INNOVATION, IMITATION & PRELIMINARY INJUNCTIONS IN PATENTS

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Abstract

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We analyze the effect of preliminary injunctions in patent cases, using a simple probabilistic model of a legal challenge to a patent's validity. We show that using current U. S. damages rules, preliminary injunctions are likely to lead to inefficient innovations, non-novel patents, and extensive litigation, since both the innovator and the imitator benefit from a preliminary injunction. We also show that a second-best patent rule is non-monotonic in the probability that the innovator successfully defends his patent, and that the probability that a preliminary injunction is granted should be quite low.

I. Introduction.

Patents are of increasing strategic importance in a range of industries, including biotechnology, computer hardware, and software. Recently, firms have obtained and defended patents for business methods (such as Amazon's one-click purchasing claim, which had a good enough patent to obtain a preliminary injunction, but not good enough to succeed at trial). At the same time, in many fields the complexity and number of patents require firms to negotiate through a thicket of patent protection. The increasing importance and number of patents is unavoidably leading to more intellectual property disputes. Given the key role of patents in stimulating innovation, the structure of the patent system—including preliminary injunctions—is exceptionally important. Indeed, Shapiro (2001) argues that in industries with rapidly changing technology, the rules governing patent litigation are more important to patentees than patent length.

There has been much interest recently in the antitrust implications of patent settlements and licensing arrangements. We extend this research by examining the use of preliminary injunctions in patent cases. Preliminary injunctions have become a very important component in patent infringement cases, with a large proportion of patent cases having injunctions sought (and sometimes imposed) on the imitator. As we show, preliminary injunctions, which are used to prevent alleged infringement during the period of the trial, may be used as a tool to create and distribute monopoly profits. In addition, the rules for preliminary injunctions lead to excessive patenting and excessive court costs, all at the expense of the consumer.

Patent cases are often very complex and require specialized information on the part of the court, and they often involve very high stakes, with pay-offs of hundreds of millions of dollars and more depending on the outcome. This leads to lengthy trials, which can extend for many years (Anton and Yao, 2000). A patent holder may thus move for a preliminary injunction at the beginning of the trial to protect its interests until the case is decided on the merits. Such an injunction will keep the alleged infringer from using the innovation during the trial. If an injunction is granted, but the patent is found invalid or not infringed, the patent holder will be required to pay damages to the wrongly enjoined party. On the other hand, if no injunction is granted, the imitator is at risk for damages if it is found at trial to have infringed a valid patent.

There are two kinds of mistakes possible in a preliminary injunction hearing: an injunction granted when there is no infringement, and no injunction granted even when there is infringement. However, there is an asymmetry between the rewards to the parties which creates incentives for patent holders to pursue preliminary injunctions and for imitators to acquiesce. As we show in this paper, this leads to several pernicious outcomes. First, the structure of preliminary injunctions may lead to non-novel "innovations" and patents of questionable merit. Second, these patents may be used to obtain monopoly profits during preliminary injunctions. Third, we find that firms gain the most from preliminary injunctions when the probability of successfully defending the patent at trial is low. Fourth, both patent holder and imitator will prefer that a preliminary injunction be granted during patent litigation. Each of these results, as we show, may reduce welfare.

Research on the economics of patents has focused principally on three areas—optimal patent policy (especially length and breadth) (e.g., Nordhaus 1969, Klemper 1990); patent settlements and licensing (e.g., Katz and Shapiro 1987, Aoki and Hu 1999); and more recently the antitrust implications of patenting and licensing (e.g., Lanjouw and Lerner 2001, Shapiro 2001). This paper contributes to each of these areas. In terms of optimal patent policy, an important approach has been to acknowledge that patents are enforced only probabilistically—as in Katz and Shapiro (1987), Meurer (1989), Ayres and Klemperer (1999), and Shapiro (2001). This is a key consideration since it affects both the willingness to innovate and consumer benefits following the innovation. Our contribution to this literature is to include preliminary injunctions into a probabilistic model, exploring how the probability of the innovator prevailing in preliminary and final injunctions changes innovative and imitative behavior.

While we do not model settlements or licensing explicitly, we do provide an extensive analysis of how preliminary injunctions are used, and we think this is essential for understanding the terms on which licenses are (or are not) granted, since the court option establishes the threat points for settlement bargaining. Thus, this paper builds a more solid foundation for research on licensing.[1]

In terms of antitrust analysis, our paper shows how patents and preliminary injunctions can be used to create inefficient market power with no offsetting benefits. This issue is of the particular interest in the pharmaceutical industry in the United States, where patent-holding firms benefit from an *automatic* 30-month preliminary injunction (Hollis 2001). The antitrust

[1] There are other reasons for not discussing licensing. First, there is already a very extensive literature on licensing and settlements. And second, as Shapiro (2001) has shown, many settlements are anti-competitive and should be prohibited. (This particularly includes settlements like those recently pursued by the FTC in generic and brand name pharmaceutical firms settled to keep the generic firms out of the market, and is likely to include many settlements that would occur in cases where a preliminary injunction is sought.) This is reason alone to consider a model in which outside settlement is not an option.

implications of these stays are currently under investigation by the FTC, with some remedies proposed in the McCain-Schumer Bill.[2] Our analysis also builds on Lanjouw and Lerner (2001), who show that preliminary injunctions may be used to impose financial stress on weak rivals. While they focus on issues related to the differential cost of financing between firms, we focus on the different market outcomes with and without a preliminary injunction . Like Schankerman and Scotchmer (2001), we employ the damages regime used in the United States, which compensates firms for lost profits, and we consider how different regimes might change the competitive outcome and the incentive to innovate.

The remainder of the paper is organized as follows. Section II reviews the law and practice of patents and preliminary injunctions. Sections III and IV set up and analyze a model of innovation, imitation and patent litigation, following the damage rules currently applied in the United States, and show some of the problems that may be expected to arise. Section V examines the welfare implications of the current rules, and derives a second-best rule based on the usefulness of the patent. Section VI examines an extension of the basic model to the cases of a non-novel innovation. Section VII concludes.

II. A Review of Patents and Preliminary Injunctions.

A patent is a government granted monopoly of the use of an innovation for a fixed period of time. It is granted when an innovator applies to the patent office with an innovation which is found to be

- a process, machine, manufacture, or composition of matter;
- new, useful, and non-obvious;

[2] Bill 512 in the 107th Congress, introduced May 21, 2001, "Greater Access to Affordable Pharmaceuticals Act."

- disclosed in sufficient detail that a skilled person could build and operate it.[3]

Our analysis pays particular attention to the criteria that a good is new and non-obvious (novelty), and usefulness. Usefulness in our model is measured by the potential surplus the innovation generates for society. Innovations of more useful goods are more beneficial to society, but they also are more beneficial to the innovator. Novelty is measured by how close the good is to an existing good. The granting of a patent for a non-novel innovation thus has the effect of reducing welfare, since it reduces the competition for the good.

Patents are not a watertight form of protection. For example, an imitator may use a non-infringing technology to compete with the patent holder. Second, even if a patent holder believes that an infringement is occurring, the innovator can only stop the imitator by litigation. Since many patents are complex, there is a probability that the patent may be found invalid at trial. The obverse of this is that even patents which are not very useful or novel may be found in court to be valid. This possibility naturally encourages weak patent applications.[4]

While the patent trial itself thoroughly examines the available evidence and testimony, the hearing for a preliminary injunction has a "High Noon" nature with the two sides having little time to prepare and even less to present a case for why an injunction should or should not be granted (Budd, 1999). As a result, preliminary injunction proceedings are "fraught with the risk of error" either of enjoining a non-infringing firm or of not enjoining an infringing firm (Stein,

[3] 35 U.S.C. 101-103 and 112.

[4] The fact that many patents are found to be invalid should not be surprising. The Patent and Trademark Office simply does not have the resources to search out prior art, and will generally overlook non-patent prior art and sometimes patented prior art too. This means that most patent validity challenges are made by firms being sued for patent infringement. Unless the prior art very clearly encompasses the patent, or there is no evidence of related prior art at all, the court will have to make a subjective decision as to whether the patent claims an innovation that would have been obvious to a person skilled in the art at the time the patent was filed. (Sometimes it is very difficult to find the prior art. As evidence of this, consider the firm BountyQuest, which offers large rewards for individuals who can find prior art for particular patents which are being challenged. The willingness to pay significant fees to individuals who find prior art invalidating a patent suggests that, in many cases, demonstrating invalidity may be very difficult.) Thus, in general, the greater is the novelty and non-obviousness of the patented innovation, the higher probability the court will find the patent is valid.

1997). Such errors typically result in damages being paid: in the United States the damages are typically calculated as the lost profits of a firm that was wrongly enjoined, or the lost profits of the patent holder who suffered infringement.[5] There are four factors usually applied in such a hearing: (1) the plaintiff's likelihood of success on the merits; (2) whether the plaintiff will suffer irreparable harm without the injunction; (3) the balance of harms to the two parties; and (4) the public interest. In practice, it appears that the first plaintiff's likelihood of success is the most important in the courts.[6] The irreparable harm criterion should lead to no injunctions at all, since any harm to the patent holder can normally be repaired financially, and if the imitator is found at trial to have been infringing, it will be liable for damages which should be able to compensate the patent holder.[7] (If there is an apprehension that the imitator may not be financially able to pay damages, the court is at liberty to require a bond.[8]) However, a recent judgment made the point that a strong showing of likelihood of success gives rise to a presumption of irreparable harm.[9] The the balance of hardships criterion is unlikely to contribute to the decision, since the damages ensure that neither firm is harmed. The fourth criterion, public interest, has been characterized as a "make weight"[10] and as a "wild card,"[11] although consumers would in general benefit from competition, contingent upon innovation.[12]

[5] In fact while damages to the patent holder are typically paid ex post, after the damages to profits have been assessed, damages to the wrongly enjoined imitator come only in the form of a bond posted at the time of the injunction, which may not always cover the losses of the imitator, especially if the trial drags on. We are also not considering the possibility of triple damages, which the court may order in the case of willful infringement, on the basis that if the court has not seen fit to impose a preliminary injunction, then the imitator must be able to make a reasonable case that infringement was not willful.

