surge to the same extent as domestic applications. In section III, I show how the variability in foreign inventors' propensities to litigate helps to explain these results. These empirical regularities frame this and all future inquiries into the nature of the surge in US patenting in the 1980s.

In attempting to identify exogenous, permanent changes to time series of interest, I appeal to structural break testing.[8] Following Vogelsang (1997), this entails running ordinary least squares (OLS) regressions of the following AR($jmax$) model:

$$\Delta y_t = \beta + \psi t + \beta' 1(t > T_B) + \psi' 1(t > T_B)(t - T_B) + \rho y_{t-1} + \sum_{j=1}^{j\max} \kappa_j \Delta y_{t-j} + \varepsilon_t \qquad (1)$$

With this model, one may test for breaks in the mean, trend or both. Any changes in the mean and/or trend parameters occur, by definition, in the first year after the break T_B. The lagged values $\{\Delta y_{t-j}\}$ are included in the regression to eliminate serial correlation in the error term and the lag-length $jmax$ is chosen by iterative testing of the statistical significance of the final lag of Δy_{t-j}. The regression is first run with $jmax = 4$. If κ_4 is statistically different from zero at the 5% level, then $jmax$ is increased to 8 and the

[8] Hall (2004) also performs structural break tests on series of US patent applications and finds similar results.

regression is run again. If it is insignificant, the regression is run again with *jmax* = 3. This is repeated until the final lag is significant or *jmax* = 0, in which case no lags are included. For each possible break date, *jmax* is estimated and the Wald statistic testing the null hypothesis that $\beta' = \psi' = 0$ is computed using a regression with *jmax* lags (when testing for a mean break only, it is specified that $\psi = \psi' = 0$). The largest Wald statistic, called the sup-Wald statistic, is used to estimate the timing of the break and to test for the statistical significance of the break. Critical values for these tests are available from Vogelsang (1997) in Table 2, p. 825.[9]

Since the critical values depend upon whether the underlying stochastic process is stationary, I also report the augmented Dickey-Fuller (ADF) t-statistic at the estimated break date. This statistic can be used to test for a unit root. Specifically, the null hypothesis is that $\rho = 0$, while the alternative is that $\rho < 0$. With this construction, the *persistence* of the series is $1 + \rho$ (so that persistence = 1 when a unit root is present). Since this statistic is also based on the estimation of T_B, this is not a standard ADF test for a unit root, so the critical values are different. This unit root test has been developed and analyzed by Zivot and Andrews (1994), however, so the critical values are available.[10]

The Surge in Patenting - In the first regression the dependent variable, Δy_t, is the first difference of the log of US patent applications. Data for this series, which covers 1951-2000, comes from two different sources. Application counts for 1963-2000 come

[9] If the underlying series is stationary, the critical values are: 10%, 9.24; 5%, 10.85; 1%, 14.99. If the underlying series contains a unit root, the critical values are: 10%, 16.14; 5%, 18.20; 1%, 22.64.

[10] The Zivot-Andrews statistic measures T_B using the same iterated procedure as the sup-Wald test, except that it picks the *smallest* ADF t-statistic. In the analysis here, the T_B selected by this procedure is the same as the T_B selected by the sup-Wald test. The critical values are: 10%, -4.58; 5%, -4.80; 1%, -5.34.

from the United States Patent and Trademark Office website (www.uspto.gov), while data for 1951-1962 come from “Industrial Property Statistics,” WIPO (http://www.wipo.org/ipstats/en/). To illustrate the Kortum-Lerner result, I also test for breaks in series of "domestic" and "foreign" applications.[11]

I consider all years from 1957-1998 as possible break dates, and separately choose *jmax* for each potential break year considered. The results of these tests are presented in the first three columns of Table 1. For the series of total applications, the sup-Wald statistic (29.80) selects 1982 as most likely break date and is highly significant, even assuming that the series includes a unit root in addition to the structural break (the 5% critical value is 25.27). The t-statistic for the coefficient estimate for β would not be significant at the 5% level even using conventional critical values, but the break in the trend is significant. The coefficient estimates for ψ' (.023) and for ρ (-.52) indicate an increase of $\frac{\bar{\psi}'}{-\bar{\rho}} = \frac{.023}{.48} = .048$, or 4.8%, in baseline trend growth.[12]

[11] In building these series, I encounter one minor data issue. For 1962, I can find an observation for “total applications” only (which is 85,180). To estimate “domestic” and “foreign” for this year I use linear interpolation of the trend in the fraction of applications attributable to foreign inventors over the years 1961-1963. In 1961, domestic applications comprised .795 of total applications, while in 1963 they comprised .777. I thus estimate that in 1962, domestic applications comprised .786 of total applications, which translates into 66,951 domestic applications. My results are not qualitatively different if only data after 1962 are used.

[12] An AR(jmax) centered on a non-zero mean is constructed as follows: $y_t = d_t + u_t$, where $d_t = \varpi + \theta t$ gives the deterministic part of the series (ϖ is the mean and θ is the trend) and $u_t = \sum_{j=1}^{j\max} \lambda_j u_{t-j} + \varepsilon_t$ gives the stochastic part. The series y_t evolves as $\Delta y_t = \beta + \psi t + \rho y_{t-1} + \sum_{j=1}^{j\max} \kappa_j \Delta y_{t-j} + \varepsilon_t$, where $\beta = -\varpi\rho + \theta(1+\rho)$ and $\psi = -\theta\rho$. Hence, the estimate of $\bar{\theta}' = \frac{\bar{\psi}'}{-\bar{\rho}}$.

For the series of domestic applications (second column), the sup-Wald statistic selects 1982 as most likely break date and is 32.21, which is also highly significant (the 1% critical value is 30.44). The coefficient estimates for ψ ' (.037) and for ρ (-.47) indicate an increase of about 7% in baseline trend growth. For the series of foreign applications (third column), the sup-Wald statistic selects 1974 as the most likely break date and is 16.56, which is not statistically significant. The ADF t-statistic of -3.76 is not significant, so the critical values for a non-stationary time series apply. Since the 10% critical value in that case is 22.60, the sup-Wald statistic is not significant.

Thus, based on these tests, the surge in US patenting appears to be the result of a permanent exogenous change. It also appears to be a domestic phenomenon, as Kortum and Lerner found. Indeed, the third column of Table 1 presents in sharp relief the puzzle to be resolved. As we show in Section III, however, the aggregate statistics hide some important features of US patenting by foreign inventors.

The Friendly Court - The Court of Appeals for the Federal Circuit (CAFC) was created by the Federal Courts Improvement Act in March 1982 and began hearing cases October 1, 1982. It was given dominion over appeals of all patent judgments in US District Courts and was thus granted considerable power over the patent law. Although various parts of the patent law changed for other reasons in the 1980s, I focus on the CAFC because its changes affected patents and patent litigation generally.[13]

[13] Other important changes to patent law include the University-Government Inventions Act (1980), commonly known as the "Bayh-Dole Act," and the Drug Price Competition and Patent Term Extension (1984), commonly known as the "Hatch-Waxman Act." The former, discussed in Thursby and Thursby (2003), granted ownership of inventions financed with federal monies to the inventors themselves. The latter permitted pharmaceutical companies to reclaim patent protection for time spent in FDA trials, and also streamlined the introduction of generic drugs. See Lawrence Kastriner (1991) for a more extensive survey of changes.

In its very first appeal, *South Corporation et al. v. United States*,[14] the CAFC adopted the holdings of its ancestors, the US Court of Claims and the US Court of Customs and Patent Appeals, as binding precedent.[15] These precedents include a presumption of patent validity that may be overcome only by "clear and convincing evidence" of invalidity shown by the alleged infringer (or patent challenger). Prior to 1982, the geographical US Circuit Courts of Appeal heard virtually all appeals of decisions in patent infringement cases. These courts adopted different standards of validity that were often clearly less favorable to the patentee. For instance, the 6th Circuit endorsed the weaker "preponderance of the evidence" standard in *Dickstein v. Seventy Corporation et al*, noting in the opinion that the 2nd Circuit used this standard as well.[16]

Numerous patent attorneys and legal scholars (Kastriner, 1991 ; Harmon, 1992 ; Goldstein, 1993) have noted the CAFC's strengthening of the presumption of validity,[17] while Dunner et al. (1995) measured an empirical rate of patent validity (under the CAFC) substantially higher than Koenig (1980) found for the geographical Circuit Courts of Appeal prior to 1982.[18] It is also generally believed that the CAFC has been

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[14] 215 USPQ 657 (October 28, 1982).

[15] The US Court of Claims and the US Court of Customs and Patent Appeals (CCPA) were combined to form the CAFC. The CCPA had heard patent appeals from primarily the US Patent and Trademark Office's Board of Patent Appeals and Interferences and the US International Trade Commission.

[16] 187 USPQ 138, 140 (6th Circuit, 1975). "We are therefore of the opinion that in this case, and in the usual patent case in which validity is proved with similar evidence, a preponderance of the evidence is sufficient to establish invalidity. In this regard we are in agreement with the Second Circuit."

[17] Kastriner (1991, p. 10) refers to the enforcement of the presumption of validity as "the first step taken by the CAFC which materially strengthened patents." Harmon (1992, p. 575) writes that "the Federal Circuit's rigorous observation of the presumption of validity" has made obviousness a more difficult defense in patent litigation. Goldstein (1993, p. 365) states "The CAFC has not only eliminated intramural conflict and forum shopping. The court has also buttressed the patent grant itself, giving new force to the statutory presumption of validity."

[18] Koenig (1980) reports that during 1968-78, Circuit Courts of Appeal found 31% of adjudicated patents valid. Dunner et al. (1995) report that during 1982-94, the CAFC found patents valid in 67% of adjudications. Koenig (1980) gathers data from the *United States Patents Quarterly* (*USPQ*). This excludes cases where the patent was found not infringed and validity was not an issue Dunner et al. (1995) provide more specific data. They report the disposition of the court on patent validity under sections 102, 103 and 112 of Section 35 of the US Code. Disregarding instances where the CAFC vacated a lower court ruling (which occurred in, respectively, 10%, 11% and 17% of cases), it held patents valid under

more favorable to patentees with respect to preliminary injunctions and damage awards.[19]

Here, I give further evidence that this increased rate of validity is directly attributable to the presence of the CAFC. I rely on a hand-gathered data set of patent decisions published in the *United States Patents Quarterly* (USPQ).[20] All patents adjudicated (i.e. ruled "invalid," "not infringed" or "valid and infringed") in cases with at least one ruling published in the USPQ during 1953-2002 are included in the data set. Thus, it includes all patents involved in published appeals court rulings and a small number of patents involved in published district court rulings whose appeals court rulings are unpublished.[21]

I focus on decisions in appeals of district court decisions finding patents "invalid." This is the cleanest way to assess the appeals courts' handling of validity, because the appeals court is almost certain to address the validity of the patent in such cases. I build a simple annual time series of the rate of affirmation of these decisions. That is, each year's measure is the number of patents affirmed invalid by appeals courts divided by the total number of patents found invalid (by the district court) that were appealed.

