Time Factors of Patent Litigation and Licensing

by

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This study incorporates the concept of time into an analysis of patent litigation and licensing. We show that increasing imitation or litigation costs with a longer imitation lag or litigation time may have effects on licensing, settlement, and fees other than increasing the pecuniary costs. A higher pecuniary imitation cost always benefits the patentee and hurts the imitator. However, the patentee may prefer faster imitation to induce *ex ante* licensing, while the imitator may prefer slower imitation to reduce the settlement fee. We also show that both parties may find longer litigation beneficial, unlike higher legal costs. (JEL: K 41, K 42, L 13)

1 *Introduction*

The focus of our analysis is the factor of time associated with patent protection. Specifically, we incorporate into a standard analysis the time required to imitate the patented technology and the time required to litigate infringements. Previous patent literature has focused on the pecuniary costs of imitation and litigation, usually a one-time fixed cost. We show that there are critical differences between pecuniary costs and the implicit cost of time and that increasing the former and the latter may lead to different outcomes.

The strength of patent protection has been measured in various ways other than duration. Breadth and novelty requirements are such examples, but all three of these measurements work in the same way: by changing the distribution of profits between the patentee and the rival. Length determines how the distribution changes over time, whereas breadth and novelty determine how instantaneous profit is distributed between the two rivals.

The time cost and the pecuniary cost of imitation and litigation do differ fundamentally. However, the length of time required for imitation works very similarly to the length of protection by changing the distribution of profit between the patentee

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and the rival over time. The same is true for longer litigation time – it increases the time over which a duopoly persists, which means it is not always costly for the imitator. However, a higher pecuniary cost would be borne by only one of the parties.[1] As we shall see, this implies that having a longer litigation time can *decrease* the settlement fee, unlike a higher pecuniary cost of litigation, which always *increases* the fee. We also show that the effect of longer litigation on profit is sensitive to the probability of the patentee prevailing and the magnitude of damages, unlike the pecuniary legal cost.

We consider a model of two firms: the patentee and its rival (the potential imitator). The patentee can offer to license the technology. If the rival rejects the offer, then it may imitate the patented technology. After imitation, the patentee can litigate for patent infringement, in which case it can offer to settle for a fee (*ex post* licensing), but there is a litigation cost for both firms. Both imitation and litigation take time to complete – neither of them is instantaneous – which gives rise to time costs. If the imitator loses the infringement suit, then, in addition to staying out of the market until the patent expires, it must pay damages proportional to the difference between monopoly and duopoly profits.

Both greater litigation costs and greater time required for litigation will induce settlement. The settlement fee also increases in the infringer's litigation cost and litigation time, because the amount of damages depends on the loss incurred, including during litigation. As a result, the patentee benefits from longer litigation. The fee is independent of the imitation cost, which is already sunk, but it decreases in the imitation lag. Slower imitation reduces the amount of damages to be paid and also reduces the time left until the patent expires.

We show that there always will be litigation, independent of whether there is settlement or not. If there is settlement, then it is obvious that it is better for the patentee to litigate and collect the fee. No settlement occurs when the efficiency effect (the difference between the monopoly and the sum of duopoly profits) is greater than the total legal costs. In this case, the patentee's private gain (the difference between monopoly and only its own duopoly profit) is more than the private legal cost. Thus, there always will be litigation when there is no settlement.

We show that a greater imitation cost and greater imitation lag may affect in opposite directions firm 2's incentive to imitate. A higher pecuniary imitation cost will always *discourage* imitation, but a longer lag can *encourage* imitation because it reduces the settlement fee. This can more than offset the reduction of profit due to there being less time left until the patent expires. Because the settlement fee depends on the likelihood of the patentee prevailing in court, if this likelihood is large enough, then the effect on the settlement fee dominates and a longer lag will encourage imitation. Quick imitation should not always be interpreted as *easy* imitation, although that is the correct characterization for a low pecuniary cost.

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[1] There may be legal costs for each party in litigation, but a greater cost for one party does not mean that the cost also increases or that it decreases for the other.

The two costs of imitation also have different implications for *ex ante* licensing. A higher pecuniary imitation cost *encourages* licensing, because it weakens the potential imitator's bargaining position. However, a greater imitation lag *discourages ex ante* licensing, because a greater lag shifts profits from the imitator to the patentee. While weakening the imitator's bargaining position, it does strengthen the patentee's bargaining position, and the efficiency effect (monopoly profit less the sum of duopoly profits) implies that the strengthening in the patentee's bargaining position is greater.

An *ex ante* licensing fee always increases in the pecuniary imitation cost, but will increase in the lag only if the probability of the patent owner's prevailing in court is small enough. The reasoning is similar to that regarding the effect of the lag on the settlement fee. The settlement fee can be interpreted as an *ex post* licensing fee. The major difference between *ex post* and *ex ante* licensing fees is that the pecuniary imitation cost is relevant only *ex ante*. *Ex ante* licensing is an opportunity for the patentee to appropriate what the imitator pays, whereas *ex post* this cost has already been sunk.

The existing literature on litigation and settlement considers only pecuniary factors such as the winner's award and legal costs (e.g., LANDES [1971], HAUSE [1989]).[2] However, there is also evidence that firms explicitly take into account the time required for litigation relative to the date of patent expiration. According to the patent litigation experience of LADAS AND PARRY INTELLECTUAL PROPERTY LAWYERS [1997], a multinational law firm specializing in intellectual property, typical lengths of patent lawsuits in different countries are: Australia (1–2 years), France (1.5–2 years), Germany (1–1.5 years), Italy (3 years), Japan (3–5 years), South Korea (3–4 months), Taiwan (4 months), Mexico (3 years for the first occurrence of a decision), China (2–4 years to finish the trials), and England (2–3 years to finish hearings and to come to a trial). Any appeals add further years to the lawsuits. We will show that even when the legal costs are small, settlement can be achieved, because litigation is time-consuming.

Although the patentee can enforce his patent right in court, it is true worldwide that very few patent disputes end with trials (LADAS AND PARRY INTELLECTUAL PROPERTY LAWYERS [1997], SMITH [1999]). Firms may agree to license *ex ante* in order to prevent imitation or to license *ex post* in order to avoid litigation. However, the length of litigation is reflected in the terms of settlement even when litigation does not occur in equilibrium. The length of imitation is reflected in the *ex ante* licensing fee even though imitation does not actually occur.

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[2] Patent litigation is usually very expensive. A 1991 survey of its members by the American Intellectual Property Law Association (AIPLA) revealed that the total litigation cost was $410,000 in Minnesota and as high as $740,000 in New York (SCHUMAN [1996]). More recently in the U.S., "the median legal fee for litigating a patent case through trial is about $2 million per side and increasing" (BERMAN [2002]).