[6] See, for example, Cunningham (1995), Martens and Conover (1998), and Lanjouw and Lerner (2001, p. 578).

[7] Lanjouw and Lerner (2001, p. 576) note that in their dataset, preliminary injunctions appear to be targeted at strong as well as financially weak defendants, implying that "the occurrence of 'irreparable harm' may not be that closely associated with defendants' financial resources."

[8] This was the approach taken by the court in Flo-Con Systems, Inc., v. Leco Corp (845 F. Supp 1576 (S. D. Ga 1993)).

[9] Reebok Int'l. Ltd. v. J. Baker Inc., 32 F. 3d 1552.

[10] Wolf (1984) p. 224.

[11] Lawson Prods., Inc. v. Avnet, inc., 782 F. 2d 1429 at 1433 (7th Cir. 1986).

[12] Courts have also interpreted the public interest as supporting the rights of the innovator. For example, in Eli Lilly

III. Description of the Game.

We consider a patent game in which the innovator, firm 1, discovers an idea that may be patentable. Firm 1 may choose to develop this idea, or innovate, at cost $c_I > 0$. If it innovates, it will also obtain a patent on the innovation.[13] An imitator, firm 2, then decides whether or not to enter the market and compete with firm 1 in the new product. Firm 1 then decides whether or not to challenge the entrant by seeking a judgment that the imitator is infringing its patent. (We label this as seeking a final injunction against infringement, to distinguish it from a preliminary injunction.) Faced with a trial over the patent, firm 2 then decides whether or not to produce during the trial period. If firm 2 does produce during the trial period, firm 1 must decide whether it wishes to seek a preliminary injunction during the trial. The game is solved by backwards induction.

In order to be more concrete about the gains from preliminary assumptions, we assume that demand is linear, $P = a - Q$, and marginal cost, c, is constant and identical across firms.[14] Thus, monopoly profits, exclusive of innovation and litigation costs are $\pi^m = Z/4$, and Cournot duopoly profits equal $\pi^d = Z/9$, where $Z \equiv (a - c)^2$.

The game tree is depicted in Fig. 1.[15] In stage 1, firm 1 chooses to innovate (I) or not innovate (NI). If firm 1 innovates, it faces costs of innovation, $c_I > 0$. If firm 1 chooses to not innovate, the game ends, and both firms 1 and 2 receive zero profits: $\pi_1^{NI} = \pi_2^{NI} = 0$.

& Co. v. Premo Pharmaceutical Laboratories, Inc., [630 F. 2d 120 (3d Cir.) cert. denied, 449 US 1014 (1980)] after determining that the patent had most likely been infringed, the court decided that the public interest factor favored granting a preliminary injunction, noting that "Congress has determined that it is better for the nation in the long-run to afford the inventors of novel, useful, and nonobvious products short-term monopolies on such products than it is to permit free competition in such goods." [p.138]

[13] We assume that firms are able to obtain, but not necessarily defend, their patents. We make the assumption that a patent will be granted because the patent office appears to grant patents relatively readily, and it appears to be the job of the courts to evaluate the validity of patents. [cite]

[14] The assumption of linear demand simplifies the analysis greatly, but we don't believe the general results are dependent on this assumption.

[15] The bolded numbers above each decision node indicate the identity of the player making a decision. The numbers under the nodes indicate the stages of the game.

In stage 2, firm 2 chooses whether to enter the market (*E*) or not (*NE*), producing a perfect substitute. If firm 2 chooses to enter, it pays a cost c_E that is immediately sunk, but may earn profits up to π^d, the duopoly profits earned during the trial period, plus $\beta\pi^d$, the present value of future duopoly profits.[16] If firm 2 chooses not to enter (terminal node 7), it earns $\pi_2^{NE} = 0$ and firm 1 earns monopoly profits less its innovation costs: $\pi_1^{NE} = (1 + \beta)\pi^m - c_I$.

At stage 3, upon observing entry by firm 2, firm 1 chooses either to seek a final injunction (*SFI*) or not (*NSFI*). Denote the probability firm 1 wins the final injunction as θ. If firm 1 seeks a final injunction, it incurs additional litigation costs of c_{L_1}. However, it also forces firm 2 to pay litigation costs of c_{L_2}.[17] The litigation costs are in addition to the costs of innovation for firm 1 and in addition to the cost of entering for firm 2. If firm 1 chooses not to seek a final injunction (node 8), then profits to firm 1 are $\pi_1^{NSFI} = (1 + \beta)\pi^d - c_I - c_{L_1}$ and profits to firm 2 are $\pi_2^{NSFI} = (1 + \beta)\pi^d - c_E - c_{L_2}$.

At stage 4, firm 2 faces a patent infringement lawsuit. Firm 2 decides whether to produce during the trial (*P*) or not (*NP*). If firm 2 produces during the trial, it faces a potential liability of D_1, the damages it must pay to firm 1 in the event that firm 1 wins the final injunction litigation. Firm 1 wins with probability θ, which we assume to be common knowledge. Firm 2 can avoid paying damages to firm 1 by choosing not to produce during the trial period. If firm 2 chooses not to produce, then the trial follows it course, and the game ends at terminal node 9. Firm 2 earns expected profits of $\pi_2^{NP} = (1 - \theta)\beta\pi^d - c_E - c_{L_2}$, while firm 1 earns expected profits of π_1^{NP}

[16] Thus, profits during the trial period are normalized to unity. If the trial period is τ units long, then $\beta = e^{-\rho\tau}\int_\tau^T e^{-\rho t}dt = e^{-\rho\tau}(e^{-\rho T} - 1)/\rho$, where *T* is the length of time before new competition appears, and ρ is the instantaneous discount rate. Implicitly, we are assuming that *T* is the same if a patent is upheld as if it is not. Katz and Shapiro (1987), for example, report that most patents are obsolete within four years.

[17] The imitator would never choose to enter the market and then exit simply because of the litigation costs, since it would know that the innovator could profitably force it into litigation in this instance. Thus, exiting after entering is not an optimal strategy.

$= \pi^m + \theta\beta\pi^m + (1 - \theta)\beta\pi^d - c_I - c_{L_1}$.

At stage 5, having observed that firm 2 has chosen to produce during the trial, firm 1 decides whether to seek a preliminary injunction (*SPI*) against the alleged infringement or not (*NSPI*). We assume that the litigation costs of seeking a preliminary injunction are trivial.[18] If firm 1 seeks a preliminary injunction, it wins the preliminary injunction with probability ϕ. However, if firm 1 wins the preliminary injunction and subsequently loses the final injunction, firm 1 is liable for damages to firm 2. We denote these damages as D_2. If firm 2 is enjoined, firm 1 earns monopoly profits π^m during the trial period. However, with probability $1-\phi$ firm 1 is unsuccessful in obtaining an injunction. In this case, firm 2 faces potential damages D_1, subject to its being found infringing at trial. Firm 2, recognizing that it may incur damages D_1, responds by producing less than it would have were it not to face damages. Thus, firm 1 earns $\pi_1(\theta) > \pi^d$, and firm 2 earns $\pi_2(\theta) < \pi^d$. In general, the functions $\pi_1(\theta)$ and $\pi_2(\theta)$ depend upon the form of the damage functions as well as the probability that firm 1 wins the final injunction. However, in the limit as $\theta \to 0$, $\pi_1(0) = \pi_2(0) = \pi^d$, since if there is zero chance that firm 1 wins the final injunction, firm 2 expects no damages and thus each firm earns duopoly profits. Similarly, with sufficient damages, as $\theta \to 1$, $\pi_1(1) \to \pi^m$ and $\pi_2(1) \to 0$.

If firm 1 chooses *NSPI*, the game ends at terminal node 10. In this case, firm 2 earns expected profits $\pi_2^{NSPI} = \pi_2(\theta) + (1 - \theta)\beta\pi^d - \theta D_1 - c_E - c_{L_2}$, and firm 1 earns expected profits $\pi_1^{NSPI} = \pi_1(\theta) + \theta(\beta\pi^d + D_1) + (1 - \theta)\beta\pi^d - c_I - c_{L_1}$. If firm 1 chooses *SPI*, the expected profits to firm 1 are $\pi_1^{SPI} = \phi[\pi^m + \theta\beta\pi^m + (1 - \theta)(\beta\pi^d - D_2)] + (1 - \phi)[\pi_1(\theta) + \theta(\beta\pi^m + D_1) + (1$

[18] There are two reasons for this. First, by their nature, the hearings for preliminary injunctions are brief and therefore the legal costs are relatively small. Preparation for the preliminary injunction hearing must to at least some extent substitute for preparation for the trial. Second, as we will show below, imitators typically do not have any incentive to fight preliminary injunctions, leading to small legal costs for both sides.

$-\ \theta)\beta\pi^d] - c_I - c_{L_1}$, where the first term is the expected profits when a preliminary injunction is granted, the second expression is the expected profits when the preliminary injunction is denied, and the last two terms are the costs of innovating and litigating. The expected profits to firm 2 in this case are $\pi_2^{SPI} = \phi(1-\theta)(\beta\pi^d + D_2) + (1-\phi)[(\pi_2(\theta) + (1-\theta)\beta\pi^d - \theta D_1] - c_E - c_{L_2}$.