Since each year's measure is, by construction, bounded between 0 and 1, a model with non-zero trend growth is unreasonable for this series. Thus, I test for a break in the mean only, and set $\psi = \psi' = 0$ in equation (1):

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these sections, respectively, 64%, 66% and 77% of the time. The 67% figure combines the data from all three sources of patent validity adjudications. Note that a patent may be adjudicated under more than one section.

[19] see Harmon (1992).

[20] These statistics are taken from a data set gathered for a separate study of patent litigation (see Henry and Turner (2004), available from the authors on request). All patents adjudicated (i.e. ruled "invalid," "not infringed" or "valid and infringed") in cases with at least one ruling published in the USPQ during 1953-2002 are included in the data set. Thus, this includes both published district court rulings and unpublished district court rulings whose appeals court ruling was published. In a fraction of this latter category of rulings, I was unable to identify a district court date. In those cases I estimated the date by using the average length of time between district and appeals court ruling among all observations.

[21] Nearly all appeals court rulings are published.

$$\Delta y_t = \beta + \beta' 1(t > T_B) + \rho y_{t-1} + \sum_{j=1}^{j\max} \kappa_j \Delta y_{t-j} + \varepsilon_t \qquad (2)$$

The mechanics of this structural break test are identical to that for the series of log patent applications, but the critical values for the sup-Wald statistic are different.[22]

The results are presented in the fourth column of Table 1. The break β' is estimated at -.36 in 1983 and the sup-Wald statistic, 26.7, is significant at the 1% level. Based on the estimate of ρ (-1.35), the estimates of β and β' imply a series mean of .84 up to 1983 and a mean of .57 after 1983 (recall footnote 12). Thus, the likelihood of overturning a decision of "invalid" on appeal increased more than two and a half times, from 16% to 43%. The break year estimate of 1983 is just one year after the CAFC was established and, other than this break, the series demonstrates little persistence (it is estimated to be -.35 and this estimate is not significantly different from zero). Thus, this is strong evidence that the CAFC's standard of patent validity is responsible for the drop in the rate of affirmation of "invalid" decisions after 1983.

***New Patent Litigation* -** Given a strengthening of patents, it would not be surprising if patent owners were to respond with more litigation. It is striking, however, to see how immediate and sharp the surge in new patent litigation was in the 1980s. Recall Figure 3. Merz and Pace (1994) identify a large, highly significant structural increase in the mean and trend of new litigation filings with an estimated break date of September 1982, six months after the CAFC was established by law and one month before it heard its first case.[23] However, their testing procedure is different than the one I use in this paper and they do not use correct statistical inference in stating their results.

[22]In the case of a stationary time series, the critical values are: 10%, 9.24; 5%, 10.85; 1%, 14.99. In the case of a unit root, the critical values are: 10%, 16.14; 5%, 18.20; 1%, 22.64. See Vogelsang (1997).

[23] The data in Figure 3 are the same that Merz and Pace (1994) analyzed, but are presented in quarterly form here. They are collected by the Administrative Office of the US Courts and are maintained

I verify here that their ultimate conclusions are correct. I test the time series of new patent litigations for 1971-91 for structural breaks in the mean and/or trend. In contrast to Merz and Pace, I analyze this series in quarterly form to emphasize how remarkably little persistence this time series has apart from one major structural break. To perform the test, I use the regression from equation (1). The results are presented in the fifth column of Table 1.

The structural break is estimated for the third quarter of 1982 and the sup-Wald statistic of 30.70 is significant at the 1% level. The evidence indicates that both a mean and trend break occurred, as the t-statistics for the coefficient estimates of β' and ψ' are both larger than 3. The estimates of β (231.91), β' (49.57) and ρ (-1.09) imply a mean of approximately 213 new litigations up to the third quarter of 1982 and 259 afterwards (recall footnote 12). The estimates of ψ (-.063) and ψ' (1.521), along with the estimate for ρ imply near zero trend growth up to the third quarter of 1982 and about 1.4 additional new litigations each quarter afterwards.[24] Just as with the affirmation rates time series, there is remarkably little persistence here. The estimate for ρ implies the series' persistence is .09 and this is not significantly different from zero. Thus, this is an extremely sharp break. Given its timing, just prior to the CAFC's first case, this strongly indicates that the establishment of the CAFC caused the surge in new patent litigation.

Summary - These statistical findings form a strong circumstantial case that the precedents adopted by the CAFC strengthened patents in a significant way, that this strengthening of patents by the CAFC was economically meaningful for patent owners

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by the Federal Judicial Center. They are available from the Inter-University Consortium for Political and Social Research (ICPSR) in Ann Arbor, MI.

[24] Note that this time series does not control for the growth in the number of US patents. If that is done, the results do not change qualitatively. Estimated trend growth is not both before and after the 3rd quarter of 1982, because the number of US patents grew consistently over 1971-91, but there is still a significant structural break in both the mean and trend in the 3rd quarter of 1982.

and that they understood it well. Given that domestic inventors' patenting also surged precisely when patent strength and new patent litigation increased, it seems likely that many of them came to view potential patents for new inventions more favorably.

Indeed, it is surprising that apparently not all inventors increased their patenting in the wake of the establishment of the CAFC. Based on the structural break test, foreign inventors responded much less - perhaps not at all. However, aggregation of all foreign inventors' patenting into one series may hide some features of foreign inventors' behavior that can help explain this discrepancy. In the next section, I identify an important source of inventor heterogeneity that explains a significant amount of it.

III. Heterogeneous Inventors

The empirical regularities described in section II make two things clear. First, the CAFC has been a substantially friendlier court than its predecessors. Second, patenting and patent litigation activity surged almost exactly when the CAFC was established. However, to explain the surge in US patenting in the 1980s, one must explain why domestic patenting accelerated more than foreign patenting and why some foreign countries' patenting did not accelerate at all.

In this section I show that inventor heterogeneity with respect to propensity to litigate explains a significant amount of the variation in the growth rate of US patent applications among inventor countries. In contrast to the structural break analysis of the previous section, the statistical analysis here is straightforward, consisting of four elementary regressions and a scatter plot. It highlights the shortcomings of the Kortum-Lerner test of the Friendly Court Hypothesis and motivates the balance of this paper.

Both an inventor's propensity to litigate and the rate of annual growth of his applications are endogenously determined. As I argue later in the paper, they are, in fact, jointly determined. They both may be affected by litigation costs, the probability of successful litigation and other factors. If so, there should expect to see a statistical association. In addition, the *determinants* of an inventor's propensity to litigate should be associated with his rate of applications growth.

I consider the ten countries accounting for the most US patents from 1950-76: 1. US, 2. Germany, 3. Great Britain 4. Japan, 5. France, 6. Canada, 7. Switzerland, 8. Sweden, 9. The Netherlands, 10. Italy. For each country, there were more than 10,000 US patents issued, during this period, to inventors living there. For each inventor country, I calculate three statistics: 1. The fraction of these (1950-76) patents adjudicated in years up to and including 1982 and published in the United States Patents Quarterly (USPQ) - I denote this measure *PLit*,[25] 2. Average growth in patent applications (APPS) from 1960-82, $\bar{g}_{60-82} \equiv \frac{1}{22}\left(\sum_{t=1961}^{1982}\left[\ln(APPS_t) - \ln(APPS_{t-1})\right]\right)$, and 3. Average growth in patent applications from 1982-2000, denoted $\bar{g}_{82-00} \equiv \frac{1}{18}\left(\sum_{t=1983}^{2000}\left[\ln(APPS_t) - \ln(APPS_{t-1})\right]\right)$.[26] I refer frequently to the difference of measures 2 and 3, $\Delta g \equiv \bar{g}_{82-00} - \bar{g}_{60-82}$.

Using ordinary least squares, I regress $\bar{g}_{82-00}$ on a constant, $\bar{g}_{60-82}$ and *PLit*. Note that *PLit,* when constructed using patents adjudicated before 1983, is essentially an instrumental variable for the determinants of *PLit* after 1983. My regression is thus

[25] I choose the 1950-76 window to get the best possible pre-1982 estimates of the adjudication rate. Because few patents are adjudicated in the first couple of years, I do not miss many adjudicated patents from 1950, 1951 and 1952, so I include these years. Additionally, I would gain few observed adjudications by adding 1977-82 patents but would add large numbers of patents, diluting the statistics further. The results I present here are robust to alternative estimation windows.

[26] Patents are assigned to countries based on the first inventor listed on the patent. Data on country-specific patent applications are from Federico (1964) for data prior to 1965 and from the USPTO's website from 1965-2000. Federico's numbers are estimates for years prior to 1960, which I why I start there.

able to measure the effect of these determinants on $\bar{g}_{82-00}$ while avoiding endogeneity bias.

The results are presented in Table 2. I run four different regressions because it is plausible to argue that two inventor countries, Japan and the US, are outliers. I run regressions that exclude each observation and one that excludes both. The first regression includes all 10 observations. There, the coefficients on both $\bar{g}_{60-82}$ and *PLit* are positive and significant at the 1% level. The estimate of the coefficient on *PLit* (.0026) implies that an additional 1 adjudicated patent per 10,000 among an inventor country's 1950-76 US patents is associated with just over an additional quarter percent of average annual growth in his patent applications from 1982-2000.

Figure 4 is a scatter plot of Δg versus *PLit*. Two observations, Japan and the US, are potential outliers. Japan (lower left) experienced an unusually large reduction in applications growth after 1982, while domestic US inventors (upper right) litigated an unusually large number of their 1950-76 patents. When I run the regression without these observations, the results change, but *PLit* remains significant. When Japan is omitted, all coefficient estimates are nearly identical to the estimates in the first regression, but that on $\bar{g}_{60-82}$ is no longer significantly different from zero. When the US is omitted, the coefficient estimates change considerably. In particular, the coefficient on *PLit*, .0057, is more than twice as large as in the first regression. When both Japan and the US are omitted, the coefficient on *PLit* rises further, to .0068.