LANJOUW AND SCHANKERMAN [2001] have empirically characterized patent litigation behavior by technology class and patent ownership. They associate both factors with the pecuniary cost of litigation. However, there are some puzzling results, such as in the electronics industry (usually associated with small imitation lags (MANSFIELD [1985])), which has little litigation per patent. Our results predict that precisely when imitation is quick, firms choose to license rather than have imitation and a dispute in court.

Several different motivations for patent licensing have been identified: entry deterrence (GALLINI [1984]), eliminating a more efficient firm (ROCKETT [1990]), preventing opponents' R&D venture (YI [1999]), or insurance against possible failure of patent protection (AOKI AND HU [1999]). In our analysis, *ex ante* licensing is also for entry deterrence (as in Gallini and in Rockett) and an *ex post* licensing or litigation settlement fee is an insurance premium paid by the imitator against an unfavorable verdict (as in Aoki and Hu). We demonstrate that the cost of imitation (in case of entry deterrence) and the cost of litigation (in case of settlement) have different effects on incentives and payoffs, depending on whether they are pecuniary or represent the opportunity cost of time.

Although imitation involves a cost, namely the duplication of R&D, imitation also creates social surplus by introducing market competition (KANNIAINEN AND STENBACKA [2000]). *Ex ante* licensing in our framework uses the threat of imitation to achieve the benefit of a superior market structure without society actually incurring the imitation cost. In fact, this will induce the socially best outcome.

This paper is organized as follows: The model is introduced in Section 2. It includes a discussion of making the imitation lag a decision variable. We characterize the equilibrium in Section 3 through solving by backward induction: the settlement, imitation and litigation, and *ex ante* licensing decisions. The section also includes a subsection on the optimal imitation lag. The last subsection, on comparative statics, also examines the possible incentive of the patentee to hasten imitation. Section 4 studies the welfare effect of each patent-law regime. Section 5 discusses the case when litigation ends after the patent expires, and Section 6 concludes this paper.

2 *Model of Time-Consuming Patent Litigation and Settlement*

Before we introduce the basic model, it will be helpful to define the following δ-*function*:

$$\delta_a^b = \int_a^b e^{-rt}\,dt = \frac{e^{-ra} - e^{-rb}}{r},$$

where r is the interest rate and e^{-rt} is the discount factor. The quantity δ_a^b is the discounted value at time 0 of getting a flow of one dollar from time a to b. Thus, getting duopoly profit π_d from time a to b is worth $\pi_d \delta_a^b$ at time 0.

Lemma 1: The δ-function has the following properties:

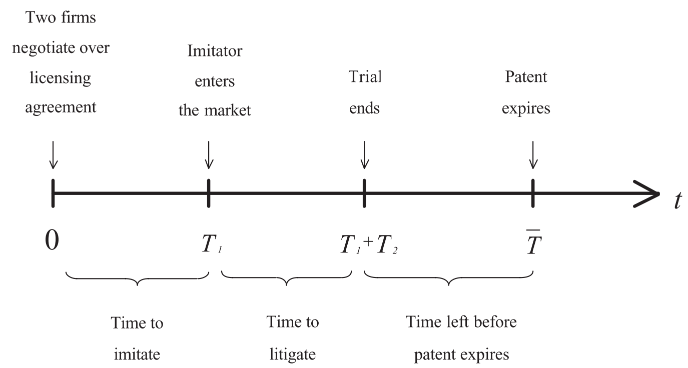
(i) $\dfrac{\partial \delta_a^b}{\partial a} < 0, \quad \dfrac{\partial \delta_a^b}{\partial b} > 0, \quad \text{and} \quad \dfrac{\partial \delta_a^b}{\partial r} < 0.$

(ii) $\delta_a^c + \delta_c^b = \delta_a^b \quad \text{for all} \quad c \in [a, b].$

(iii) $\delta_{a+c}^{b+c} = e^{-rc}\delta_a^b \quad \text{for all} \quad c > 0.$

The last property states that the discounted value at time 0 of getting one dollar from time $c + a$ to time $c + b$, δ_{c+a}^{c+b}, can be obtained by discounting to time 0 the value at time $c + a$ of a dollar flow for length $b - a$.

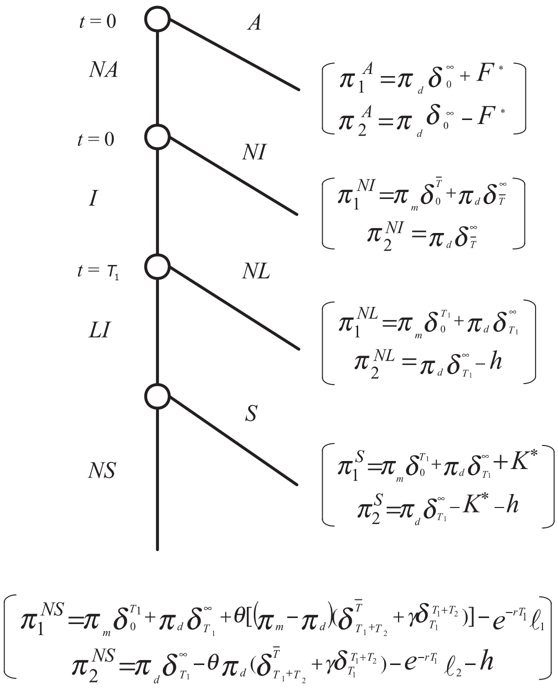
Figure 1
The Time Line of the Basic Model



In the model there are two firms, 1 and 2. At time 0, firm 1 has a product patent, which expires at time $\bar{T}$. Firm 2 is the potential imitator. In order to focus on the effects of time factors on *ex ante* and *ex post* licensing, we do not take into account the patentee's R&D decision stage and simply assume that the patented technology already exists.[3] The timing of the actions and events to be described below is summarized in Figure 1. Here T_1 is the length of time required for imitation, and T_2 is the length required for infringement litigation to reach a verdict. The game with payoffs is summarized in Figure 2. Although some decisions are made after time 0, all payoffs are discounted sums at time 0. At time T_1 any profit obtained previously is sunk and should be irrelevant to the decision at that time. This is reflected in the payoffs by the term $\pi_m \delta_0^{T_1}$ (discounted sum of monopoly profit from time 0 to T_1) appearing in all of firm 1's payoffs at the nodes reached after T_1.

[3] This framework is often seen in the literature on *ex ante* and *ex post* licensing, e.g., Gallini [1984], Meurer [1989], Rockett [1990], and Yi [1999]. Takalo [1998] investigated the case of a single innovator and a potential imitator under imperfect patent protection. Aoki and Hu [1999] studied duopolistic R&D competition under imperfect patent protection with instantaneous licensing and litigation.