IV. Analysis of the Game under Current U. S. Liability Rules.

U.S. legal standards essentially require the loser in a patent litigation battle to compensate the winner for the losses imposed upon them by the other firm. Thus, $D_2 = \pi^d$ and $D_1 = \pi^m - \pi_1(\theta)$. Under the assumptions of linear demand, constant marginal costs, and these damage rules, Shapiro (2001) has derived the exact functional form for $\pi_1(\theta)$ and $\pi_2(\theta)$:[19]

(1) $$\pi_1(\theta) = \left(\frac{a-c}{3-\theta}\right)^2 = \frac{Z}{(3-\theta)^2} \quad \text{and} \quad \pi_2(\theta) = \frac{(1-\theta)(a-c)^2}{(3-\theta)^2} = Z\left(\frac{1-\theta}{3-\theta}\right)^2.$$

These are plotted in Fig. 2 for $a = 25$ and $c = 5$ (i.e., $Z = 20$), in which case monopoly profits are $\pi^m = 100$ and per firm duopoly profits are $\pi^d = 400/9 \approx 44.44$. From (1), at $\theta = 0$, $\pi_1(0) = \pi_2(0) = \pi^d$, and at $\theta = 1$, $\pi_1(1) = \pi^m$ and $\pi_2(0) = 0$. Thus, as θ increases, output by firm 2 decreases, until in the limit, firm 2 produces zero and earns zero.

Node 5: Firm 1's Choice of Whether or Not to Seek a Preliminary Injunction.

The net benefit to firm 1 of seeking a preliminary injunction is the difference in expected

[19] The derivation is as follows. If each firm produces during the trial, then expected profits to each firm are

$$V_1 = (a-c-q_1-q_2)q_1 + \theta[\beta\pi^m + \pi^m - (a-c-q_1-q_2)q_1] + (1-\theta)[\beta\pi^d + \pi^d],$$

$$V_2 = (a-c-q_1-q_2)q_2 + (1-\theta)\beta\pi^d - \theta[\pi^m - (a-c-q_1-q_2)q_1].$$

The Nash equilibrium thus solves the system of first-order necessary conditions:

$$\partial V_1/\partial q_1 = (1-\theta)(a-c-2q_1^*-q_2^*) = 0,$$

$$\partial V_2/\partial q_2 = a-c-(1+\theta)q_1^*-2q_2^* = 0.$$

Solving these yields $q_1^* = (a-c)/(3-\theta)$, and $q_2^* = (1-\theta)(a-c)/(3-\theta)$. Thus, $\pi_1(\theta) = (a-c-q_1^*-q_2^*)q_1^*$ and $\pi_2(\theta) = (a-c-q_1^*-q_2^*)q_2^*$, yielding the solutions in (1).

profits between π_1^{SPI} and π_1^{NSPI}. Let $\Delta\pi_1(SPI)$ define this difference:

$$\text{(2)} \qquad \Delta\pi_1(SPI) \equiv \pi_1^{SPI} - \pi_1^{NSPI} = \phi(1-\theta)[\pi^m - \pi^d - \pi_1(\theta)].$$

Thus, for $\phi > 0$ and $\theta < 1$, it is optimal for firm 1 to choose to seek a preliminary injunction whenever $\pi^m - \pi^d - \pi_1(\theta) > 0$. Because $\pi^m > 2\pi^d$ and $\pi_1(\theta)$ is bounded by π^d at $\theta = 0$, and by π^m at $\theta = 1$, this expression vanishes for some value $\theta_{SPI} \in (0,1)$ (see Fig. 2). For the linear demand and constant marginal cost case, this occurs for $\theta_{SPI} \approx 0.32$, for any value of Z. Thus, $\Delta\pi_1(SPI) > 0$ for $\theta < \theta_{SPI}$, and $\Delta\pi_1(SPI) \leq 0$ otherwise. The intuition behind this result is that for high θ, $\pi_1(\theta)$ is close to π^m, so the benefit of obtaining a preliminary injunction is slight. The damages firm 1 may be liable for are π^d. Thus, even though litigation costs are negligible, the innovator does not always wish to seek a preliminary injunction because of the potential damages he may face, but is more likely to seek a preliminary injunction in cases where the probability of winning the final injunction is low.[20]

Node 4: Firm 2's Choice of Whether to Produce while the Final Injunction is being Litigated.

Case 1: $\theta < \theta_{SPI}$. If $\theta < \theta_{SPI}$, firm 2 at node 4 faces expected profits π_2^{SPI} if it chooses to produce and expected profits π_2^{NP} if it does not. Define $\Delta\pi_2(P \mid SPI)$ as the expected net profits to firm 2 from choosing to produce at node 4, given that B chooses SPI at node 5:

$$\text{(3)} \qquad \Delta\pi_2(P \mid SPI) \equiv \pi_2^{SPI} - \pi_2^{NP} = \phi(1-\theta)\pi^d + (1-\phi)[\pi_2(\theta) - \theta(\pi^m - \pi_1(\theta)].$$

The first term in (3) is non-negative. As $\theta \to 0$, $\Delta\pi_2(P \mid SPI)$ approaches π^d. Thus for θ close to zero, producing is optimal. As $\theta \to \theta_{SPI}$, $\Delta\pi_2(P \mid SPI)$ approaches $(1-\phi)[\pi_2(\theta_{SPI}) - \theta_{SPI}\,\pi^d]$

[20] The intuition that the innovator seeks a preliminary injunction only when θ is low holds even if the cost of litigating the preliminary injunction is not negligible. For preliminary injunction litigation costs $c_{T1} > 0$, it can be shown that the area SPI remains to the left of θ_{SPI}, but only occurs for values of ϕ sufficiently high to offset the litigation costs. This intuition is confirmed by Berenato (1989, p. 40), who notes that some inventors "may consider damages the only return" on their investment.

$\approx 0.06(1 - \phi)Z > 0$, for $\phi > 0$ and $Z > 0$. Therefore, with linear demand and constant marginal cost, firm 2 chooses to produce whenever $\theta < \theta_{SPI}$.

Case 2: $\theta \geq \theta_{SPI}$. If $\theta \geq \theta_{SPI}$, firm 2 faces expected profits π_2^{NSPI} if it chooses to produce and expected profits π_2^{NP} if it does not. Define $\Delta\pi_2(\mathrm{P} \mid \mathrm{NSPI})$ as the expected net profits to firm 2 from choosing to produce at node 4, given that firm 1 chooses NSPI at node 5:

(4) $$\Delta\pi_2(P \mid NSPI) \equiv \pi_2^{NSPI} - \pi_2^{NP} = \pi_2(\theta) - \theta[\pi^m - \pi_1(\theta)].$$

As we discovered in (3), this expression has limit $\pi_2(\theta_{SPI}) - \theta_{SPI}\,\pi^d \approx 0.06Z > 0$ for all $Z > 0$. As $\theta \to 1$, $\pi_2(1) - \pi^m + \pi_1(1) = 0$. Thus (4) is non-negative for all θ. This implies that P dominates NP, at least weakly, for all values of θ.

Node 3: Firm 1's Choice of Whether or Not to Seek a Final Injunction.

Case 1: $\theta < \theta_{SPI}$. The expected profits to firm 1 of seeking a final injunction are given by π_1^{SFI}, which firm 1 compares to the profits of not seeking a final injunction, given by π_1^{NSFI}. Define $\Delta\pi_1(SFI \mid P, SPI)$ as the expected gain from seeking a final injunction:

(5) $$\Delta\pi_1(SFI \mid P, SPI) \equiv \pi_1^{SFI} - \pi_1^{NSFI} =$$

$$-c_{L_1} + \beta\theta(\pi^m - \pi^d) + \pi_1(\theta) - \pi^d + \theta[\pi^m - \pi_1(\theta)] + \phi(1 - \theta)[\pi^m - \pi^d - \pi_1(\theta)].$$

Solving (5) for the locus of points $\phi_{SFI}(\theta)$ such that $\Delta\pi_1(SFI \mid P, SPI) = 0$ yields

(6) $$\phi_{SFI}(\theta) = \frac{c_{L_1} - \beta\theta(\pi^m - \pi^d) - (\pi_1(\theta) - \pi^d) - \theta[\pi^m - \pi_1(\theta)]}{(1 - \theta)[\pi^m - \pi^d - \pi_1(\theta)]}.$$

Differentiating (5) with respect to ϕ yields $\partial\Delta\pi_1(SFI \mid P, SPI)/\partial\phi = (1 - \theta)[\pi^m - \pi^d - \pi_1(\theta)] > 0$. Thus, above ϕ_{SFI}, it is optimal for firm 1 to choose to seek a final injunction, and below ϕ_{SFI} it is optimal for firm 1 to not seek a final injunction. Taking the limit as $\theta \to 0$ yields $\phi_{SFI}(0) = c_{L_1}/(\pi^m$

$- 2\pi^d) > 0$. For values of $c_{L_1} < \pi^m - 2\pi^d$, $\phi_{SFI}(0) < 1$. When this condition is satisfied, for $\phi > \phi_{SFI}(0)$, firm 1 has an incentive to seek a final injunction even though it has zero probability of winning the final injunction. This occurs because $\pi^m > 2\pi^d$, so that firm 1 earns more by winning a preliminary injunction than it has to pay out in damages if it loses the final injunction.