Based on these regressions, it is clear that *PLit* explains a significant amount of the variation in $\bar{g}_{82-00}$. Perhaps the most interesting finding is that *PLit* is more important among the foreign inventor countries. The US, despite having the largest

$PLit$ and largest Δg values, is not driving this statistical result. Moreover, given the number of observations and nature of the data, this is not a particularly powerful test. Thus, this strongly suggests that the Friendly Court played a role in driving the surge in US patent applications by foreign inventors and had a greater effect on inventor countries that more frequently litigate their patents. Interestingly, the country with the second-largest $PLit$ and Δg values is Canada, which Kortum and Lerner (1998) did not include in their analysis.

One must be careful not to conclude too much from this analysis, however. Because patent cases usually settle before the patents are adjudicated, my estimates of the propensity to litigate understate empirical rates of initiated litigation and include additional noise.[27] Most importantly, though, this analysis uses perhaps the simplest reduced-form model and the instrument used does not reveal the true determinants of $\bar{g}$ and $PLit$. Thus, these statistical results motivate the development of theory to explain how and why they are jointly determined.

IV. A Model of Patenting and Patent Litigation

I begin with several definitions, diagrams and assumptions to assist the analysis.

> **Definition:** An *invention* is a product or process that is potentially patentable. It is described by the pair (v,π). Inventions are exogenously distributed according to the cumulative density function $F(v,\pi):[0,\infty) \times (0,1] \rightarrow [0,1]$, whose corresponding probability density function is $f(v,\pi): [0,\infty) \times (0,1] \rightarrow [0,\infty)$.[28]

The parameter v gives the payoff to the inventor if he patents his invention and it is not infringed. It is proper to think of v as an inventor's profits as an unchallenged

[27] However, litigation rates are understated for all inventor countries and in a way that should not affect the ranking of inventor countries by their litigation rates. This is discussed further in section V.

[28] Note the uninteresting case where $\pi = 0$ is ruled out here.

monopolist. The parameter π gives the probability that the invention will be issued as a patent if the inventor makes it into an application. Inventors have correct expectations about the probability of issue.

> **Definition**: An *application* is any invention for which an inventor seeks patent protection.

> **Definition**: A *patent* is any application for an invention deemed novel, useful and non-obvious by the patent authority. A patent has the following properties:
>
> i) It is a public declaration of invention. I assume that all of the inventor's payoffs related to a patented invention are common knowledge.
>
> ii) It grants the patent owner monopoly rights over any market for the patented invention.
>
> iii) It grants additional (non-legal) value by reducing the asymmetric information between inventors and their observers and by signaling product quality, inventor productivity and/or commitment to the product markets that the patent protects.

The first property reflects the empirically public nature of issued patents.[29] The second and third properties, also derivative of empirical features of patents, reflect the ways in which patents hold value. These latter two properties warrant some further discussion.

The primary legal role of a patent is to grant to its inventor exclusive rights to the commercial exploitation of the patented technology. Thus, a patent owner is a legal monopolist, and can recover lost profits due to competition if he can prove his competitors infringed on the patent. Since such legal action would be initiated by the patent owner, I refer to value from this source as "attacking."

Most patents have additional virtues, however. As argued by Long (2002) and others, patents, relative to trade secrets, significantly reduce transactions costs due to asymmetric information. They help certify product quality, increasing demand for the

[29] The full text of any US patent, for instance, can be viewed at http://www.uspto.gov.

patented product and/or resolving uncertainty on the part of potential partners and investors. Costly advertisements routinely tout products' uses of their company's "patented technology," and products are routinely sold in packages that disclose one or more patent numbers. A patent may also signal excellence in inventive ability and commitment to the product market where the patent applies, attracting investment.[30] I refer to value from this source as "signaling."

The Inventor's Decisions and the Determinants of the Marginal Propensities to Patent and Litigate- Inventions are exogenously given. The decision tree in Figure 5 shows the possible life paths of an invention and the corresponding payoffs to the inventor. The inventor first decides whether to make the invention into an application. If he chooses to do so, he pays a fixed fee $P > 0$, and nature decides whether the application is issued as a patent. If a patent is issued, it exists for one period, which itself is divided into two sequential stages. From the standpoint of the inventor, nature decides whether the patent is infringed. If it is infringed, the inventor decides, in the second stage, whether to initiate litigation on the patent. If the owner initiates patent litigation, nature determines the outcome of a trial if it proceeds. The expected payoff from litigation forms the inventor's threat point in settlement negotiations. Inventors are assumed risk-neutral.

I first describe the payoffs. I assume that if an inventor successfully litigates an infringed patent, he recovers a gross benefit of v, which is what he would have received

[30] It may also help protect a product, an inventor and/or a firm from being sued for patent infringement by another patent owner. For instance, patent ownership can improve the chance of successfully defending an infringement suit. In the surveys reported by Cohen et al. (2000), 58.8% of respondents answered that product patents are sought, in part, to prevent patent suits (Figure 6, p. 48).

absent infringement.[31] If he litigates and loses, he receives a gross benefit of μv, with $0 \leq \mu \leq 1$. Regardless of the outcome of a trial, he must pay the litigation cost $L > 0$.[32] I assume that the probability that patent litigation is successful is $\delta \in [0,1]$, and refer to this parameter hereafter as "legal strength." If he chooses not to litigate, he also receives a payoff of μv but does not have to pay the litigation cost.[33] If he does not patent the invention, he adopts his next-best alternative form of protection and receives a payoff of γv, with $0 \leq \gamma \leq \mu$.[34] I assume, for simplicity, that the payoff γv obtains regardless of whether a patent is sought. In practice, failed patent applications may destroy some of the alternative forms of protection available, but specifying a lower payoff for such cases, while not qualitatively changing my results, would force me to carry around an extra parameter.[35]

We have that $v \geq \mu v \geq \gamma v$. These payoffs are best viewed as payoffs to market activity in three different states of the world. The inventor receives the top payoff of v when he obtains a patent and there is no infringement, so he operates as a monopolist. he receives the next payoff of μv when he owns a patent, but faces competition because of infringement, and receives the lowest payoff of γv when he does not obtain a patent

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[31] The statutory guideline for infringement awards is to "make whole" the patent owner, as stated in Section 284 of the Patent Act. My results do not hinge upon whether the inventor is made entirely whole, only that the inventor is paid in proportion to v.

[32] Often victors in patent cases are remunerated for their costs. My results are the same if they are.

[33] The payoff to an inventor when a patent is litigated and the litigation is lost can take many different forms. For instance, if a patent is ruled invalid, the court declares that it should never have been granted in the first place. The exclusivity value of invalidated patents thus drops to zero. However, if a court finds a patent not infringed, the patent, though probably weaker, remains active and certainly retains some exclusivity value. Both varieties of defeated patents may retain some value as signals. My specification of the value of defeated patents as μv is done for the simplification of notation only. All of my results hold qualitatively if instead this value is specified as ηv, with $\eta < \mu$.

[34] Levin et al. (1987) report data from a 1981 survey of R&D managers indicating that they often favor trade secrecy, advance lead-time and other methods over patents in appropriating the returns to R&D. In our context, the γv payoff can be thought of as the best of these alternatives.

[35] For instance, the USPTO recently began publishing patent applications after 18 months. Prior to this publication, inventors do have the option to withdraw their applications, thereby retaining some alternative forms of protection. However, if a patent fails to issue after the application is published, many alternative forms of protection are destroyed. The USPTO did not publish applications in the 1980s, however, so my specification is more accurate for the time period under consideration.

and faces competition. The parameter μ is assumed at least as large as γ to permit the patent to potentially offer signaling value.

How a patent's value is divided between the attacking and signaling sources is given by the relative magnitude of μ. When μ is well above γ and very close to 1, there may be considerable value to patent ownership, but being infringed is not very costly. In this situation, the patent offers relatively little attacking value. When $\mu = \gamma$, the value to patent ownership is entirely attacking.

I approach the analysis recursively, and thus begin with the litigation stage, shown in the bottom right portion of the tree. Given this payoff structure, a risk-neutral inventor will choose to initiate litigation for any infringed patent (v,π) such that

$$v \geq \frac{L}{\delta(1-\mu)} \equiv v_L \qquad (3)$$

This is a credibility constraint, and I define patent types accordingly.

Definition: A patent or application is *attacking* if $v \geq v_L$ and *signaling* otherwise.

Remark 1: v_L is increasing in litigation costs L and signaling value μ and decreasing in legal strength δ.

For an attacking patent, the inventor's expected payoff from litigation (and minimum payoff from settlement) is $\delta v + (1-\delta)\mu v - L$. It is unnecessary to model a litigation/settlement subgame directly, because the inventor's payoff, in either case, is affected by the legal parameters L and δ.[36] However, settlement does make the inventor's *credible* litigation rate different from his *observed* litigation rate. Since

[36] The alleged infringer will have a maximum permissible settlement. If there is a gap between these numbers, settlement is efficient and, with sufficiently small transaction costs, the parties will divide the surplus and preclude a trial. Studies of settlement of patent litigation include Meurer (1989), Lanjouw (1998) and Crampes and Langinier (2002).

empirical litigation rates form an important unexplained regularity, I do account for the possible effects of settlement on these rates.

Next, I take a step up the tree in Figure 5 and consider the infringement stage. Recall that, from the standpoint of the inventor, I assume that nature determines infringement. This bears explaining. Because of the role that a patent plays, in monopoly-oligopoly entry games where the entrant weighs the potential costs of being sued for infringement against profits from entry, the decision to enter may depend upon whether the patent is attacking.

When a patent and its related payoffs are publicly known, as I have assumed, potential infringers anticipate correctly whether a patent owner would be willing to litigate a given patent and factor the expected loss from infringement litigation into their decision making. In particular, infringement of signaling patents is costless and should occur whenever entry into that market brings any value to the entrant. [37] I thus assume that infringement of signaling patents is certain.[38]

Infringement of attacking patents is not costless, however. An entrant facing an attacking patent must anticipate being sued and factor that into its entry decision.[39] Infringement of attacking patents should therefore occur less often.[40] In this model, I assume that infringement of attacking patents occurs with probability θ, in the [0,1] interval. For ease of explanation only, I focus on the case where θ does not depend upon

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[37] In a related paper, Lanjouw (1998) points out that patent owners unwilling to litigate their patents will never rationally choose to renew them, because they will invariably be infringed unabatedly in subsequent periods.