Figure 2
The Decision Tree of the Basic Model



At time 0, firms 1 and 2 negotiate over the *ex ante* licensing agreement. As is common in the literature, we assume that all bargaining is of a take-it-or-leave-it form: The patentee (firm 1) makes an offer to license the technology to firm 2 for a fixed fee F. Firm 2 can accept or reject the offer. If an offer F^* is accepted, then an *ex ante* licensing agreement has been achieved (A in Figure 2). Firm 2 pays F^* to firm 1 at time 0, and the market will be a duopoly forever. The game ends with payoffs

$$\pi_1^A = \pi_d \delta_0^\infty + F^*, \qquad \pi_2^A = \pi_d \delta_0^\infty - F^*,$$

where π_d is the duopoly profit. If no *ex ante* licensing agreement is reached (NA), then firm 2 decides whether to imitate firm 1's patent (I) or not (NI).

If firm 2 imitates, then it incurs a one-time cost $h > 0$ at time zero. It takes time T_1 to achieve the imitation. The industry is a monopoly until T_1, when firm 2 will enter the market, and it will be a duopoly thereafter. If firm 2 decides not to imitate the patent, then firm 1 enjoys the monopoly profit (π_m) and firm 2 receives nothing until the patent right expires at time $\bar{T} \in (0, \infty)$. The market is a duopoly after the patent expires. The payoffs are

$$\pi_1^{NI} = \pi_m \delta_0^{\bar{T}} + \pi_d \delta_{\bar{T}}^\infty, \qquad \pi_2^{NI} = \pi_d \delta_{\bar{T}}^\infty.$$

We have made the model tractable by assuming the cost of imitation is fixed, in particular independent of T_1. If h were a function of T_1, then it would have to be decreasing in T_1 and the imitation decision would include the optimal choice of T_1. Changing T_1 then has two effects: changing the equilibrium outcome and changing the imitation cost. One expects that faster imitation is always good for the imitator. The only reason an imitator does not choose instantaneous imitation ($T_1 = 0$) is that it is costly. However, this obvious trade-off is not the interesting question. The more fundamental question is "even if $T_1 = 0$ does not cost any extra, is there a situation where firm 2 has an incentive to delay imitation?" Assuming that h is constant allows us to address this question directly. Instead of making T_1 a decision variable, we will analyze how the equilibrium payoffs change in T_1.

If firm 2 enters the market before the patent expires, then it incurs the imitation cost h at time 0. The market will be a firm 1 monopoly until imitation is completed at time T_1. At T_1, firm 1 chooses whether to litigate (LI) or not (NL). If there is no litigation, then the market will be a duopoly after T_1, and the firms' payoffs discounted to time 0 are

$$\pi_1^{NL} = \pi_m \delta_0^{T_1} + \pi_d \delta_{T_1}^{\infty}, \qquad \pi_2^{NL} = \pi_d \delta_{T_1}^{\infty} - h.$$

If litigation occurs, then firm 1 offers to settle the suit for a payment of K (in time-0 dollars). If firm 2 accepts, then a settlement is reached (S); otherwise the outcome will be determined by a court decision (NS). If a settlement is reached, then there is a transfer payment K from firm 2 to firm 1. If no settlement is reached (NS), then at time T_1 firm 1 incurs a legal cost of $\ell_1 \geq 0$ and firm 2 incurs $\ell_2 \geq 0$, which discounted to time 0 means $e^{-rT_1}\ell_i$, $i = 1, 2$.

Firms 1 and 2 both expect firm 1 to win with probability θ. If firm 1 wins, then firm 2's imitation is judged as infringement by the court, and it takes a time span $T_2 \in [0, \infty]$ for a final verdict to be reached. That is, during the period of patent litigation ($[T_1, T_1 + T_2]$), both firms coexist in the product market. If firm 1 wins the lawsuit, then it will be a monopolist until the patent right expires at time $\bar{T}$ and will recover its loss in the amount D, again in dollars of time 0.

Since the damage award is based on the patentee's loss of profit, this can be expressed as $D = \gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2}$. The parameter γ is the damage award rate, with $1 \leq \gamma \leq 3$.[4] Therefore, the damage award (D) is also a function of the time factors (T_1 and T_2). In this case firm 2 must pay damages D and stay out of the market until the patent expires at $\bar{T}$. If firm 1 loses, then the market becomes a duopoly from time $T_1 + T_2$.

[4] Usually, the maximum amount of damage compensation is no larger than three times the amount to restore the plaintiff's loss. The U.S. Patent Act authorizes damages "in no event less than a reasonable royalty for the use made of the invention by the infringer" (35 U.S.C.A. §284).

If firm 2 does not imitate the patent, then it enters the market after the patent expires at time $\bar{T}$ without any imitation cost.[5] In this section we consider the case of $T_1 + T_2 \leq \bar{T}$; that is, patent litigation ends no later than when the patent expires.

Note that Figure 2 is not a game tree. In a complete extensive-form representation of the game, the node with choices A and NA should be replaced by two stages: firm 1 makes an offer $F \in [0, \infty]$ and then firm 2 accepts or rejects the offer. Firm 2's equilibrium strategy is characterized by one offer level, F^*: firm 2 will accept the offer F if $F \leq F^*$ and reject it if $F > F^*$. The equilibrium F^* is determined by the subgame equilibrium payoffs from the remainder of the game.

Whether firm 1 wants its offer to be accepted or rejected also depends on the subgame equilibrium. If it wants rejection, then it is optimal for it to offer any $F > F^*$. Therefore, there is a continuum of equilibrium strategies where the outcome will be NA. If firm 1 wants acceptance, then there is only one equilibrium offer F^*, the maximum offer that will be accepted. If the offer is rejected, then the remainder of the game is independent of what the offer was. Figure 2 hence only makes a distinction between whether $F > F^*$ was offered and was then rejected (NA) and whether F^* was offered and accepted (A). Note that F^* is part of the equilibrium and the actual characterization of F^* will be done later when we characterize the subgame-perfect Nash equilibrium.

The last node, with S and NS, should be similarly replaced by two stages in order for the tree to be the extensive form of the game: Firm 1 makes an offer K, and then firm 2 accepts or rejects this offer. The equilibrium K^* is the maximum offer that firm 2 will accept, and the outcome is S. The outcome is NS for any offer $K > K^*$, which will be rejected.

3 Equilibrium Outcomes

We solve the game by backward induction to obtain the following characterization of the subgame-perfect Nash equilibrium.