In the limit as $\theta \to \theta_{SPI}$, the denominator of (6) vanishes and the numerator equals $c_{L_1} - \overline{c_{L_1}}$, where $\overline{c_{L_1}} \equiv \pi^m - 2\pi^d + \beta\theta_{SPI}(\pi^m - \pi^d) + \theta_{SPI}[\pi^m - \pi_1(\theta_{SPI})]$. For $c_{L_1} < \overline{c_{L_1}}$, the limit of ϕ_{SFI} as $\theta \to \theta_{SPI}$ is negative infinity. Thus, the $\phi_{SFI}(\theta)$ locus has a positive intercept and a negative slope as it approaches θ_{SPI}. Conversely, if $c_{L_1} > \overline{c_{L_1}}$, the limit of ϕ_{SFI} as $\theta \to \theta_{SPI}$ is positive infinity. However, if $c_{L_1} > \overline{c_{L_1}}$, then $c_{L_1} > \pi^m - 2\pi^d$, which implies that $\phi_{SFI}(0) > 1$. Thus, it is optimal for firm 1 to choose *NSFI* for all ϕ and for $\theta < \theta_{SPI}$.

The ϕ_{SFI} curve shifts upwards as c_{L_1} increases, and downwards as β increases or Z increases. Thus, higher litigation costs cause seeking a final injunction to be chosen for a smaller set of $\{\phi, \theta\}$ combinations, while higher expected profits, either due to an increase in β or in Z, cause seeking a final injunction to be the best response for a larger set of $\{\phi, \theta\}$ combinations.

Case 2: $\theta \geq \theta_{SPI}$. Whenever $\theta \geq \theta_{SPI}$, firm 1 chooses NSPI and firm 2 chooses P, no matter what firm 1 chooses with respect to seeking a final injunction. Thus, the expected profits of choosing SFI are the difference between π_1^{SFI} and π_1^{NSPI}:

(7) $$\Delta\pi_1(SFI \mid P, NSPI) \equiv \pi_1^{SFI} - \pi_1^{NSPI} = -c_{L_1} + \beta\theta(\pi^m - \pi^d) + \pi_1(\theta) - \pi^d - \theta[\pi^m - \pi_1(\theta)].$$

Taking the limit as $\theta \to 1$ yields $\Delta\pi_1(SFI \mid P, NSPI) = (\pi^m - \pi^d)(1 + \beta) - c_{L_1}$. If this term is not positive, it cannot pay for firm 1 to ever enter into litigation to defend its patent. Thus, for Z sufficiently high, $\Delta\pi_1(SFI \mid P, NSPI) > 0$ as $\theta \to 1$. The limit as $\theta \to \theta_{SPI}$ is identical but opposite in sign to the limit of the numerator of (6). Thus, for $c_{L_1} < \overline{c_{L_1}}$, this expression is positive, which means that firm 1 chooses SFI for $\theta \geq \theta_{SPI}$, whenever $c_{L_1} < \overline{c_{L_1}}$. Whenever $c_{L_1} > \overline{c_{L_1}}$, NSFI is the best response for all θ.

Node 2: Firm 2's Choice of Whether or Not to Enter.

There are three separate cases that firm 2 must consider when it chooses whether or not to enter.

Case 1: $\theta \geq \theta_{SPI}$. In this case, firm 1 seeks a final injunction, firm 2 produces, and firm 1 seeks a preliminary injunction. Thus, if firm 2 enters, it earns expected profits of π_2^{STI} and it if does not enter it earns profits of $\pi_2^{\mathrm{NE}} = 0$. Thus, the expected profits of entering are:

(8) $$\Delta\pi_2(E \mid SFI, P,NSPI) \equiv \pi_2^{SPI} - \pi_2^{NE} = \pi_2(\theta) + (1-\theta)\beta\pi^d - \theta(\pi^m - \pi^d) - c_E - c_{L_2}.$$

When $\theta = 1$, $\Delta\pi_2(E \mid SFI, P,NSPI) = -(\pi^m - \pi^d) - c_E - c_{L_2} < 0$. Thus, for θ sufficiently high firm 2 does not wish to enter. Taking the limit as $\theta \rightarrow \theta_{SPI}$ yields $\Delta\pi_2(E \mid SFI, P,NSPI) = \overline{c_E} - c_E - c_{L_2}$, where $\overline{c_E} = \pi_2(\theta_{SPI}) + \beta(1 - \theta_{SPI})\pi^d - \theta_{SPI}\pi^d$. If this expression is negative, the decision to not enter holds in the entire region $\theta \geq \theta_{SPI}$. An increase in β makes it more likely that entry is optimal for firm 2 for some $\theta > \theta_{SPI}$, and an increase in c_E or c_{L_2} makes it less likely that entry can be optimal for firm 2 for any $\theta > \theta_{SPI}$. Let $\theta_E \geq \theta_{SPI}$ denote the value of θ such that firm 2 is just indifferent between entering and not entering, given that $\overline{c_E} > c_E + c_{L_2}$ when evaluated at θ_{SPI}.

Case 2: $\theta < \theta_{SPI}$ *and* $\{\theta, \phi\} < \phi_{SFI}(\theta)$. Since $\{\theta, \phi\}$ is less than $\phi_{\mathrm{SFI}}(\theta)$, firm 1 chooses to not seek a final injunction. In this case, the profits firm 2 earns by entering are

(9) $$\Delta\pi_2(E \mid NSFI) \equiv \pi_2^{NSFI} - \pi_2^{NE} = (1+\beta)\pi^d - c_E.$$

This is the most favorable position in which the imitator can expect to be. Thus, for a sufficiently valuable innovation (i.e. for Z sufficiently large), firm 2 enters in this instance if it enters at all.

Case 3: $\theta < \theta_{SPI}$ *and* $\{\theta, \phi\} > \phi_{SFI}(\theta)$. In this case, firm 1 seeks both a final and preliminary injunction and firm 2 produces and earns profits $\pi_2(\theta)$ during the period of the trial, if it enters. The expected profits to firm 2 from entering are thus

$$(10) \qquad \Delta\pi_2(E \mid SFI, P, SPI) \equiv \pi_2^{SPI} - \pi_2^{NE} =$$

$$\phi(1-\theta)(\beta\pi^d + \pi^d) + (1-\phi)[\pi_2(\theta) + (1-\theta)\beta\pi^d - \theta(\pi^m - \pi^d)] - c_E - c_{L_2}.$$

Since (10) is linear in ϕ, differentiating the expected profits of entering with respect to ϕ yields $\partial\Delta\pi_2(E \mid SFI, P, SPI)/\partial\phi = \pi^d - \pi_2(\theta) + \theta[\pi^m - \pi^d - \pi_2(\theta)]$, which is greater than zero for $\theta < \theta_{SPI}$. Thus for sufficiently high ϕ, entry is profitable. Solving (10) for the locus $\phi_E(\theta)$ such that firm 2 is indifferent between entering and not entering yields

$$(11) \qquad \phi_E(\theta) = \frac{c_{L_2} + c_E - \beta(1-\theta)\pi^d - \pi_2(\theta) + \theta[\pi^m - \pi_1(\theta)]}{\pi^d - \pi_2(\theta) + \theta[\pi^m - \pi^d - \pi_2(\theta)]}.$$

The denominator of (11) is non-negative for $\theta < \theta_{SPI}$, and the numerator is opposite in sign as the expression on the right-hand-side in (8). Taking the limit of $\phi_E(\theta)$ as $\theta \to 0$ causes the denominator to vanish and the numerator to approach $c_{L_2} + c_E - (1+\beta)\pi^d$. For a sufficiently valuable innovation, this expression is negative, so $\phi_E(0) \to -\infty$. Taking the limit as $\theta \to \theta_{SPI}$ yields $\phi_E(\theta_{SPI}) = [c_{L_2} + c_E - \overline{c_E}]/(\pi^d - \pi_2(\theta_{SPI}))$. The denominator of this expression is positive in sign. If the numerator is positive, then there exists a region below $\phi_E(\theta)$ such that NE is optimal. If the numerator is negative, then E is optimal for all $\theta < \theta_{SPI}$, and (8) implies that E will also be optimal for some values of $\theta > \theta_{SPI}$. From (11), we see that an increase in entry or litigation costs makes it more likely that *NE* is likely to be optimal, since the $\phi_E(\theta)$ curve shifts up as $c_E + c_{L_2}$ increases. However, an increase in β or the value of the innovation increases $\overline{c_E}$, which causes the $\phi_E(\theta)$ curve to shift upwards. Fig. 3 shows the full set of equilibrium points. Panel (a) displays the case where $\phi_E(\theta) > 0$ for $\theta < \theta_{SPI}$, and panel (b) displays the case where $\phi_E(\theta) < 0$ for $\theta < \theta_{SPI}$.

Node 1: Firm 1's Choice of Whether or Not to Innovate.

From Fig. 4, there are as many as four possibilities that firm 1 may face when it makes its decision of whether or not to innovate. These are now considered in order.

Case 1: Firm 1 chooses NSFI if firm 2 enters. If firm 1 chooses *NSFI* upon seeing entry by firm 2, then $\{\theta, \phi\}$ is below the $\phi_{SFI}(\theta)$ loci. In this case, the expected profits to firm 1 are

$$\Delta\pi_1(I \mid NSFI) = \pi_1^{NSFI} - \pi_1^{NI} = (1+\beta)\pi^d - c_I. \tag{12}$$

If this expression is positive, then no patent policy is required, since the incentive to innovate is sufficiently provided by the market. Thus, when the innovation is sufficiently valuable, firm 1 chooses to innovate. Only when the innovation is unprofitable at duopoly profits will the choice be to not innovate.