[38] If infringement carries a cost of imitation, it might not occur with certainty. But the exact probability of infringement of signaling patents is unimportant. For instance, if infringement occurs with probability q between 0 and 1, my results will hold, but I must carry around the additional parameter.

[39] Lerner (1995) shows that, in the US biotechnology industry, firms' choices of research areas for inventive activity depend upon the presence or absence of competitors' patents. This indicates that the presence of patents has a deterrent effect.

[40] In particular, an infringer of an attacking patent must pay an imitation cost and expect to lose some profits through litigation. Thus, such an entrant would need to have a lower imitation cost than an entrant not facing litigation. Thus, entry into markets protected by attacking patents should occur less often, ceteris paribus.

strength δ. When θ does depend on δ, it is intuitive that, if anything, infringement would become less likely the stronger patents become, that is, $\theta(\delta)$ is a decreasing function. Under this assumption, the main results in the paper continue to hold.

Throughout, I shall assume that the probability of infringement of signaling patents does not depend upon legal parameters.[41] I can now write down the expected benefit $W(v)$ to the inventor of any newly issued patent:

$$\mathrm{W}(v) = \begin{cases} (\delta v + (1-\delta)\mu v - L)\theta + v(1-\theta) & \text{if } v \geq v_L \\ \mu v & \text{otherwise} \end{cases} \tag{4}$$

The top and bottom terms correspond, respectively, to attacking and signaling patents.

At the top of the tree in Figure 5 is the inventor's application decision. Recall that π is the probability that the patent office will issue a patent on application (v,π); the expected benefit to filing a patent application on invention (v,π) is then $\pi W(v)+(1-\pi)\gamma v$. Recall also that each application costs $P > 0$ to file and that the inventor receives a ("trade secret," e.g.) payoff of γv if he does not file an application. When deciding whether or not to make an invention into an application, an inventor simply weighs the expected benefits of the two options. An invention (v,π) thus becomes an application if

$$\mathrm{W}(v) \geq \frac{P}{\pi} + \gamma v \tag{5}$$

We now illustrate this application threshold in Figures 6-7. Consider the two alternatives in equation (4), and neglect, for a moment, the credibility constraint on v.

[41] In a comparative static sense, however, changes in legal parameters can turn a signaling patent into an attacking patent.

Inserting each into (5), separately, the following two inequalities emerge:

$$v \geq \frac{1}{\theta(\delta + (1-\delta)\mu) + (1-\theta) - \gamma}\left(L\theta + \frac{P}{\pi}\right) \equiv v_A(\pi) \qquad (6)$$

$$v \geq \frac{P}{(\mu - \gamma)\pi} \equiv v_S(\pi) \qquad (7)$$

The two curves $v_A(\pi)$ and $v_S(\pi)$ in Figure 6 show (6) and (7) when they hold with equality. $v_A(\pi)$ is the attacking curve and $v_S(\pi)$ is the signaling curve. They intersect at

$$\pi_A = \frac{P}{\theta(\delta v_L + (1-\delta)\mu v_L - L) + (1-\theta)v_L - \gamma v_L}. \qquad (8)$$

When $\theta = 1$, condition (5) becomes

$$\max\{\delta v + (1-\delta)\mu v - L, \mu v\} \geq \frac{P}{\pi} + \gamma v.$$

In this case any invention (v, π) that lies above either curve in Figure 6 satisfies (5).

When $\theta < 1$, there is an additional constraint, as shown in Figure 7. Once again, all inventions above the signaling curve satisfy (5). However, the expected value of inventions that are above only the attacking curve depends upon whether $v \geq v_L$, the credibility constraint in (4). For inventions above the attacking curve but with $v < v_L$, litigation is not credible, so $W(v) = \mu v$. Since these are beneath the signaling curve, they do not satisfy (7). Thus, v_L is an additional constraint for $v < v_S(\pi)$. Noting that $v_L = v_A(\pi)$ at

$$\pi_{AL} = L^{-1}\left(\frac{P(\delta(1-\mu))}{\mu-\gamma}\right), \tag{9}$$

Figure 7 shows the inventions that will be filed: those in the shaded areas above the three-piece boundary. Those in the dark gray area are attacking because they satisfy $v \geq v_L$. The reason that the third constraint appears only when $\theta < 1$ is that when $\theta = 1$, there are no inventions above the attacking curve but with $v < v_L$ (Note: it is easily shown that $\pi_{AL} = \pi_A$ in this case).

Although my results extend to more general distributions of inventions, the following simple case is sufficient for the analysis here. There are two possible probabilities of patent issue, π_{LO} and π_{HI}, with $0 < \pi_{LO} < \pi_{HI} < 1$, and an invention has $\pi = \pi_{LO}$ with probability .5. The invention value v has a continuous positive marginal density $f(v)$ on $[0,\infty)$ that does not depend on π. Thus, the cumulative distribution is $F(v,\pi):[0,\infty)\times\{\pi_{LO},\pi_{HI}\}\rightarrow[0,1]$.

Given these assumptions, we now define the fraction of inventions for which patent protection is worth seeking.

Definition. Let $v_A^*(\pi) = \max[v_L, v_A(\pi)]$. The *marginal propensity to patent*

$$MPP(L,\delta) = .5\{1-F(\min[v_A^*(\pi_{LO}), v_S(\pi_{LO}))\} + .5\{1-F(\min[v_A^*(\pi_{HI}), v_S(\pi_{HI})])\}$$

The *number of patents granted*

$$NP(L,\delta) = .5\pi_{LO}\{1 - F(\min[v_A^*(\pi_{LO}), v_S(\pi_{LO}))\} + .5\pi_{HI}\{1 - F(\min[v_A^*(\pi_{HI}), v_S(\pi_{HI})])\}$$

For each value of π, the argument of F is the constraint that binds (recall Figure 7). In Figure 8, for instance, v_L binds for $\pi = \pi_{LO}$ and $v_S(\pi_{HI})$ binds for $\pi = \pi_{HI}$.

It is also straightforward to measure the frequency of credible litigation as well.

Definition. The *marginal propensity to litigate*

$$MPL(L,\delta) = \theta\left(\frac{.5\pi_{LO}\{1 - F(v_A^*(\pi_{LO}))\} + .5\pi_{HI}\{1 - F(v_A^*(\pi_{HI}))])\}}{NP(L,\delta)}\right)$$

Recall that θ is the probability of infringement and note that the $MPL(L,\delta)$ is based on issued patents, so it depends on π_{LO} and π_{HI}. The term in parentheses gives the fraction of issued patents for which litigation is credible. It corresponds to the ratio of the light gray area to the full shaded area in Figure 7.

The model in this section is geared toward explaining the "sensitivity" of inventors to a "friendly" court.

Definition. An inventor is *sensitive* to patent strength if his MPP changes with δ. When MPP is differentiable, the inventor's sensitivity to patent strength is $\frac{dMPP}{d\delta}$.

I now state the main results.

Proposition 1. Let $L^* = \dfrac{P(1-\mu)\delta}{(\mu-\gamma)\pi_{LO}}$. An inventor with litigation cost L is sensitive to patent strength if and only if $L \le L^*$. If an inventor is sensitive to patent strength, his MPP is strictly increasing in δ.

Inventors with "high" litigation costs are insensitive to patent strength and inventors with "low" litigation costs are sensitive in an intuitive way - increases in patent strength lead to increased patenting. Note that if one wished to model inventor heterogeneity with respect to δ (e.g. to study the effects of "xenophobia"), Proposition 1 could be written in terms of a δ^* that uses the same expression that generates L^*. In that case, all inventors with $\delta > \delta^*$ would be sensitive to patent strength. All of the subsequent analysis could be adjusted similarly.[42]

The threshold value L^* depends most on the signaling value of patents μ.

Corollary 1. If patents have no signaling value ($\mu = \gamma$), all inventors are sensitive to patent strength.

In this special case, which is the simplest version of the model, patents are only sought if they are worth litigating, so patent strength must affect the MPP. We discuss the many implications of this result a bit later.

Now consider how litigation rates vary with L. Litigation costs may also affect the likelihood of settlement. When litigation costs are larger, *ceteris paribus*, there is more surplus to divide in a settlement, and the parties jointly have more to lose, from an efficiency standpoint, from litigation. Thus, larger litigation costs may make settlement

[42] Conceptually, however, the model would need a slight adjustment to account for how a single court system would change two different values of δ simultaneously.

more likely. Assume that the probability of settlement $\sigma(L)$ is non-decreasing in L, so that $(1-\sigma(L))$ is non-increasing in L.

Proposition 2. For $\mu \in (\gamma,1)$, an inventor's $MPL(L,\delta)$ is non-increasing in L. It is strictly decreasing in L when less than θ. If the probability of settlement is non-decreasing in L, an inventor's

observed propensity to litigate $OPL(L,\delta) = (1-\sigma(L))\ MPL(L,\delta)$

is also non-increasing in L and strictly decreasing when $MPL(L,\delta) < \theta$. For $\mu = \gamma$, $MPL(L,\delta) = \theta$ and $OPL(L,\delta) = (1-\sigma(L))\ \theta$.

Thus, inventors with large litigation costs litigate their patents less often. If, in addition, such inventors tend to settle their cases out of court more often, then the difference in observed litigation rates will exaggerate the difference in credible litigation rates.

The following corollary links inventor sensitivity to litigation rates.

Corollary 2. Suppose the probability of settlement is non-decreasing in L. An inventor is sensitive to patent strength if and only if his $OPL \geq OPL(L^*,\delta)$.

Based on Corollary 2, the lower an inventor's observed litigation rate, the more likely it is that he is insensitive to patent strength.[43] This result bears directly on the empirical analysis of section III (Figure 4) and on the Kortum-Lerner test of the Friendly Court Hypothesis. I illustrate it with an example.

An Example - Assume some small signaling value for patents ($\mu = .05$, $\gamma = 0$) and, for simplicity, set $\theta = 1$ and assume that there is no settlement of litigation. The latter assumption is done so that OPL = MPL. Neither simple assumption qualitatively affects the results. Let the patent filing fees $P = 1{,}000$ and let initial patent strength $\delta = .5$. For the distribution of inventions, let v be distributed Exponential(λ) with λ=.0001 (so that

[43] This also holds if δ is the source of inventor heterogeneity.

the average invention has a monopoly value of 10,000). That is, $F(v)=1-.0001e^{-.0001v}$. Finally, let $\pi_{LO}=.25$ and $\pi_{HI}=.75$. Inventor heterogeneity is restricted here to litigation costs.