3.1 Settlement Condition

We first begin with the last node. If there is litigation, then firm 1 can offer to settle for a payment K from firm 2. If firm 2 rejects the offer, then firm 2 gets

$$\pi_2^{NS} = \pi_d \delta_{T_1}^{\infty} - \theta\big[\pi_d \delta_{T_1+T_2}^{\bar{T}} + \gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2}\big] - e^{-rT_1}\ell_2 - h,$$

and firm 1 gets

$$\pi_1^{NS} = \pi_m \delta_0^{T_1} + \pi_d \delta_{T_1}^{\infty} + \theta\big[(\pi_m - \pi_d)\delta_{T_1+T_2}^{\bar{T}} + \gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2}\big] - e^{-rT_1}\ell_1.$$

[5] This assumption is plausible, since in most countries the acquisition of a patent requires disclosure of the manner and process of making and using it. Flow charts showing how the invention operates are also commonly included. Thus, the patented technology is well known even before the patent expires.

If there is no settlement, then firm 1 wins with probability θ and obtains monopoly profit until time $\bar{T}$. If firm 2 accepts, then it receives

$$\pi_2^S = \pi_d \delta_{T_1}^{\infty} - K - h,$$

and firm 1 gets

$$\pi_1^S = \pi_m \delta_0^{T_1} + \pi_d \delta_{T_1}^{\infty} + K.$$

Firm 2 will hence accept if $\pi_2^S \geq \pi_2^{NS}$, while firm 1 would want the offer accepted only if $\pi_1^S \geq \pi_1^{NS}$. The two requirements imply the settlement condition,

$$e^{-rT_1}(\ell_1 + \ell_2) \geq \theta(\pi_m - 2\pi_d)\delta_{T_1+T_2}^{\bar{T}},$$

or equivalently,

$$\text{(s)} \qquad \ell_1 + \ell_2 \geq \theta(\pi_m - 2\pi_d)\delta_{T_2}^{\bar{T}-T_1}.$$

The first relation is the condition evaluated at time 0, whereas (s) is evaluated at time T_1. The sufficient and necessary condition for a settlement is that the joint payoff for both firms with a settlement is no less than that of a verdict. The efficiency effect ($\pi_m > 2\pi_d$) should hold, since antitrust law bans the firms from achieving monopolist profit collusively (GILBERT AND NEWBERY [1982]). It is immediate from (s) that symmetric beliefs do not guarantee settlement if the efficiency effect exists (MEURER [1989]). The efficiency effect implies that the plaintiff's cost of not settling is greater than the defendant's benefit from settling.

Lemma 2: If there is no efficiency effect, then the two patent litigants will always achieve settlement.

With symmetric beliefs, the settlement decisions do not depend on the magnitude of the damage award [$D = \gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2}$] at all, because the damage award is a transfer payment between the two parties. From equation (s), we obtain the following corollary:

Corollary 1: There will be more settlement when (i) $\ell_1 + \ell_2$ increases; (ii) T_1 increases, T_2 increases, $\bar{T}$ decreases, and r increases; (iii) π_m decreases and π_d increases; or (iv) θ decreases.

An increase in the time to litigate (T_2) encourages settlement. As we observed in Section 1, in Japan patent litigation is quite lengthy. This can explain why Japan has very high settlement and licensing rates. The shorter the patent length ($\bar{T}$) is, the more likely a settlement will take place. This is because even if the patentee wins, there is not much time left for his monopoly privilege. As is well known in bargaining games, greater impatience (higher r) encourages settlement.

It is optimal for firm 1 to offer the largest K that firm 2 will accept, i.e., the K that makes firm 2 indifferent between accepting and rejecting,

$$\text{(1)} \qquad \begin{aligned} K^* &= \theta\big[\pi_d \delta_{T_1+T_2}^{\bar{T}} + \gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2}\big] + e^{-rT_1}\ell_2 \\ &= e^{-rT_1}\left(\theta\big[\pi_d \delta_{T_2}^{\bar{T}-T_1} + \gamma(\pi_m - \pi_d)\delta_0^{T_2}\big] + \ell_2\right). \end{aligned}$$

Items in large parentheses in (1) are the value of the settlement fee at time T_1. It only reflects profits and costs at and after time T_1. The equilibrium payoffs from settlement, discounted to time 0, are

$$\pi_1^S = \pi_m \delta_0^{T_1} + \pi_d \delta_{T_1}^{\infty} + K^*,$$
$$\pi_2^S = \pi_d \delta_{T_1}^{\infty} - K^* - h.$$

Corollary 2: The settlement payment K^* from the defendant to the plaintiff has the following properties: $\partial K^*/\partial T_1 < 0$, $\partial K^*/\partial T_2 > 0$, $\partial K^*/\partial \bar{T} > 0$, $\partial K^*/\partial \pi_m > 0$, $\partial K^*/\partial \pi_d < 0$, $\partial K^*/\partial \theta > 0$, $\partial K^*/\partial \gamma > 0$, $\partial K^*/\partial r < 0$, and $\partial K^*/\partial \ell_2 > 0$.

The settlement fee is the *ex post* licensing fee that firm 2 is willing to pay to use the patent for sure. Interestingly, firm 2's willingness to pay declines with increasing T_1, because litigation and settlement take place after imitation has already occurred. Slower imitation means there is less time left until the patent expires, and this reduces the value of settling. An increase in the two costs of litigation, ℓ_2 and T_2, has the same effect on settlement. Firm 2's willingness to pay declines with increasing duopoly profit (π_d), because that reduces the damages (the difference between monopoly and duopoly profits) it must pay if it loses. This follows from the function of the settlement fee as insurance against losing in litigation.

The above result depends critically on the fact that we assume that there is no available injunction. For instance, China has no formal preliminary injunction procedure. Although in China the court can give an order of advance execution, this is rare in patent infringement suits (LADAS AND PARRY INTELLECTUAL PROPERTY LAWYERS [1997]). LANJOUW AND LERNER [2001] theoretically and empirically research the use of preliminary injunctions in the U.S. patent lawsuits. They find that "injunction requests allow plaintiffs to go beyond the avoidance of 'irreparable harm' to extract even greater profit by raising the costs of legal profits." Introducing injunctions as an available strategy into our model will increase the patentee's bargaining power and hence his payoff in each legal regime. As a result, the *ex ante* and *ex post* licensing fees will both increase if preliminary injunctions are available. However, that will not change our major findings with respect to *ex ante* and *ex post* licensing. That is, the market will be a duopoly for sure until litigation ends. Incorporation of an injunction does not mean that the effect of the length of litigation will immediately be reversed, because the use of injunction is a choice, thus having an effect on the behavior of the potential infringer. Ultimately, this again may influence the precautionary licensing behavior.