Case 2: Firm 2 chooses NE. If firm 2 chooses *NE*, then the expected profits to firm 1 are

$$\Delta\pi_1(I \mid NE) = \pi_1^{NE} - \pi_1^{NI} = (1+\beta)\pi^m - c_I. \tag{13}$$

This is the polar opposite to the last case. Here, firm 1 chooses to innovate for marginally beneficial innovations, simply because the market power obtained through the patent more than compensates for the innovation costs. As in the case where firm 1 subsequently chooses not to seek a final injunction, an increase in the value of the patent or an increase in β increases the benefit to innovating, and increases in innovation costs decrease the benefit to innovating.

Case 3: Firm 2 chooses E and P, firm 1 chooses SFI and SPI. In this case, the probabilities

$\{\theta, \phi\}$ lie above both the $\phi_E(\theta)$ and $\phi_{SFI}(\theta)$ curves. The expected profits to firm 1 if it chooses to innovate are:

(14) $$\Delta\pi_1(I \mid E, SFI, P, SPI) = \pi_1^{SPI} - \pi_1^{NI} = \phi[\pi^m + \theta\beta\pi^m + (1-\theta)(\beta\pi^d - \pi^d)]$$
$$+ (1-\phi)[\pi_1(\theta) + \theta(\beta\pi^m + \pi^m - \pi_1(\theta)) + (1-\theta)\beta\pi^d] - c_I - c_{L_1}.$$

Differentiating (14) with respect to ϕ yields $\partial\Delta\pi_1(I \mid E, SFI, P, SPI)/\partial\phi = (1-\theta)[\pi^m - \pi^d - \pi_1(\theta)]$, which is positive for $\theta < \theta_{SPI}$. Let $\phi_I(\theta)$ denote the locus of points where firm 1 is just indifferent between innovating and not innovating. This derivative suggests that above the $\phi_I(\theta)$, innovation is profitable to firm 1, given the subsequent play in the game. Solving the expression on the right-hand-side for the loci $\phi_I(\theta)$ where $\Delta\pi_1(I \mid E, SFI, P, SPI) = 0$ yields

(15) $$\phi_I(\theta) = \frac{c_I + c_{L_1} - \theta(1+\beta)\pi^m - (1-\theta)[\pi_1(\theta) + \beta\pi^d]}{(1-\theta)[\pi^m - \pi^d - \pi_1(\theta)]}.$$

Comparing the $\phi_I(\theta)$ and $\phi_{SFI}(\theta)$ loci reveals that

(16) $$\phi_I(\theta) - \phi_{SFI}(\theta) = \frac{c_I - (1+\beta)\pi^d}{(1-\theta)[\pi^m - \pi^d - \pi_1(\theta)]}.$$

For any innovation of low enough quality that patent protection is required, this expression is positive. This implies that for these types of innovations, $\phi_I(\theta)$ lies everywhere above $\phi_{SFI}(\theta)$. Taking the limit of (15) as $\theta\to 0$ yields $\phi_I(0) = [c_I + c_{L_1} - (1+\beta)\pi^d]/(\pi^m - 2\pi^d)$, which is greater than $\phi_{SFI}(0)$ so long as $c_I > (1+\beta)\pi^d$. Taking the limit as $\theta\to\theta_{SPI}$, one can see that the denominator of (15) vanishes.

Fig. 4 summarizes the possible subgame perfect equilibria. For a given Z, β, c_I, c_{L_1}, c_E, c_{L_2}, ϕ, and θ there are at most four types of equilibria. To the left of the $\phi_I(\theta)$ curve, firm 1 chooses not to innovate. This area is labeled NI in panels (a) and (b) of Fig. 4. With sufficiently high innovation or litigation costs (e.g., $c_{L_1} > \overline{c_{L_1}}$), NI is firm 1's best response for all $\{\phi, \theta\}$. To the right of $\phi_I(\theta)$ and to the left of the $\phi_E(\theta)$ curve, firm 1 innovates, firm 2 enters, firm 1 seeks a final injunction, firm 2 produces, and firm 1 seeks a preliminary injunction. This area is labeled SPI. To the right of the $\phi_E(\theta)$ curve in panel (a), firm 2 chooses to not enter. If this area exists on the left side of θ_{SPI}, then "not enter" is optimal for all $\theta > \theta_{SPI}$ as well, as shown in panel (a). This area is labeled NE. The area NE increases as $c_E + c_{L_2}$ increases. The fourth area that is possible occurs only if $c_E + c_{L_2}$ is small, so that entry occurs for all $\theta < \theta_E$, where $\theta_E > \theta_{SPI}$. Then in the region between θ_{SPI} and θ_E, the best responses are firm 1 innovates, firm 2 enters, firm 1 seeks a final injunction, firm 2 produces, and firm 1 does not seek a preliminary injunction. This is the area labeled NSPI in panel (b).

Preliminary Injunctions and Patent Protection.

One very interesting conclusion from this analysis is that preliminary injunctions can cause innovation by firm 1 in instances where it has literally zero chance of defending the patent at the final injunction level. In panel (a) of Fig. 4, any point $\{\phi, 0\}$ that lies above $\phi_I(0)$ has zero chance of winning patent protection. Nevertheless, firm 1 is willing to innovate, simply because of the chance that it will receive temporary protection, and the concomitant temporary monopoly profits, through the use of a preliminary injunction.

Second, more generally, protection from competition via preliminary injunctions is only used by the innovator when the probability of winning a final injunction is relatively low (i.e., less that $\theta = 0.32$ in the model considered). This suggests that preliminary injunctions create an incentive to claim a patent when the value of the patent is relatively low to society.

A third conclusion regarding preliminary injunctions is that both the innovator and the imitator prefer the probability of a preliminary injunction being granted be high.[22] For the innovator, this occurs because the innovator earns monopoly profits during the time the preliminary injunction is enforced, and only pays damages equal to duopoly profits if the final judgment goes against him. For the imitator, an increase in ϕ, holding θ constant, and given I, E, SFI, and SPI, is positive:

$$\frac{\partial \pi_2^{SPI}}{\partial \phi} = \pi^d - \pi_2(\theta) + \theta[\pi^m - \pi_1(\theta) - \pi^d] > 0.$$

This implies that both the innovator and the imitator benefit from higher ϕ.[23]

Using this method, it is possible to characterize the profit contours for each firm in each of the four regions. We complete the analysis in the region SPI by observing that the imitator's profits are decreasing in θ and the innovator's profits are increasing in θ:

$$\frac{\partial \pi_2^{SPI}}{\partial \theta} = (1-\theta)\pi_2'(\theta) - \beta\pi^d - (1-\phi)[\pi^m - \pi_1(\theta)] - \phi\pi^d < 0,$$

$$\frac{\partial \pi_1^{SPI}}{\partial \theta} = \phi\pi^d + (1-\phi)[\pi^m - \pi_1(\theta)] + \beta(\pi^m - \pi^d) + (1-\phi)\pi_1'(\theta) > 0.$$

Thus, when the equilibrium is in region SPI, the innovator and imitator's interests are aligned with respect to the probability the innovator wins the preliminary injunction, but are opposed with respect to the probability the innovator wins the final injunction.

When the equilibrium result is NI, both firms earn zero profits, so within this region an increase in ϕ or θ has no effect on the profits of either the innovator or the imitator. Similarly, in the region where the imitator chooses to not enter, the imitator earns zero profits and the innovator earns monopoly profits. Thus, within this region, an increase in ϕ or θ has no effect on

22 Lanjouw and Lerner (2001, p. 580, n. 19), referring to their 1996 NBER paper, make a similar point.

23 If an additional stage is added to the game, where the imitator chooses whether or not to fight the preliminary injunction, this result implies that the imitator chooses to not fight the preliminary injunction. This is thus consistent with our assumption that litigation costs are negligible at the preliminary injunction stage.

profits. In the region NSPI in panel (b) of Fig. 5, both innovation and entry has occurred, and the innovator seeks a final injunction, but not a preliminary injunction. In this region, ϕ does not affect the profits of either firm, but profits to the innovator are increasing in θ,

$$\frac{\partial \pi_1^{NSPI}}{\partial \theta} = \pi^m - \pi_1(\theta) + (1-\theta)\pi_1'(\theta) > 0,$$

and profits to the imitator are decreasing in θ,

$$\frac{\partial \pi_2^{NSPI}}{\partial \theta} = -\beta\pi^d - [\pi^m - \pi_1(\theta)] + \pi_2' + \theta\pi_1'(\theta) < 0,$$

where $\pi_2' + \theta\pi_1'(\theta) = -Z(1-\theta)/(3-\theta)^3 < 0$.

The fact that both innovator and imitator benefit from higher ϕ suggests that in any preliminary injunction hearing, the innovator is likely to make a real effort to persuade the court of the need for an injunction, while the imitator is unlikely to make much effort, and may even accept the injunction.[24] (This is in part a justification for our assumption that preliminary injunction legal costs are likely to be negligible.) An implication of this is that ϕ will be endogenous: rather than fighting over preliminary injunctions, both sides will choose $\phi = 1$ provided that the imitator has entered and the innovator has chosen SFI. Let us suppose that $\phi = 1$ if the innovator and imitator each prefer it, conditional on entry and SFI. Using the subgame perfect Nash equilibrium concept, this implies that provided that profits for both innovator and imitator are positive at $\phi = 1$ given θ, the outcome must be characterized by I, E, SFI, SPI, and $\phi = 1$. Consider, for example, the axis $\theta = 0$ in Figure 5(a). The optimal strategy given SPI is for the imitator to admit the preliminary injunction so that $\phi = 1$. For $\phi = 1$ and $\theta =$

[24] Even worse, if both parties prefer the preliminary injunction, they may also prefer to stretch the trial out for as long as possible. Certainly, the patent holder should be expected to try to delay resolution of the trial if a preliminary injunction is in place, and the imitator cannot lose from a longer trial.