For this specification, $L^{*}=38{,}000$ and $OPL^{*}=.013$. I compute the inventor's sensitivity to patent strength ($dMPP/d\delta$) and his OPL for $L\in[30{,}000,\ 45{,}000]$. Figure 9 shows a plot of sensitivity vs. OPL. Note that sensitivity is zero for $OPL\leq OPL^{*}$. This pattern is similar to the empirical association between patent growth and the litigation rate for the top 10 "inventor countries" patenting in the US (recall Figure 4). Most importantly, it can account for the Kortum-Lerner finding that there was no statistically significant surge in patent applications growth by French, German, Japanese and British inventors, as well as my finding that Δg was quite large for both US and Canadian inventors. Namely, the former group has high litigation costs (and thus low OPLs), while the latter has low litigation costs (and thus high OPLs).

In fact, my model predicts that empirical estimations of the association between inventor sensitivity to patent strength and the observed propensity to litigate will tend to show positive association whenever some inventor countries with very low OPLs and some with very high OPLs are included. Thus is because in such a case, there is a mix of insensitive inventors (low OPLs), and sensitive inventors, (high OPLs). However, although $dMPP/d\delta$ always increases with OPL when OPL > OPL* for the specification I consider here, this monotonicity result does not universally hold. For the exponential distribution, this condition tends to fail to hold at large levels of OPL.

The Case of $\mu = \gamma$ - This is a striking and important special case of the model where, regardless of litigation cost, inventors are sensitive to patent strength (recall Corollary

1). It is, essentially, the type of model that Kortum and Lerner had in mind when they concluded the Friendly Court Hypothesis to be false. When it holds, if one inventor country's US patenting increases while another's does not, the source of the surge cannot be legal strength. In fact, it must come from outside the model. In this context, a surge in R&D productivity is a logical alternative source of patent growth.

However, this case also implies that if δ increases, then all inventors must increase their patenting. Since the empirical evidence strongly indicates that the CAFC has increased patent strength but that some inventors' patenting did not surge, the $\mu = \gamma$ case is contradicted by the data. Only two findings would resurrect it. Either all inventors' patenting did increase in the 1980s or the CAFC was not friendly.

This case has further implications as well. When $\mu = \gamma$, the $MPL = \theta$ and does not depend on either patent strength or litigation costs. Thus, variations in inventor countries' *OPL*s depend on rates of settlement only. Clearly, if this is the case, the results of Lanjouw and Schankerman (2001) and Moore (2003) must be reinterpreted.

V. Conclusion

This paper studies the surge in US patenting in the 1980s. I first argue that, under the standard view of patents, where value depends only on the appropriable rents created by the patent's exclusive property rights over related technologies and product markets, this puzzle cannot be solved. I then adopt an alternative view, based on the recent work of Long (2002), where patents confer additional value by minimizing asymmetric information between patentees and observers. Under this view, the puzzle can be solved.

In contrast to past work on the subject, I relate statistics on patent applications to statistics on patent litigation to frame my inquiry. There is strong evidence that these statistics are associated. Time series of patent applications, new patent litigations and patent litigation outcomes have significant, synchronized structural breaks, and the 1982-83 break dates provide evidence that supports the Friendly Court Hypothesis. Statistics on patent litigation rates by foreign inventors explain a significant amount of the variation in US applications growth by foreign inventors, yielding a potential explanation for why foreign inventors' US applications growth did not surge in the 1980s. Namely, foreign inventors are less sensitive to patent legal strength because of higher litigation costs, xenophobia, etc. My theoretical model details how inventor heterogeneity with respect to these factors give rise to the positive association of an inventor's sensitivity (to a friendly court) and his litigation rate.

Clearly, further research is needed to better explain the fundamental relationship between patent strength and patent counts, and the CAFC provides a useful laboratory for investigating it further. For instance, while it is widely believed that the CAFC has been "pro patent," most of the research into this question has analyzed the CAFC's impact on validity. Little has been done to assess its impact on patent scope and the resulting effects on patenting.[44] This is unfortunate, because, since establishing the strong presumption of validity, the CAFC has modified the law affecting patent scope more than the law affecting validity (*Festo* is a prominent recent example of this). Innovations to the law affecting scope are likely to change the way inventors write patent applications, which may change the number of patent applications sought.

The R&D investment decision also plays an important role in the patent strength-count relationship. I abstract from it in this paper to focus on other issues, but it is clearly an important piece of the puzzle. Indeed, while I firmly believe that the Friendly Court Hypothesis explains the surge in US patenting in the 1980s, my paper is by no

[44] Merges and Nelson (1990) provide an excellent overview of the law and economics of patent scope.

means the final word. The Friendly Court Hypothesis does not preclude the possibility that R&D became more productive in the US in the 1980s, so the R&D Productivity Hypothesis, in particular, bears further investigation. Research has yet to identify how or why R&D productivity might have surged in the US in the 1980s, but this is a useful inquiry to make. I look forward to further progress in this area.