3.2 Litigation and Imitation Decisions

When (s) holds, there will be settlement, and since $\pi_1^S > \pi_1^{NL}$ holds for any parameter values, there always will be litigation. If (s) does not hold – which we denote as ($\sim$ s) – then firm 1 will choose LI if and only if

$$\text{(g)} \qquad e^{-rT_1}\ell_1 \leq \theta\left[(\pi_m - \pi_d)\delta_{T_1+T_2}^{\bar{T}} + \gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2}\right].$$

It is easy to show that ($\sim$ s) implies (g), reflecting the externality of litigation that is not taken into account by firm 1 when it makes its litigation decision. Settlement does not occur when the social gain (the efficiency effect) is more than the social cost (sum of litigation costs); litigation occurs if firm 1's private gain is greater than its private cost. Firm 1's gain is in fact greater than the efficiency effect, for it is the difference between monopoly and duopoly profit; but its private cost does not take into account its rival's litigation cost.

If there is litigation, then firm 2 will choose I if and only if $\pi_2^{NI} \leq \pi_2^S$, or

$$\pi_d \delta_{T_1}^{\bar{T}} - K^* - h \geq 0. \tag{$\mathrm{i^K}$}$$

Firm 2's payoff in the subgame-perfect Nash equilibrium is the same with and without settlement, because K^* makes the firm exactly indifferent between accepting and not accepting the settlement offer. Summarizing, we have the following proposition:[6]

Proposition 1: The subgame-perfect Nash equilibrium actions and outcomes when *ex ante* licensing agreement is not reached are as follows:

When (s) holds,

Conditions	Actions	Outcome
($\mathrm{i^K}$)	I,LI	S
($\sim \mathrm{i^K}$)	NI,LI	NI

When ($\sim$ s) holds,

Conditions	Actions	Outcome
($\mathrm{i^K}$)	I,LI	NS
($\sim \mathrm{i^K}$)	NI,LI	NI

The proposition is represented in Figures 3 and 4, where lines marked (s) and ($\mathrm{i^K}$) represent the corresponding constraints that hold with equality. The lines in Figure 4 divide the (ℓ_1, ℓ_2) space into four possible regimes. Figure 3 occurs when h is close to zero. Given parameters of an economy, the position of (ℓ_1, ℓ_2) relative to constraints (s) and ($\mathrm{i^K}$) is identified. The list of actions comprises the equilibrium actions for the

[6] When characterizing equilibrium, we focus on equilibrium actions and not on equilibrium strategies. Firm 1's strategy is (F, σ_1, σ_1'), where $F \in [0, \infty)$, σ_1 is a function from $[0, \infty)$ to $\{LI, NL\}$, and σ_1' is a function from $[0, \infty)$ to $[0, \infty)$. Firm 2's strategy is $(\sigma_2, \sigma_2', \sigma_2'')$, where σ_2 is a function from $[0, \infty)$ to $\{A, NA\}$, σ_2' is a function from $[0, \infty)$ to $\{I, NI\}$, and σ_2'' is a function from $[0, \infty) \times [0, \infty)$ to $\{A, NA\}$. We just denote the equilibrium actions that will occur at each node given the equilibrium strategies.

Figure 3
Subgame Equilibrium Actions and Outcomes

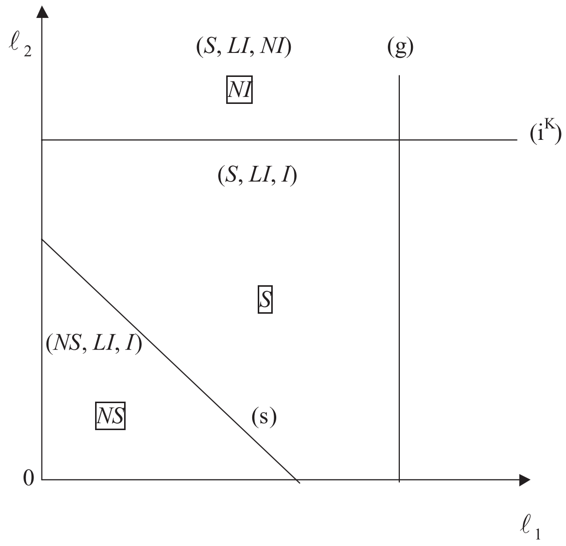
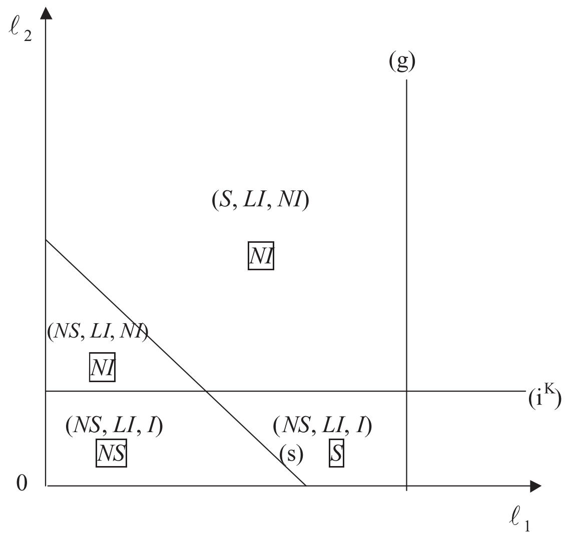


Figure 4
Subgame Equilibrium Actions and Outcomes



economy regime, and the boxed letter is the corresponding equilibrium outcome. We can characterize the equilibrium outcomes in the following way:

Corollary 3: In the subgame-perfect Nash equilibrium: (1) There will be litigation, independent of whether there is settlement or not. (2) The imitation decision is independent of whether there is settlement or not.

The right-hand side of (s) is decreasing in T_1. Delayed imitation reduces the benefit of capturing the efficiency gain by settling. If there is settlement for $T_1 = 0$, then there will be settlement for any T_1. If there is no settlement for $T_1 = 0$, then when T_1 increases, eventually the benefit from settling becomes small enough so that there will be no settlement beyond some imitation lag T_1^S.

The imitation condition (i^K) includes the cost of imitation, h. Thus, there is no relationship between (s) and (i^K), as there was between ($\sim$ s) and (g). When (i^K) holds, then the subgame equilibrium does not involve settlement if $T_1 < T_1^S$, while it does involve settlement if $T_1 \geq T_1^S$. If ($\sim \mathrm{i}^\mathrm{K}$), then the equilibrium outcome does not involve imitation, independent of whether there is settlement.

3.3 *The Optimal Timing of Imitation*

We now inquire whether the imitator ever benefits from delayed imitation, i.e., larger T_1. Recall that firm 2's subgame-perfect Nash equilibrium payoff is the same with a settlement and without settlement,

$$\pi_2^{NS} = \pi_2^S = \pi_d \delta_{T_1}^{\infty} - K^* - h,$$

where K^* is characterized by (1). The first term is the profit after imitation, which decreases with increasing T_1. However, as we observed before, the second term, the settlement fee K^*, also decreases with increasing T_1, because damages are discounted more with greater T_1 and the time left after settlement is reduced. Therefore, the benefit of imitation is decreasing in T_1, but the cost of imitation from litigation (which will always occur) is also decreasing in T_1. Therefore, payoff π_2^S can be increasing or decreasing in T_1.