0, as we have already established, the optimal strategy must be I, E, SFI, SPI. Thus even if, from an outsider's perspective, the patent is worthless, meriting neither a preliminary nor a final injunction with any probability, the innovator will innovate in order to benefit from the monopoly profits created by the temporary exercise of the preliminary injunction on competition.

This raises the question of what is the meaning of a patent of $\theta = 0$. We defer answering this question until section VI, after developing some terminology to address ideas related to welfare.

A further interesting perspective which derives from this analysis is that the damages payable (and therefore required in a bond) to the patent holder if no preliminary injunction is granted are *negatively* related to the probability that the patent holder wins at trial. The damages paid to the patent holder are $\pi^m - \pi_1(\theta)$. Since $\pi_1(\theta)$ approaches π^m as $\theta \rightarrow 1$, the damages become vanishingly small when the patent is most likely to be found valid, and largest when the patent is most likely to be found invalid. Allegedly infringing firms which are hesitant to produce at risk will therefore be at most risk when they are most likely to be found not infringing, which suggests that the predatory potential of preliminary injunctions may be particularly high for patents having low θ.

V. Welfare Analysis.

We now turn to a welfare analysis of the model. As a preliminary, we examine how welfare under different patent rules depends on market size $Z \equiv (a - c)^2$, where Z is a measure of the "usefulness" of an innovation, which is one of the criteria for a patent.[25] A good with extremely high Z is one that is valuable to society, but it is also one that will be profitable even without patent protection.[26] A good with extremely low Z is one that may not be valuable to society, but

[25] Increasing Z is of course equivalent to a decrease in the various non-marginal costs, so the discussion in terms of Z could be framed as a discussion related to innovation, entry, and litigation costs.
[26] This is assuming duopoly competition in the absence of patent protection. This assumption is not entirely

will also be unlikely to be valuable to the innovator, since profits will be small or even negative. Thus, the problem is to set ϕ and θ such that one prompts innovations that would not occur without patent protection, but encourages entry if patent protection is not required. We will consider how the novelty of the innovation should be reflected in the optimal patent rule in the following section.

Define welfare under any $\{\phi, \theta\}$ rule as the sum of industry profits plus consumers surplus less innovation, entry, and litigation costs. Thus, welfare depends upon the equilibrium outcome in the patent game. Define $S^m \leq S_{12} \leq S^d$ as the consumer's surplus under monopoly, Cournot duopoly of the form associated with profits π_1 and π_2, and pure Cournot duopoly, respectively.[27] Then aggregate surplus under the different market structures are related according to

(17) $$\pi^m + S^m \ < \ \pi_1 + \pi_2 + S_{12} \ < \ 2\pi^d + S^d.$$

If no innovation occurs in equilibrium, then aggregate welfare is

(18) $$W^{NI}(\phi, \theta, Z) \equiv \ 0.$$

If innovation occurs, but entry by an imitator does not, then aggregate welfare is monopoly surplus less innovation costs:

(19) $$W^{NE}(\phi, \theta, Z) \equiv \ (\pi^m + S^m)(1 + \beta) - c_I.$$

For Z sufficiently high, this is positive in sign, since both π^m and S^m are increasing in Z. If innovation and entry each occur, and the innovator seeks a final injunction but not a preliminary injunction, then welfare is given by Cournot competition in the first period, affected by the

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objectionable, as the results follow even if the market becomes perfectly competitive eventually.

[27] When $\theta = 0$, $\pi_1(0) + \pi_2(0) = 2\pi^d$, and when $\theta = 1$, $\pi_1(1) + \pi_2(1) = \pi^m$. Furthermore, aggregate profits are increasing in θ, which implies that writing consumer's surplus $S_{12}(\theta)$ as a function of θ yields $S_{12}(0) = S^d$ and $S_{12}(1) = S^m$, with $S_{12}'(\theta) < 0$.

damages structure, plus either monopoly or surplus after the trial is conducted, less innovation, entry, and litigation costs:

$$W^{NSPI}(\phi, \theta, Z) \equiv \pi_1 + \pi_2 + S_{12} + \theta\beta(\pi^m + S^m) + (1-\theta)\beta(2\pi^d + S^d) - c_I - c_E - c_{L_1} - c_{L_2}, \tag{20}$$

As in the NE case, for sufficiently large Z, welfare will be positive. Finally, if innovation and entry occurs, and the innovator seeks both a preliminary and final injunction, social welfare is given by

$$\begin{aligned} W^{SPI}(\phi, \theta, Z) \equiv\ & \phi\theta(\pi^m + S^m)(1+\beta) + (1-\phi)\theta[\pi_1 + \pi_2 + S_{12} + \beta(\pi^m + S^m)] \\ & + \phi(1-\theta)[\pi^m + S^m + \beta(\pi^d + S^d)] + (1-\phi)(1-\theta)[\pi_1 + \pi_2 + S_{12} + \beta(\pi^m + S^m)] \\ & - c_I - c_E - c_{L_1} - c_{L_2}. \end{aligned} \tag{21}$$

The first term is the stream of surplus under monopoly, which occurs only if the innovator wins both the preliminary and final injunctions. The second term occurs if the innovator loses the preliminary injunction but wins the final injunction. The third term occurs if the innovator wins the preliminary injunction but loses the final injunction. The fourth term occurs if the innovator loses both the preliminary and final injunctions. The third line is the innovation, entry, and litigation costs. Again, for sufficiently high Z, welfare is positive.

The Effect of Changes in θ *and* ϕ *on Welfare.*

From (18)-(20), it is clear that ϕ does not affect welfare when there is no innovation, no entry, or no preliminary injunction sought. However, when a preliminary injunction is sought, welfare is decreasing in ϕ:

$$\frac{\partial W^{SPI}}{\partial \phi} = \pi^m + S^m - (\pi_1 + \pi_2 + S_{12}) < 0.$$

This is interesting, because we observed earlier that both the innovator and the imitator wished for ϕ to be as large as possible in this region. Thus, social interests and the interests of both the innovator and imitator are at odds with respect to the granting of preliminary injunctions. In the region where SPI is chosen, welfare is also decreasing in θ:

$$\frac{\partial W^{SPI}}{\partial \theta} = \beta[\pi^m + S^m - (2\pi^d + S^d)] + (1-\phi)\frac{\partial(\pi_1 + \pi_2 + S_{12})}{\partial \theta} < 0.$$

Thus, in this region, society's indifference curves are downward sloping, implying that the social optimum occurs somewhere along the $\phi_I(\theta)$ curve. Unfortunately, the social optimum will be difficult to achieve in practice, since if the pair $\{\phi, \theta\}$ is very slightly below the $\phi_I(\theta)$ curve, the result is no innovation at all, a result that makes society much worse off for Z sufficiently high.

Similarly, in region NSPI, welfare is decreasing in θ:

$$\frac{\partial W^{NSPI}}{\partial \phi} = \beta[\pi^m + S^m - (2\pi^d + S^d)] + \frac{\partial(\pi_1 + \pi_2 + S_{12})}{\partial \theta} < 0.$$

This occurs because an increase in θ decreases the imitator's production during the trial and because it increases the chance that the innovator wins the final injunction. Since innovation and entry occur in this region, it is in society's interest to have as much competition as possible.

At the boundary between NSPI and NE (see Fig. 5 panel (b)), a small increase in θ has the following effect on welfare:

$$W^{NE} - W^{NSPI} = c_E + c_{L_1} + c_{L_2} - \{\pi_1 + \pi_2 + S_{12} - (\pi^m + S^m) + \beta(1-\theta)[2\pi^d + S^d - (\pi^m + S^m)]\}.$$

While in general this expression is ambiguous in sign, for sufficiently large Z the expression is curly brackets dominates, which implies that welfare decreases as a result of not having entry by an imitator. The intuition is simply that, conditional upon innovation, society is better off with competition.

At the boundary between NSPI and SPI (Fig. 5 panel (b)), the change in welfare of an increase in θ is

$$W^{NSPI} - W^{SPI} = \phi[\pi_1 + \pi_2 + S_{12} - (\pi^m + S^m)] > 0.$$

Thus, welfare is improved by having the innovator not seek a preliminary injunction, since this lessens the chance that there will be monopoly production during the trial period.

The welfare changes from moving from NI to either SPI or NE each depend upon Z. For sufficiently large Z, $W^{NE} > W^{NI} = 0$, and $W^{SPI} > W^{NI} = 0$. For a sufficiently valuable innovation, society gains more by allowing monopoly production than by not having any production.

Finally, at the boundary between SPI and NE an increase in ϕ (pushing the equilibrium into the SPI region) has the following effect:

$$W^{SPI} - W^{NE} = (1 - \phi)[\pi_1 + \pi_2 + S_{12} - (\pi^m + S^m)] + (1 - \theta)\beta[2\pi^d + S^d - (\pi^m + S^m)] \\ - c_E - c_{L_1} - c_{L_2}.$$

While in general, this expression is ambiguous in sign, as the innovation becomes more useful, encouraging entry dominates the entry and litigation costs associated with entry, so social welfare is improved by increasing ϕ or reducing θ.

Optimal (Second-Best) Patent Policy

We are now in a position to evaluate patent policy in the context of probabilistic rules for granting preliminary and final injunctions, still assuming that the innovation has sufficient novelty to merit a patent. Our analysis suggests that the optimal patent rule $\theta^*(Z)$ should be bounded from above, since once $\theta^*(Z)$ is sufficient to encourage innovation, it needs to be restricted so as not to discourage imitation, since imitation increases aggregate surplus. Secondly, an optimal patent policy is one that sets $\phi^*(Z)$ as low as possible, conditional upon encouraging innovation. Again, this is to encourage imitation, since imitation increases aggregate surplus.