Figure 1

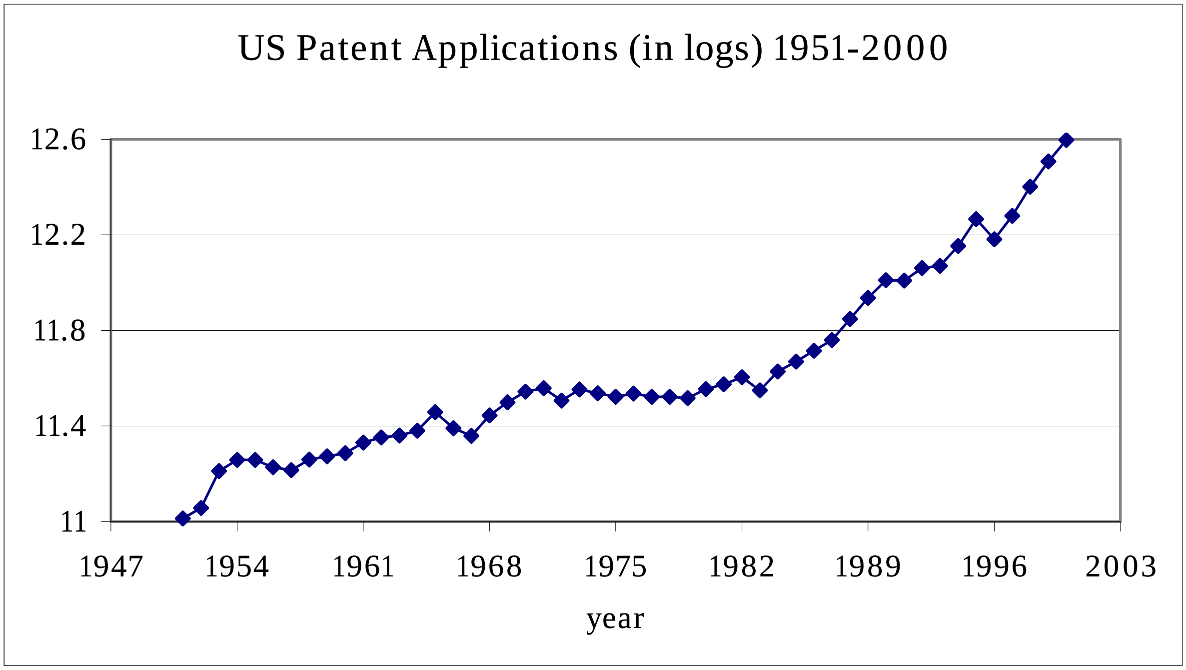


Figure 2

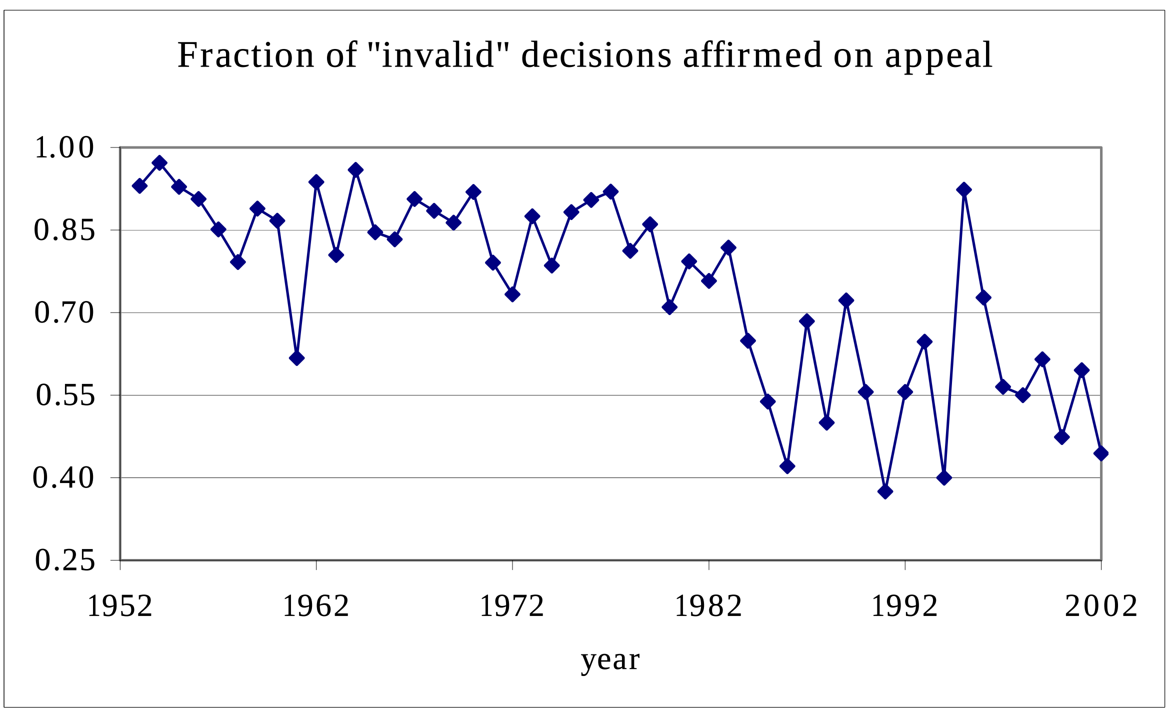


Figure 3

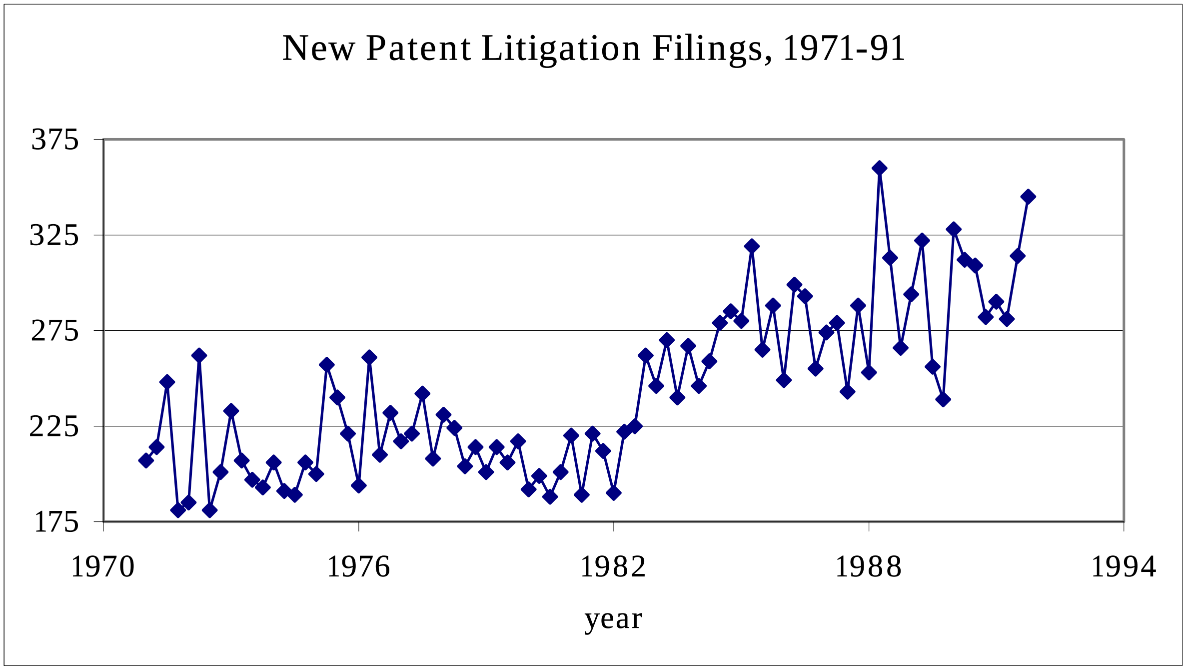

New Patent Litigation Filings, 1971-91
375
325
275
225
175
1970
1976
1982
1988
1994
year

Table 1 - Structural Break Tests[45]

	US Patent Applications			***Patent Validity***	***Patent Litigation***
Δy_t	Total (in logs)	Domestic (in logs)	Foreign (in logs)	Fraction of "invalid" decisions affirmed on appeal	New Litigations (Quarterly)
constant	5.43 (1.22)	5.89 (1.65)	3.57 (.94)	1.13 (.22)	231.91 (24.72)
time	0.007 (.002)	-0.002 (.001)	0.023 (.006)	-	-0.063 (.26)
constant $*1(t > T_B)$	-0.052 (.029)	-.064 (.042)	-0.101 (.024)	-0.36 (.07)	49.57 (11.36)
(time- T_B *)* $*1(t > T_B)$	0.023 (.005)	.037 (.008)	-0.002 (.002)	-	1.52 (.47)
y_{t-1}	-0.48 (.11)	-0.55 (.15)	-0.38 (.10)	-1.35 (.25)	-1.09 (.11)
Δy_{t-1}	-	-0.12 (.15)	-	.18 (.22)	-
Δy_{t-2}	-	-0.19 (.14)	-	.29 (.20)	-
Δy_{t-3}	-	-0.22 (.12)	-	.44 (.17)	-
Δy_{t-4}	-	-0.29 (.12)	-	.29 (.12)	-
Break	1982	1982	1974	1983	1982:3
sup-Wald	29.80**	32.21***	16.56	26.70***	30.70***
ADF t-stat	-4.43	-3.55	-3.76	-5.40***	-9.78***
T	49	45	49	49	83
R^2	0.43	0.55	0.32	0.66	0.54

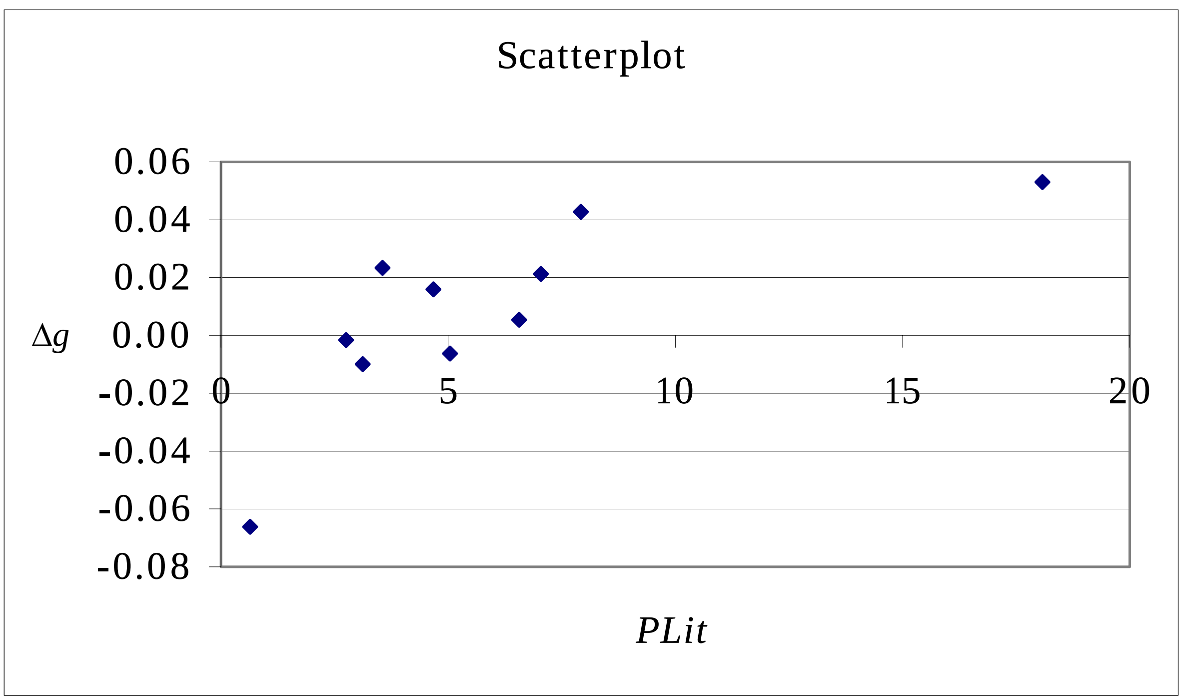
[45] Standard errors in parentheses. Asterisks indicate statistical significance at the *10%, **5% and ***1% levels, but only for test statistics of interest.

Table 2 - Explaining Foreign Applications Growth[46]

Observations Included

	All	Excluding JP	Excluding US	Excluding JP & US
constant	0.014 (.009)	0.015 (.015)	-0.004 (.012)	0.006 (.012)
$\bar{g}_{60-82}$	0.382*** (.121)	0.336 (.409)	0.473*** (.116)	-0.109 (.338)
PLit	0.0026*** (.0009)	0.0025** (.0011)	0.0057*** (.0018)	0.0068*** (.0017)
N	10	9	9	8
R^2	0.57	0.42	0.69	0.70

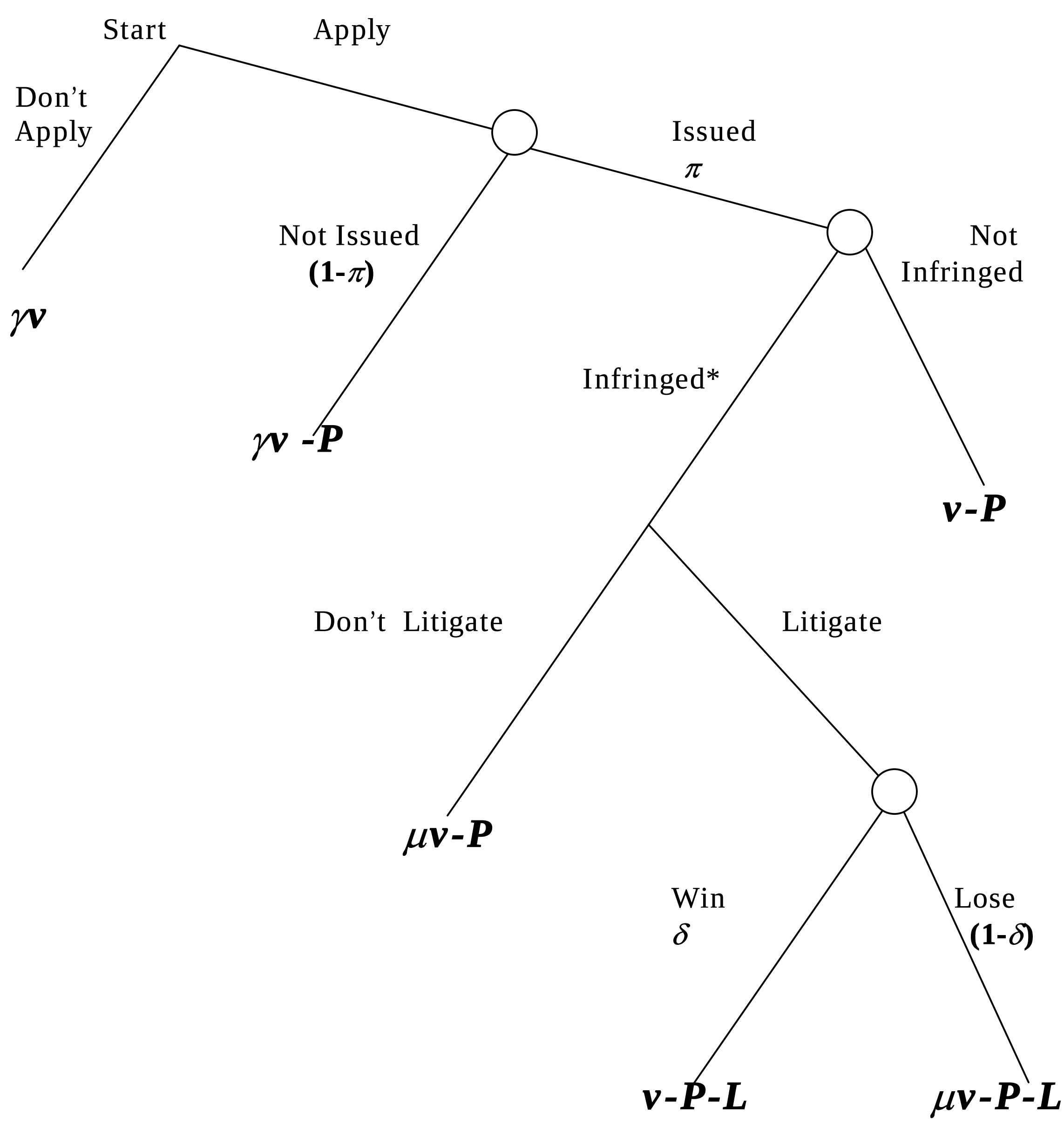
Figure 4



46 Dependent variable: $\bar{g}_{82-00}$. Standard errors in parentheses. Asterisks indicate statistical significance at the *10%, **5% and ***1% levels.