Note that (i^K) is the condition for $\pi_2^S \geq \pi_2^{NI}$ and that π_2^{NI}, the no-imitation payoff, is independent of T_1. Thus, how π_2^S changes with T_1 determines if there will be imitation when T_1 is small and when T_1 is large. If π_2^S is increasing and ($\sim \mathrm{i}^\mathrm{K}$) holds at $T_1 = 0$, but (i^K) at $T_1 = \bar{T} - T_2$, then firm 2 will not imitate when T_1 is small, but will instead imitate when T_1 is large. Firm 2's subgame-perfect equilibrium payoff will be π_2^{NI} when T_1 is small and π_2^S when it is large, and π_2^S is increasing in T_1, so that T_1 should be as large as possible. That is, imitation should be delayed as much as possible. It is possible to characterize a condition under which π_2^S is increasing in T_1. Straightforward differentiation of the payoff with respect to T_1 yields:

Proposition 2: π_2^S is increasing in T_1 if and only if

$$\theta > \frac{\pi_d - \ell_2}{\pi_d \delta_{T_2}^{\infty} + \gamma(\pi_m - \pi_d)\delta_0^{T_2}}. \tag{2}$$

In addition, if there is a value of T_1 such that (i^{K}) is satisfied, then firm 2's subgame-perfect Nash equilibrium payoff will be increasing in T_1. That is, firm 2 will want to delay imitation.

Condition (2) states that when the probability of the patent owner winning the lawsuit is sufficiently large, then the benefit of decreased damages by delaying imitation offsets the decreased duopoly profit. Given other parameter values, we can always find h such that (i^{K}) always holds for some T_1, because only (i^{K}) includes the parameter h. Note that the upper bound of T_1 is when the constraint (i^{K}) is violated. This may happen within $T_1 + T_2 \leq \bar{T}$ or with a larger T_1. We will see in Section 5 that there will always be settlement (and hence the equilibrium payoff is π_S^2) when $T_1 + T_2 > \bar{T}$. Condition (i^{K}) is violated when $T_1 = \bar{T}$, so there is some finite $T_1 < \bar{T}$ at which imitation no longer makes sense and firm 2's equilibrium payoff will be π_2^{NI}, which is independent of T_1.

Firm 1's equilibrium payoff can also be increasing or decreasing in T_1. When there is settlement, delayed imitation increases the length of firm 1's monopoly, but decreases the settlement fee. Its payoff is increasing in T_1 when the damages and thus the settlement fee do not decrease too much. This occurs when the probability of the patentee winning the lawsuit is small. When there is no settlement, there is the benefit of a longer monopoly due to delayed imitation, but the damages will be smaller. Firm 1 can thus be hurt by delayed imitation. It is easy to show that:

Proposition 3: π_1^{NS} is increasing in T_1 if and only if

$$\theta < \frac{\pi_m - \pi_d + \ell_1}{(\pi_m - \pi_d)\left(\delta_{T_2}^{\infty} + \gamma\delta_0^{T_2}\right)}.$$

π_1^S is increasing in T_1 if and only if

$$\theta < \frac{\pi_m - \pi_d + \ell_2}{\pi_d \delta_{T_2}^{\infty} + \gamma(\pi_m - \pi_d)\delta_0^{T_2}}.$$

This characterizes exactly when the patentee prefers quick imitation. The condition is satisfied when the probability of winning and collecting the damages is large and T_2 is large. A longer trial increases the damages; and the quicker the imitation, the sooner the litigation will start and the clock will start ticking.

Corollary 4: If

$$\theta < \frac{\pi_m - \pi_d + \ell_1}{(\pi_m - \pi_d)\left(\delta_{T_2}^{\infty} + \gamma\delta_0^{T_2}\right)},$$

then firm 1's equilibrium payoff when there is imitation in subgame equilibrium is increasing in T_1. That is, firm 1 also prefers delayed imitation.

It is possible for this condition to hold with (2), in which case both firms benefit in equilibrium from slower imitation.

Propositions 2 and 3 together imply that if θ is sufficiently large, then the patentee prefers a short imitation lag while the imitator prefers a longer lag. This is more of a knife-edge case, because in addition to θ being sufficiently large, (i^{K}) must hold, which also depends on the size of h. There is thus imitation, since h is small, and it is very likely that the imitator pays damages to the patent owner.

3.4 Ex Ante Licensing

We now characterize the *ex ante* licensing decision. When firm 1 offers to license the technology for a fixed fee F, firm 2 will accept if $\pi_2^A \geq \pi_2^{NA}$, where π_2^{NA} will be π_2^{NI}, π_2^{NS}, or π_2^S according to the subgame equilibrium outcome. Firm 1 will offer the maximum fee F^*, which will be accepted if $\pi_1^A \geq \pi_1^{NA}$, where π_1^{NA} is also determined by the equilibrium outcome of the subgame. The equilibrium offer will be F^*, and it will be accepted when

(3) $$\pi_1^A + \pi_2^A = 2\pi_d \delta_0^\infty \geq \pi_1^{NA} + \pi_2^{NA}$$

and $$F^* = \pi_2^A - \pi_2^{NA}.$$

The equilibrium outcome will therefore be A.

We now need to determine when (3) holds for different subgame equilibrium outcomes. When the outcome is NI,

$$\sum \pi_i^{NA} = \sum \pi_i^{NI} = \pi_m \delta_0^{\bar{T}} + 2\pi_d \delta_{\bar{T}}^\infty > 2\pi_d \delta_0^\infty = \sum \pi_i^A.$$

Therefore, there will never be licensing when there is no imitation. With no threat of imitation, there is no need for the patent owner to relinquish the monopoly power.

Now we consider the case when the subgame-perfect Nash equilibrium outcome is S:

$$\sum \pi_i^{NA} - \sum \pi_i^A = \sum \pi_i^S - \sum \pi_i^A = (\pi_m - 2\pi_d)\delta_0^{T_1} - h.$$

Ex ante licensing will occur when

(a) $$(\pi_m - 2\pi_d)\delta_0^{T_1} \leq h,$$

that is, when the cost of imitation is sufficiently large relative to the efficiency effect. The equilibrium fee F^* is set so that firm 2 is indifferent between licensing and no licensing. The gain from *ex ante* licensing is all appropriated by the patentee, which is also the case with settlement. The difference between *ex ante* licensing and settlement is that with settlement the cost of imitation is already sunk. By offering *ex ante* licensing, the patentee can appropriate the imitation cost. The patentee's cost of course is that the industry immediately becomes a duopoly.