We first show that a patent policy that uses instruments $\{\phi, \theta\}$ is incapable of always maximizing social welfare. The intuition is that the innovator and the imitator do not capture consumer's surplus S. This can be seen most clearly by considering the case where $Z = \underline{Z}$, such that profits to the innovator just cover innovation costs when $\phi = \theta = 1$. In this case, the imitator has no incentive to enter, and, writing π^m and S^m explicitly as functions of Z, social welfare is

$$W^{NE}(1, 1, \underline{Z}) = (1 + \beta)[\pi^m(\underline{Z}) + S^m(\underline{Z})] - c_I = (1 + \beta)S^m(\underline{Z}), \tag{22}$$

where the second equality occurs because the innovator's profits just cover its innovation costs. Social welfare is positive even for $Z = \underline{Z} - \varepsilon$, even though profits to the innovator are negative. Thus, to maximize social welfare in this instance, the social planner needs an additional instrument, such as a subsidy for the innovator. Since $\pi^m(Z) \equiv Z/4$, we can solve for $\underline{Z}$ using the fact that $(1 + \beta)\pi^m(\underline{Z}) = c_I$, yielding $\underline{Z} = 4c_I/(1+\beta)$. As a rationality check, it is clear that for $\phi = \theta = 1$, $\pi_2^{NSPI} = -c_E - c_{L_2} < 0$, so the imitator does not wish to enter.

Alternatively, we can solve for the value $\overline{Z}$ such that when $\theta = \phi = 0$, the innovator is just willing to enter, even though the imitator is also willing to enter. In this case, $\phi_I(0) = 0$, and $\phi_E(0) < 0$, implying $\pi_1^{SPI} = (1 + \beta)\pi^d(\overline{Z}) - c_I - c_{L_1} = 0$ and $\pi_2^{SPI} = (1 + \beta)\pi^d(\overline{Z}) - c_E - c_{L_2} \geq 0$. In this case, social welfare is $W^{SPI}(0, 0, \overline{Z}) = (1 + \beta)S^d(\overline{Z}) + \pi_2^{SPI} > 0$. Solving for $\overline{Z}$ yields $\overline{Z} = 9(c_I + c_{L_1})/(1+\beta)$.

Now, we see an interesting conundrum: $\overline{Z} > \underline{Z}$, yet at $\overline{Z}$, $\theta = \phi = 0$ is optimal, since setting either θ or ϕ higher results in social welfare of zero, while at $\underline{Z}$, setting $\theta = \phi = 1$ is optimal, since setting $\theta < 1$ results in zero welfare. This suggests that the optimal (second-best) policy is to set θ higher when Z is lower, rather than θ higher when Z is higher. We have already seen that setting ϕ as low as possible to secure entry is optimal. When $Z = \underline{Z}$, ϕ may be set as high as possible, without affecting the outcome. However, when $Z = \overline{Z}$, it is optimal to set $\phi = 0$. Thus, we conclude that an optimal (second-best) policy is to have ϕ^* and θ^* decreasing as Z increases. The intuition is simply that higher Z-type innovations are already sufficiently valuable to society that innovation will occur, thus one wishes to set θ and ϕ as low as possible to encourage imitation. Conversely, with low Z-type innovations, it is optimal to set θ and ϕ high enough to encourage innovation.

Unfortunately, actual patent rules take no account of market size. The outcome has a predictable bias compared to what is optimal according to our rule: for very useful innovations with assumed high novelty, patents will be granted which should not optimally be granted, since the innovation would occur with or without the patent.

VI. Non-Novel Innovations.

Let us now consider the case of non-novel innovations. Our interpretation of a non-novel innovation is one that claims a patent on the competitively provided prior art,[28] and which has $\theta = 0$. We will also assume that the prior art is being competitively (duopolistically) exploited, so the innovation is simply that one of the firms active in the market files a patent on the technology. Thus the cost of innovation c_I is in this case simply the cost of developing the patent application. The competing imitator firm then has a choice to exit the market if it wants to avoid fighting a legal battle. If it does not exit, the innovator may sue for patent infringement ("seek a final injunction"). The rest of the game is the same as in Figure 1, differing only in the expected payoffs. The differences are that even without innovation, the market will be a duopoly; there is

[28] In general, if the prior art is being exploited by a monopolist, it will already be patented, which will make a new patent unlikely. Unpatented prior art allows for competitive use of the innovation, but the Patent Office is more likely to overlook it.

a zero cost of entry for the imitator firm ($c_E = 0$), as it was already in the market; and $\theta = 0$. Figure 5 shows the game tree with payoffs.

Again using backwards induction, at decision node 5 the firm 1 seeks a preliminary injunction; and at node 4, firm 2 chooses to produce. Firm 1 initiates an infringement lawsuit if the costs of litigation are less than probability-weighted extra profits in case it is successful in winning a preliminary injunction, i.e. if $c_{L_1} < \phi(\pi^m - 2\pi^d)$. This will be true for Z sufficiently large, for any ϕ, but becomes more likely the higher is ϕ. If litigation costs are not too high, firm 2 chooses to stay in the market.[29] Finally, working back to node 1, firm 1 will choose to "innovate" if $c_I + c_{L_1} < \phi(\pi^m - 2\pi^d)$. Thus, if the costs of developing the non-novel patent application and then pursuing its baseless litigation are low compared to the expected benefits from the chance of a preliminary injunction.[31]

The welfare effects from non-novel innovations are unambiguously negative. Comparing the results of having no sham innovation to having firm 1 "innovating" and then seeking a preliminary injunction, welfare unambiguously decreases from $W^{NI} = (1 + \beta)(2\pi^d + S^d)$ without the "innovation" to $W^I = (1 - \phi + \beta)(2\pi^d + S^d) + \phi(\pi^m + S^m) - c_I - c_{L_1} - c_{L_2}$ with the "innovation." Consumers suffer a loss in welfare of $\phi(S^d - S^m)$; the imitator suffers a decrease in profits of c_{L_2}; and the patent holder's profits increase by $\phi(\pi^m - 2\pi^d) - c_I - c_{L_1}$. There is also an increase in

[29] This assumption is of course related to the point made by Lanjouw and Lerner (2001), that if financing costs are sufficiently high for the "infringing" firm, preliminary injunctions may be used as a predatory device.
[31] If the firm is found to have pursued "objectively baseless litigation", it is subject to antitrust sanction (*Professional Real Estate Investors,* 508 U.S. 49.), so the patent application has to have at least a semblance of novelty. As we discussed above, if the probability of the patent being found infringed is greater than zero, the "infringing" firm will actually prefer to be enjoined out of the market, leading to a higher ϕ than might be objectively expected given the merits of the patent.

patent office and court costs. Furthermore, the incentives to pursue this kind of worthless patent are largest in high-*Z* markets, exactly the markets where the welfare losses will be largest if the preliminary injunction is granted.

Many patents are found at trial to lack novelty, suggesting that preliminary injunctions are used by firms to gain market power. Such patented innovations might include Amazon's celebrated patent on "one-click" purchasing, or U.S. patent 6,368,227, issued for a method of swinging sideways on a child's swing. The firm BountyQuest offers rewards to individuals who can find prior art for specific patents, and they have found evidence of patents that claims the prior art.[32] In pharmaceuticals, it is very common to see generic firms challenging patents held by innovator firms on the basis of invalidity. Such patents are often found invalid on the basis of obviousness or lack of novelty.

Note that it is the combination of the damages rule and the incentives created by preliminary injunctions that is likely to lead to non-novel innovations being patented. Without the possibility of gaining a preliminary injunction, the non-novel innovation would never be pursued. This suggests that preliminary injunctions are at least in part responsible for creating very considerable costs and deadweight losses.

VII. Discussion & Conclusions.

In any discussion of patent policy, it is important to account for the fact that many patents impinge to some extent on the prior art. If an innovation is sufficiently close the prior art, granting a patent on it may harm competition more than it increases welfare through stimulating innovation—that is to say, the deadweight loss created through the exercise of market power is disproportionately large compared to the value created by the innovation. It is for this reason that patents are found valid with very low probability when they disclose innovations which are "close" to the prior art. Thus, in the design of a patent system it is important to choose a patent

[32] "Suddenly, 'Idea Wars' Take On a New Global Urgency", New York Times, November 11 2001.

rule that provides protection to encourage novel innovations but not provide protection to obvious, non-novel innovations.

In general, this will imply that if θ the probability of receiving a patent is low, then the degree of novelty is small. This has important implications for the case of preliminary injunctions, since as we showed in section VI, firms may be willing to apply for a patent which has a zero probability of being upheld only in order to benefit from the temporary monopoly protection it may confer. Such patents create market power and deadweight losses with no compensating benefits from innovation. Without the possibility of a preliminary injunction, the "innovation" and patent application would never occur, and thus there would be no possibility of an ultimately mistaken preliminary injunction ever being granted. Consider the region denoted NI in Figure 4a. In this region, any innovation has such a small chance of getting patent protection, that if ϕ is sufficiently low, the innovation will be privately unprofitable, and, depending on market size Z, socially undesirable. However, since the patenting firm knows that such an innovation is likely to receive temporary protection through a preliminary injunction, it may go ahead with developing the innovation and applying for patent protection.

At the heart of the problem is that while imitators can get damages when they are wrongly enjoined, consumers – who pay high prices while the preliminary injunction protects the monopoly – are uncompensated. Thus, preliminary injunctions create extra profits to be shared between the firms in the industry. The patent holder gets monopoly profits less a (possible) payment to the imitator; and the imitator bears no risk of having to pay even larger damages to the incumbent. This is, in effect, an anti-competitive settlement between firms, created and enforced by the courts.