Figure 5

Decision Tree



*the probability of infringement is 1 if the patent is "signaling" and θ if the patent is "attacking."

Figure 6

Attacking and Signaling Curves

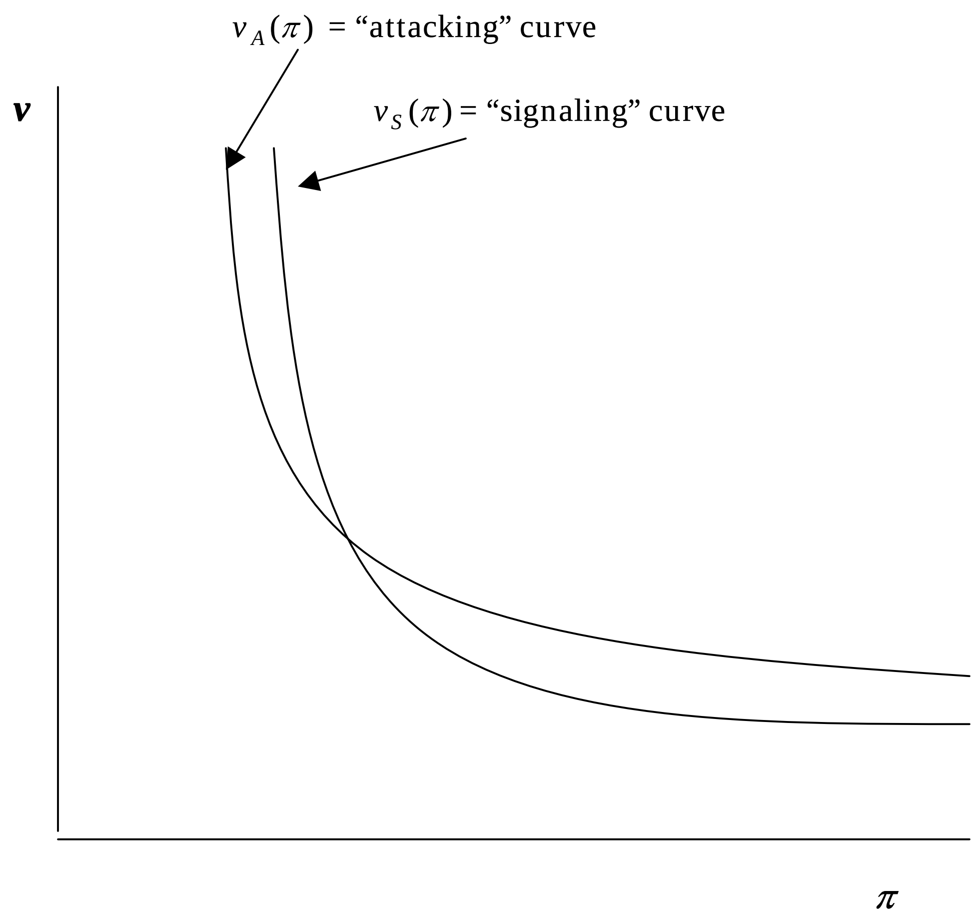
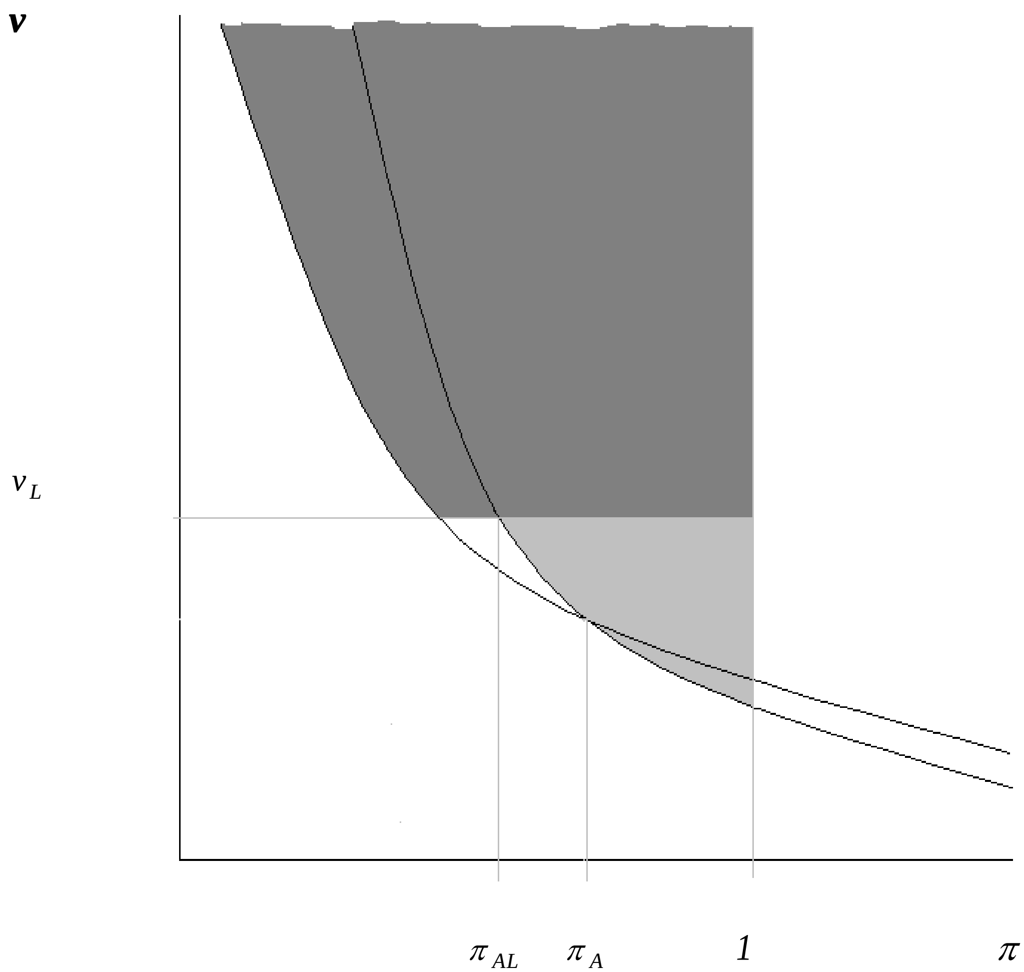


Figure 7

Attacking and Signaling Applications: θ < 1



Attacking Applications:

Signaling Applications:

Alternative Protection:

Figure 8

EXAMPLE

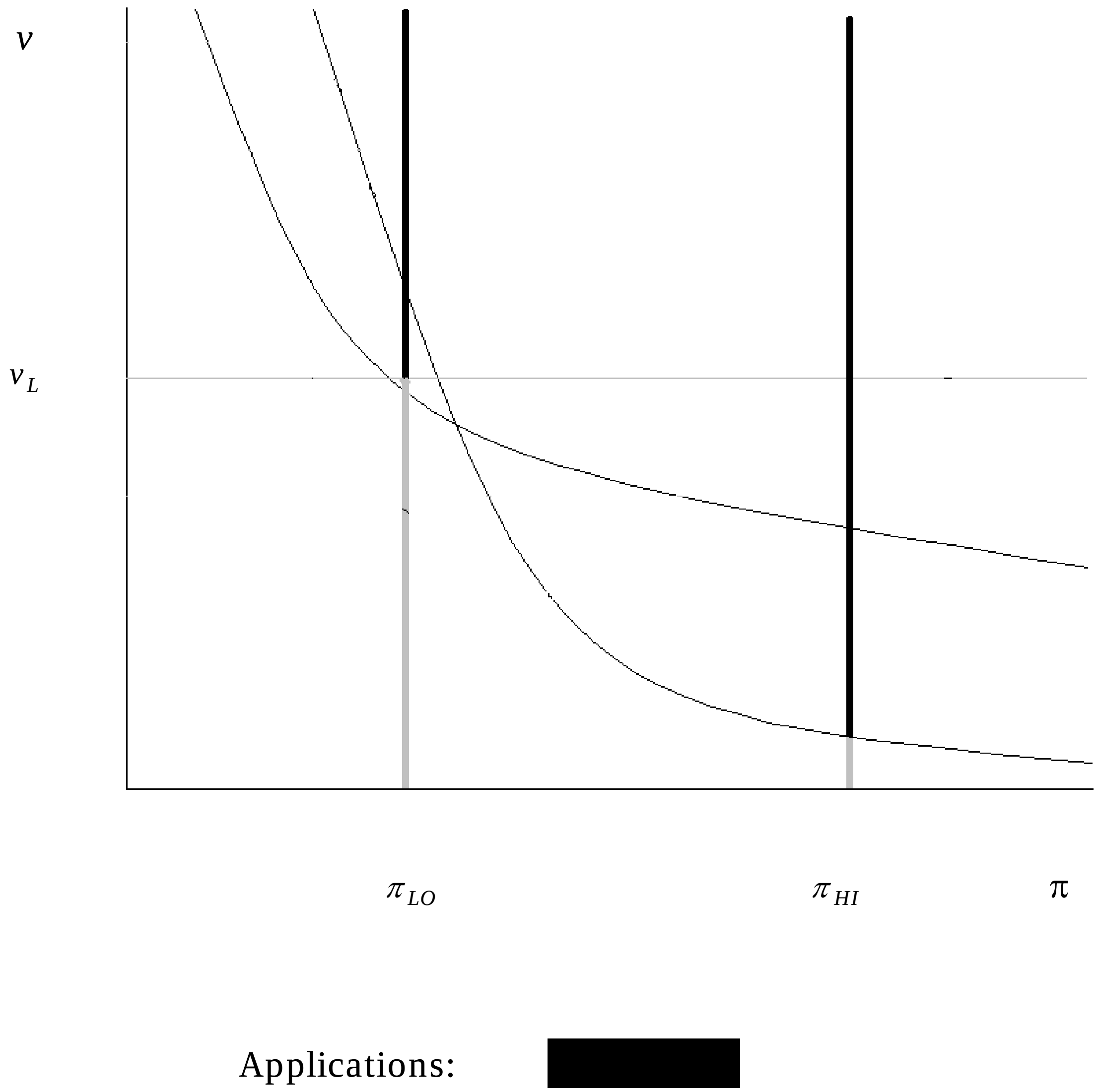
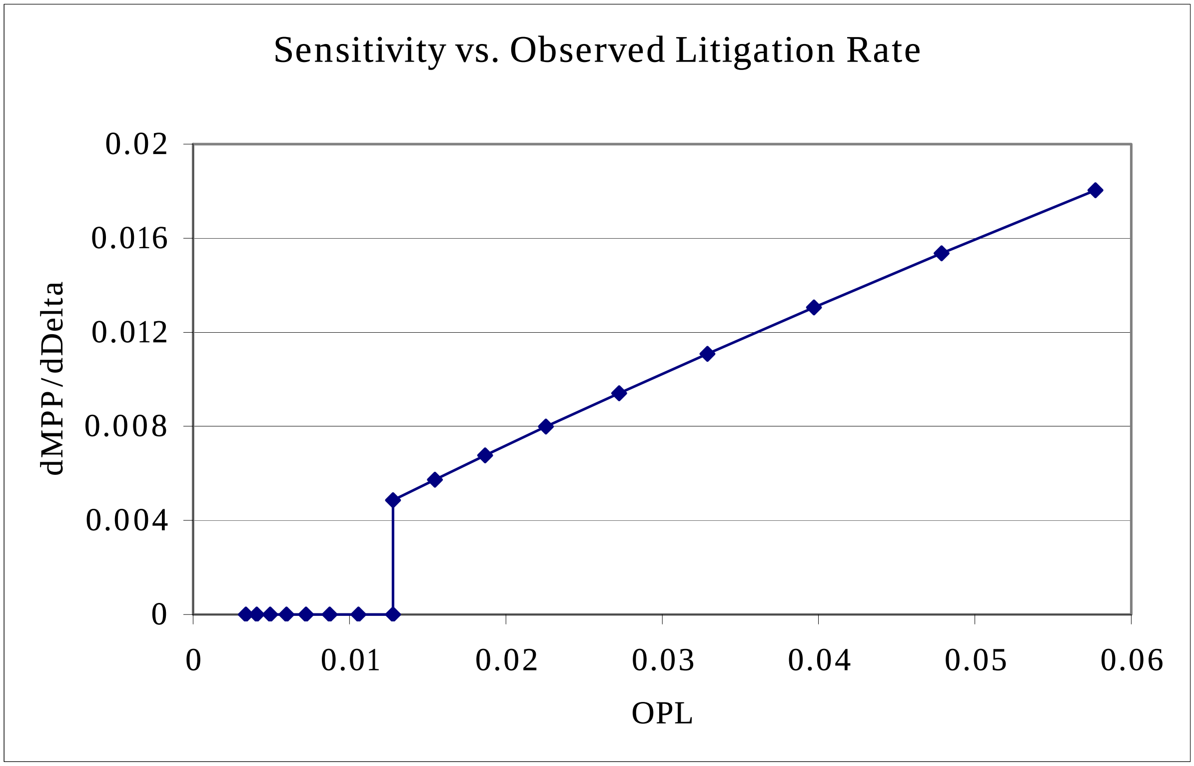


Figure 9



Sensitivity vs. Observed Litigation Rate
0.02
0.016
0.012
0.008
0.004
0
dMPP/dDelta
0
0.01
0.02
0.03
0.04
0.05
0.06
OPL

VI. Appendix

Proof of Proposition 1: First, note that if $\pi \leq \pi_{AL}$, we have $v_L \leq v_S$ by the definition of π_{AL}. Because $\frac{dv_S}{d\pi} < 0$, we also know that $v_L > v_S$ for $\pi > \pi_{AL}$. Second, note that if $\pi \leq \pi_A$, we have $v_A \leq v_S$ by the definition of π_A. Because $\frac{d(v_S - v_A)}{d\pi} < 0$, we also know that $v_A > v_S$ for $\pi > \pi_A$. Thus, since $\pi_{AL} \leq \pi_A$, it must be true that if $\pi \leq \pi_{AL}$, then $v_A^* = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ and if $\pi > \pi_{AL}$, we have $v_S = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$.

Since $f(\bullet)$ has positive continuous density on $[0,\infty)$ and v_A^* is clearly decreasing in δ, MPP(L, δ) is increasing in δ whenever $v_A^*(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ or $v_A^*(\pi_{HI}) = \min[v_A^*(\pi_{HI}), v_S(\pi_{HI})]$. Thus, it is increasing whenever $\pi_{LO} \leq \pi_{AL}$ or $\pi_{HI} \leq \pi_{AL}$. But since $\pi_{LO} < \pi_{HI}$, we have that $\pi_{LO} \leq \pi_{AL}$ or $\pi_{HI} \leq \pi_{AL}$ if and only if $\pi_{LO} \leq \pi_{HI}$. Thus, MPP(L, δ) is increasing in δ whenever $\pi_{LO} \leq \pi_{AL}$ (note that if $\pi_{LO} = \pi_{AL}$, then $v_A^*(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ and $v_S(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$. If δ increases, $v_A^*(\pi_{LO})$ becomes the unique minimum at a value strictly less than $v_S(\pi_{LO})$) and the MPP increases. If, on the other hand, $\pi_{LO} > \pi_{AL}$, then $v_S(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ and $v_S(\pi_{HI}) = \min[v_A^*(\pi_{HI}), v_S(\pi_{HI})]$ are unique. Since v_S does not depend on δ, the MPP does not depend on δ and the inventor is insensitive.

(⇒) Suppose $L \le L^*$. This implies that $\pi_{LO} \le \frac{P(1-\mu)\delta}{(\mu-\gamma)L} = \pi_{AL}$, so $v_A^* = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$. Thus, the MPP is increasing in δ and the inventor is sensitive to patent strength.

(⇐) Suppose the inventor is sensitive to patent strength. Then $v_A^*(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$, so that $\pi_{LO} \le \frac{P(1-\mu)\delta}{(\mu-\gamma)L} = \pi_{AL}$, and $L \le \frac{P(1-\mu)\delta}{(\mu-\gamma)\pi_{LO}} = L^*$. ***QED***

Proof of Corollary 1: If $\mu = \gamma$, then $L^* = \infty$. Since $0 < L < \infty$, all inventors are sensitive by Proposition 1.

Proof of Proposition 2: There are three cases: (1) $\pi_{AL} < \pi_{LO}$; (2) $\pi_{AL} > \pi_{HI}$; and (3) $\pi_{LO} \le \pi_{AL} \le \pi_{HI}$. For case (1), the NP does not depend on *L*, because $v_S(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ and $v_S(\pi_{HI}) = \min[v_A^*(\pi_{HI}), v_S(\pi_{HI})]$ are unique (see the Proof of Proposition 1). Thus, it suffices to show that $\pi_{LO}(1-F(v_A^*(\pi_{LO}))) + \pi_{HI}(1-F(v_A^*(\pi_{HI})))$ is decreasing in *L*. Since v_A and v_L are strictly increasing in *L*, v_A^* is strictly increasing and *MPL(L, δ)* is strictly decreasing in *L*.

For case (2), $v_A^*(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ and $v_A^*(\pi_{HI}) = \min[v_A^*(\pi_{HI}), v_S(\pi_{HI})]$, so that MPL = θ and does not depend on *L*.

For case (3), note that $v_A^*(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ and $v_S(\pi_{HI}) = \min[v_A^*(\pi_{HI}), v_S(\pi_{HI})]$, so the MPL may be written as $\theta\left(\frac{x+y}{x+y+z}\right)$, where *x*

= $\pi_{LO}(1-F(v_A^*(\pi_{LO})))$, y = $\pi_{HI}(1-F(v_A^*(\pi_{HI})))$ and z = $\pi_{HI}(F(v_A^*(\pi_{HI}))-F(v_S(\pi_{HI})))$. Clearly, x and y are each decreasing in L, while z is clearly increasing in L. Thus, $\left(\frac{x+y}{x+y+z}\right)$ is decreasing in L.

Thus, the MPL is non-increasing in L and is strictly decreasing in L when $MPL < \theta$. The OPL follows this same pattern, because if (1 - $\sigma(L)$) is non-increasing in L and the MPL is non-increasing in L, then (1 - $\sigma(L)$)MPL is also non-increasing in L.

When $\mu = \gamma$, it is clear that $v_A^*(\pi_{LO}) = \min[v_A^*(\pi_{LO}), v_S(\pi_{LO})]$ and $v_A^*(\pi_{HI}) = \min[v_A^*(\pi_{HI}), v_S(\pi_{HI})]$, so that all patents are attacking and MPL = θ. ***QED***.

Proof of Corollary 2: When $L = L^*$, $v_A^*(\pi_{LO}) = v_S(\pi_{LO})$. Since $\frac{dv_S - v_L}{d\pi} < 0$ and $\frac{d(v_S - v_A)}{d\pi} < 0$, we have that $v_A^*(\pi) > v_S(\pi)$ for all $\pi > \pi_{LO}$, so $v_S(\pi_{HI}) = \min[v_A^*(\pi_{HI}), v_S(\pi_{HI})]$. Thus, the inventor files some signaling applications, and $MPL(L^*,\delta) < \theta$ and is strictly decreasing in L at $L = L^*$ by Proposition 2. Thus, $OPL(L^*,\delta)$ is also strictly decreasing at this litigation cost, so that $OPL(L,\delta) \geq OPL(L^*,\delta)$ if and only if $L \geq L^*$.

(⇒) Suppose the inventor is sensitive to patent strength. Then $L \leq L^*$ by Proposition 1, so that $OPL(L, \delta) \geq OPL(L^*,\delta)$.

(⇐) Suppose that an inventor's $OPL \geq OPL(L^*,\delta)$. Since $OPL(L, \delta)$ is strictly decreasing at $L = L^*$, that inventor's $L \leq L^*$. By Proposition 1, he is sensitive to patent strength. ***QED***.

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