We also note that condition (a) holds when h is large and T_1 is small, everything else being equal. This condition highlights the difference in "ease of imitation" being defined as quick imitation (small T_1) and as low fixed cost (h). Quick imitation encourages licensing, because this is a threat to the patentee; while a lower imitation cost discourages licensing, because it improves firm 2's bargaining position.

A change in timing of imitation will directly change the patentee's profit while the imitation cost directly influences only firm 2's profit.

When the subgame-perfect Nash equilibrium is *NS*, there will be *ex ante* licensing if

$$(\mathrm{a}^{\mathrm{NS}}) \qquad \sum \pi_i^{NS} - \sum \pi_i^{A} = (\pi_m - 2\pi_d)\big(\delta_0^{T_1} + \delta_{T_1+T_2}^{\bar{T}}\big) - e^{-rT_1} \sum \ell_i - h \geq 0.$$

The outcome *NS* will not occur unless (∼ s) holds. Therefore, (a) is a sufficient condition for *ex ante* licensing to occur in this case.

Proposition 4: The subgame-perfect Nash equilibrium actions and outcomes of the game are

		(a)	(∼ a)
(s)	$(\mathrm{i}^{\mathrm{K}})$	(S, LI, I, A) , A	(S, LI, I, NA), NA
	$(\sim \mathrm{i}^{\mathrm{K}})$	(S, LI, NI, NA), NI	(S, LI, NI, NA), NA
(∼ s)	$(\mathrm{i}^{\mathrm{K}})$	(NS, LI, I, NA), NS if $(\sim \mathrm{a}^{\mathrm{NS}})$ (NS, LI, I, A), A if $(\mathrm{a}^{\mathrm{NS}})$	(NS, LI, I, NA), NS
	$(\sim \mathrm{i}^{\mathrm{K}})$	(NS, LI, NI, NA), NI	(NS, LI, NI, NA), NI

There are two regimes with *ex ante* licensing. In both regimes, *ex ante* licensing occurs so as to prevent imitation, because the threat of litigation does not prevent imitation. These two regimes only differ in the outcome of litigation (and hence the subgame equilibrium outcomes), *NS* and *S*. However, since firm 2's payoff is the same under the two subgame equilibrium payoffs, the equilibrium *ex ante* licensing fee will be the same:

$$\begin{aligned} F^* &= \pi_d \delta_0^{T_1} + K^* + h, \\ &= \pi_d \delta_0^{T_1} + \theta\big[\pi_d \delta_{T_1+T_2}^{\bar{T}} + \gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2}\big] + e^{-rT_1}\ell_2 + h. \end{aligned}$$

By comparing cells under (s) and (∼ s) in the proposition, we conclude that the threat of litigation with or without settlement will be effective in preventing imitation. In both cases, imitation will not occur when the likelihood of loss is large and cost of imitation is small [$(\sim \mathrm{i}^{\mathrm{K}})$ holds].

Corollary 5: The settlement payment F^* from the defendant to the plaintiff has the following properties: $\partial F^*/\partial T_2 > 0$, $\partial F^*/\partial \bar{T} > 0$, $\partial F^*/\partial \pi_m > 0$, $\partial F^*/\partial \theta > 0$, $\partial F^*/\partial \gamma > 0$, $\partial F^*/\partial r < 0$, $\partial F^*/\partial \ell_2 > 0$, and

$$\frac{\partial F^*}{\partial T_1} < 0 \quad \Leftrightarrow \quad \theta > \frac{\pi_d - \ell_2}{\pi_d \delta_{T_2}^{\infty} + \gamma(\pi_m - \pi_d)\delta_0^{T_2}}.$$

Although increasing the pecuniary cost of imitation h will always increase the fee, increasing the implicit cost (i.e., increasing T_1) will decrease the fee if the probability of the patentee winning in court is sufficiently large, since the damages will be smaller. This means π_1^A can be decreasing in T_1, i.e., the patent owner prefers quicker imitation. There are several ways in which the patentee can choose the imitation lag. It can publish information, provide spillover through the labor market, or reveal more information in the patent application. Information revealed through a patent application has credibility not available in other announcements. Since both the left-hand side of (a) and π_1^A are decreasing in T_1, the patentee would prefer to have a short imitation lag in order to have *ex ante* licensing in equilibrium.

The following corollary is a direct consequence of (s):

Corollary 6: If the imitation is imminent (T_1 is zero), then the patentee that is willing to settle in the event of litigation will license to prevent imitation.

If there is no efficiency effect, then the patentee that is willing to settle always *ex ante* licenses in the event of litigation.

The first part implies that even if the legal system offers no effective patent protection, the patent owner can still obtain a transfer payment from the potential imitator by *ex ante* licensing. Due to antitrust laws in many countries, firms are not allowed to collude in the output market to achieve monopoly profit. Therefore, the efficiency effect exists for all markets with antitrust regulation. The efficiency effect makes the patentee more hesitant to license *ex post*, since the joint profit with a license will be strictly less than the monopoly profit. The efficiency effect is thus an obstacle to *ex post* licensing. The second part of Corollary 6 says that the efficiency effect is a barrier to licensing before imitation, since the patentee would rather obtain the possibility of monopoly profit.

3.5 Comparative Statics

Now we consider the effect of stronger patent protection. This is represented in our model by a greater θ (probability of the patentee winning) and a greater γ (ratio of damage award to loss of profit). A larger θ affects (s) and (i^K). Recall that one given set of parameters determines the position of the constraints (s) and (i^K), and the corresponding economy is presented by one point in Figures 3 and 4. In Figures 3 and 4, an increase in θ moves (s) outward and (i^K) downward. An increase in γ will move (i^K) downward. Depending on where the economy was originally at position (ℓ_1, ℓ_2), the equilibrium outcome may change from S to NS or NI. Note that equilibrium payoffs may also change with θ and γ, as π_1^S is increasing and π_2^S is decreasing in θ and γ, but π_i^{NI} ($i = 1, 2$) does not depend on θ or γ.

Proposition 5: Increasing the likelihood of the patentee winning will change some no-settlement equilibrium outcomes to settlement ones, and some settlement equilibrium outcomes to no-imitation ones.

Increasing the size of damages will change some settlement equilibrium outcomes to no-imitation ones.

Both types of patent protection strengthening make firm 1 better off and firm 2 worse off.