Although there is not space to fully examine them, there are a number of ways in which the current system could be improved. One would be to ensure that consumers are paid damages when an imitator is wrongly enjoined. Since paying damages to individual consumers of most products is improbable, the damages would have to be paid in the form of fines. This would eliminate the excess profits earned through preliminary injunctions, and prevent firms from applying for patents in order to get preliminary injunctions. This solution would respect the fourth criterion for granting a preliminary injunction—the public interest—by actually protecting the public in case the patent was found to be invalid or not infringed.

A second possible solution is to not grant preliminary injunctions. It should be possible to force the imitator to post a bond equal to the loss per sale made by the imitator. This remedy does not deal with cases where the imitator is financially unable to post such a bond, but allowing for some flexibility in the structure of the bond—for example setting the bond to increase monthly according to sales of the allegedly infringing product—such a solution might be able to deal with many cases.[33]

[33] This was the solution wisely adopted in Flo-Con Systems, Inc., v. Leco Corp (845 F. Supp 1576 (S. D. Ga 1993)).

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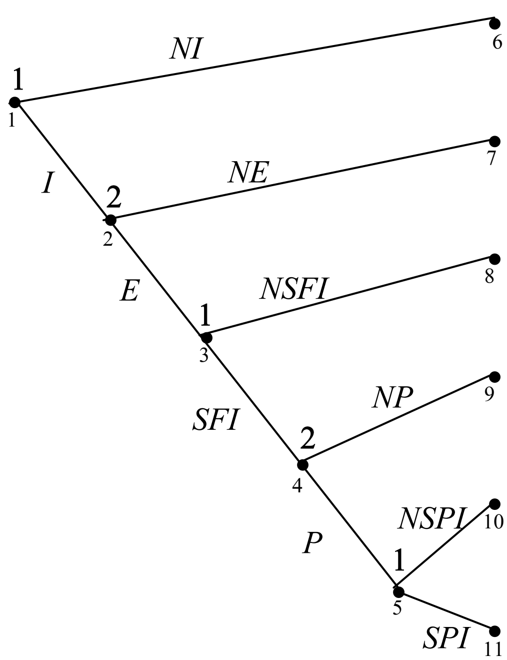
Fig. 1: Game Tree For Patents and Injunction Game



$$\pi_1^{NI} = 0$$
$$\pi_1^{NI} = 0$$

$$\pi_1^{NE} = (1+\beta)\pi^m - c_I$$
$$\pi_2^{NE} = 0$$

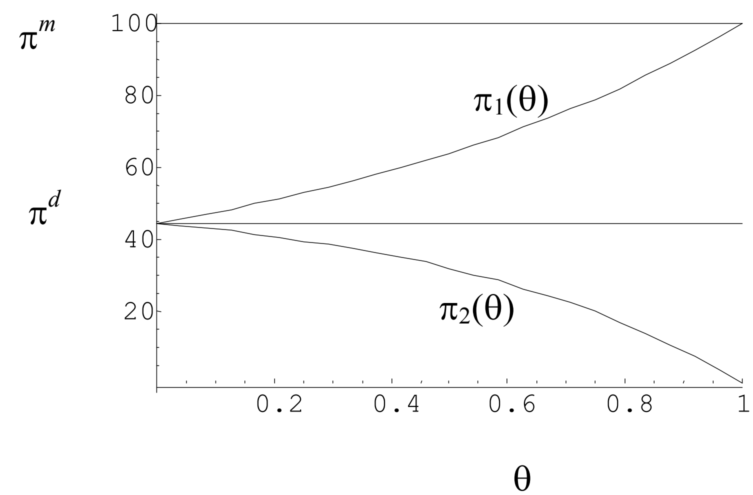
$$\pi_1^{NSFI} = (1+\beta)\pi^d - c_I$$
$$\pi_2^{NSFI} = (1+\beta)\pi^d - c_E$$

$$\pi_1^{NP} = \pi^m + \theta\beta\pi^m + (1-\theta)\beta\pi^d - c_I - c_{L_1}$$
$$\pi_2^{NP} = (1-\theta)\beta\pi^d - c_E - c_{L_2}$$

$$\pi_1^{NSPI} = \pi_1(\theta) + \theta(\beta\pi^d + D_1) + (1-\theta)\beta\pi^d - c_I - c_{L_1}$$
$$\pi_2^{NSPI} = \pi_2(\theta) + (1-\theta)\beta\pi^d - \theta D_1 - c_E - c_{L_2}$$

$$\pi_1^{SPI} = \phi[\pi^m + \theta\beta\pi^m + (1-\theta)(\beta\pi^d - D_2)] + (1-\phi)[\pi_1(\theta) + \theta(\beta\pi^m + D_1) + (1-\theta)\beta\pi^d] - c_I - c_{L_1}$$
$$\pi_2^{SPI} = (1-\phi)[(\pi_2(\theta) + (1-\theta)\beta\pi^d - \theta D_1] + \phi(1-\theta)(\beta\pi^d + D_2) - c_E - c_{L_2}$$

Fig. 2: First Period Profits for Firm 1 and Firm 2 as a Function of the Probability Firm 1 Wins the Final Injunction.



NOTES: Drawn with linear demand $P = a - Q$, and constant marginal cost c, with $a - c = 20$. Thus, $\pi^m = 100$ and $\pi^d = 44.44$.

Fig. 3: Subgame Perfect Equilibrium for Nodes 2 – 5.

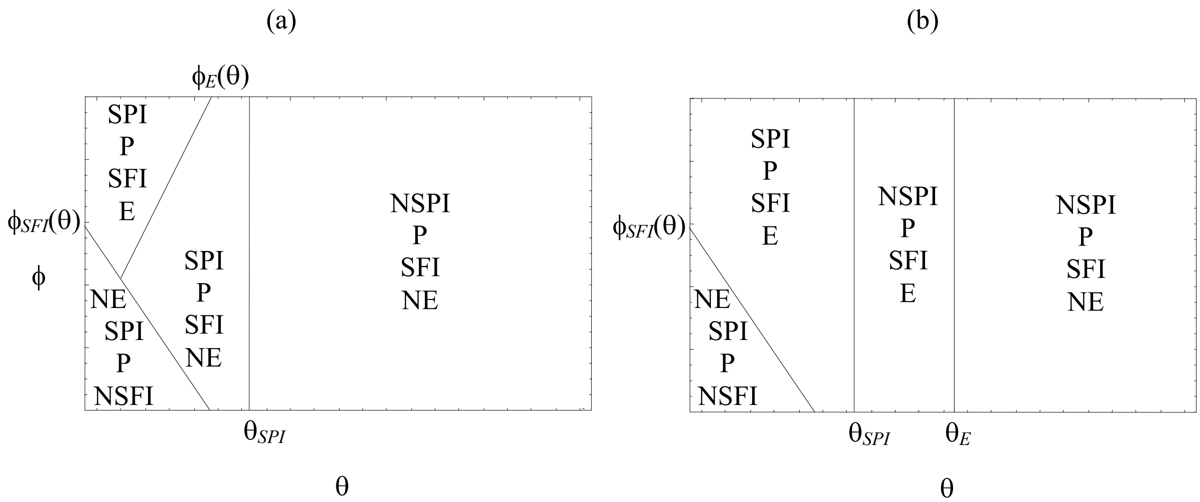


Fig. 4: Subgame Perfect Equilibrium Nodes 1 – 5.

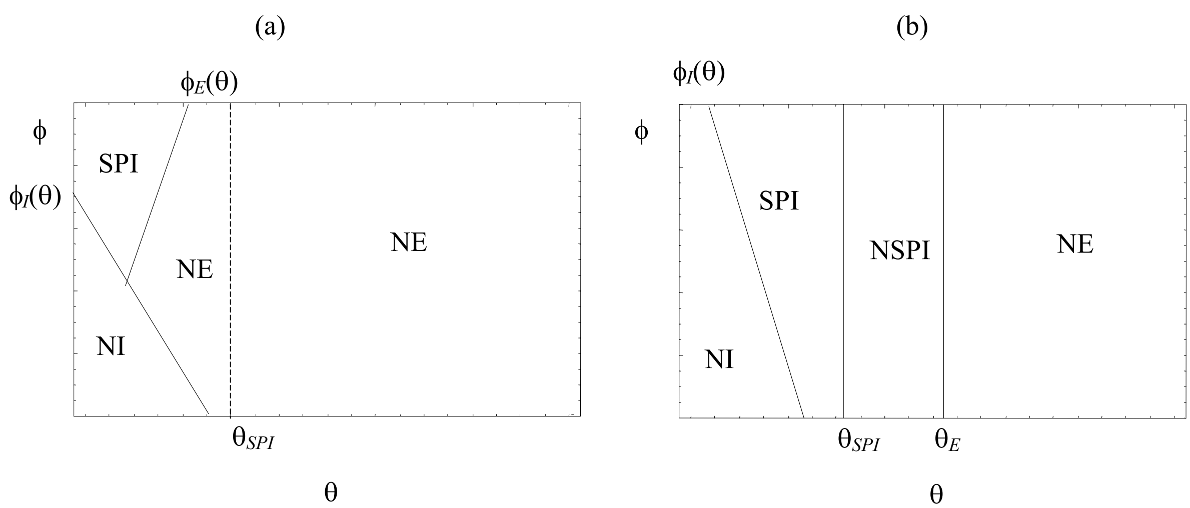


Fig. 5: Game Tree For Non-Novel Patents and Injunction Game