Now let us consider the effect of making litigation more costly. In the model, increasing litigation costs ℓ_i, $i = 1, 2$, and increasing the length of litigation T_2

both have this effect. In the figures, increasing ℓ_1 moves the economy to the right, and increasing ℓ_2 moves the economy up. Increasing T_2 moves (s) outward and (i^{K}) upward. Depending on where the economy was originally at the position (ℓ_1, ℓ_2), the equilibrium outcome may change from NS to S when ℓ_i increases, and a greater T_2 may change the equilibrium outcome from S to NS. Furthermore, both π_1^{NS} and π_2^{NS} are decreasing in T_2, and K^* is increasing in T_2. The no-settlement payoff of each firm decreases when the litigation cost increases. An increase in firm 1's litigation cost does not affect π_i^S, $i = 1, 2$, but π_1^S is increasing and π_2^S is decreasing in ℓ_2. Finally, the no-imitation payoffs are independent of T_2 and the ℓ_i's. Summarizing:

Proposition 6: If the patent owner's litigation cost increases, then some no-settlement equilibrium outcomes change to settlement ones. The patentee will therefore be better off, and firm 2's payoff will remain unchanged.

If the imitator's litigation cost increases, then some no-settlement equilibrium outcomes change to settlement or no imitation ones, and some settlement equilibrium outcomes change to no-imitation ones. The patentee is therefore better off and firm 2's payoff remains unchanged if the equilibrium outcome changes to settlement. If the equilibrium outcome changes to no imitation, then the patentee is better off and the imitator is worse off.

Increasing the length of time required for litigation will change some equilibrium outcomes from no settlement to settlement. It will also change some no-imitation outcomes to settlement or no-settlement ones. In all cases the patent owner is better off and the imitator is worse off.

We finally identify a situation where the patentee may want to reduce the imitation lag so that *ex ante* licensing will occur in equilibrium. The patentee's payoff will increase if the equilibrium changes to *ex ante* licensing, because now it is able to obtain the licensing fee, *ceteris paribus*. Although reducing T_1 will let (a) hold when it did not before, in order to make such a reduction profitable for firm 1, its nonlicense profit must be increasing in T_1. From Propositions 2 and 3, if θ satisfies

$$\theta > \frac{\pi_m - \pi_d - \ell_2}{\pi_d \delta_{T_2}^{\infty} + \gamma(\pi_m - \pi_d)\delta_0^{T_2}},$$

then the patentee's profit is decreasing in T_1 and that of firm 2 is increasing. If the equilibrium does not involve *ex ante* licensing, then by reducing T_1 just enough for (a) to hold, firm 1's profit will be greater.

4 Welfare Analysis

This section analyzes the welfare consequences of strategic licensing and obtains some possible improvements to the patent-law system.

We denote the social surpluses (consumer surplus together with producer surplus) under the monopolistic and duopolistic market structures by S_m and S_d, respectively. It is reasonable to assume

$$S_d > S_m > \pi_m \geq 2\pi_d,$$

which implies

$$S_d - 2\pi_d > S_m - \pi_m.$$

That is, the consumer surplus is larger under the duopolistic market structure than under the monopolistic market structure. This assumes that despite the imitation cost, imitation may also create a surplus by introducing market competition (KANNIAINEN AND STENBACKA [2000]). We now can characterize the socially optimal legal regime.

The four possible values of equilibrium social surplus by equilibrium outcomes are

$$S^A = S_d \delta_0^{\infty},$$
$$S^{NI} = S_m \delta_0^{\bar{T}} + S_d \delta_{\bar{T}}^{\infty},$$
$$S^S = S_m \delta_0^{T_1} + S_d \delta_{T_1}^{\infty} - h,$$
$$S^{NS} = S_m \delta_0^{T_1} + S_d \delta_{T_1}^{\infty} - \theta(S_d - S_m)\delta_{T_1+T_2}^{\bar{T}} - e^{-rT_1}\ell_1 - e^{-rT_1}\ell_2 - h.$$

Proposition 7: Legal systems that induce *ex ante* licensing agreements maximize the realized social surplus.

The orderings in the social surpluses are $S^A > S^S > S^{NS}$ and $S^A > S^{NI}$. Although the regimes inducing a licensing agreement before imitation maximize welfare, they do not maximize the expected payoff of the patentee and hence are detrimental to the R&D incentive. Indeed, the legal system that prevents imitation before the patent expires maximizes the patentee's payoff and hence provides maximum R&D incentives. Thus, there is a trade-off between the *ex ante* R&D incentive and *ex post* realized social value, which must be balanced by the strength of patent protection.[7] The relationship between S^S and S^{NI} is not clear, since the latter incurs a welfare loss caused by monopoly, but has a cost saving of h.

5 Discussion on Extremely Lengthy Litigation

In the basic model we assume that litigation ends before the patent expires. However, litigation can be so lengthy that the verdict comes after the patent expires. In this case, $T_1 + T_2 > \bar{T}$. Therefore, after successful imitation (T_1), the patentee can never force the imitator to leave the market, but in this case the patentee may still have an incentive to sue the imitator in order to obtain a damage award or a settlement fee (*ex post* licensing fee).

If $T_1 + T_2 > \bar{T}$, then the expected payoff of firm 1 at patent litigation without settlement is

$$\pi_1^{NS} = \pi_m \delta_0^{T_1} + \pi_d \delta_{T_1}^{\infty} + \theta\gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2} - e^{-rT_1}\ell_1.$$

[7] By balancing the innovator's incentive and society's benefits, AOKI AND HU [1999] show that under Cournot competition, a patent-law system inducing *ex ante* licensing is socially optimal.

Firm 1 has an incentive to litigate if and only if

$$\theta\gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2} - e^{-rT_1}\ell_1 \geq 0.$$

That is, expected gains from litigation are nonnegative. The expected payoff of firm 2 for patent litigation without settlement is

$$\pi_2^{NS} = \pi_d\delta_{T_1}^{\infty} - \theta\gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2} - e^{-rT_1}\ell_2 - h.$$

Firm 2 has an incentive to imitate the patent if and only if

$$\pi_d\delta_{T_1}^{\bar{T}} - \theta\gamma(\pi_m - \pi_d)\delta_{T_1}^{T_1+T_2} - e^{-rT_1}\ell_2 - h \geq 0.$$

That is, the expected gains from imitation are nonnegative. The sufficient and necessary condition for a settlement during patent litigation is

$$\ell_1 + \ell_2 \geq 0,$$

which always holds. That is, if the patent litigation ends after the patent expires, then the two parties will always settle.

The *ex post* licensing fee (F^*), with litigation continuing after the patent expires, will actually be lower than that when litigation ends no later than the patent expiration. An extremely lengthy litigation also makes *ex ante* licensing more likely to occur. This result is consistent with Lemma 2, whereby a longer time to litigate promotes settlement. This is because a longer litigation time decreases the patentee's bargaining power.

Proposition 8: If litigation is extremely lengthy ($T_1 + T_2 > \bar{T}$), then the two parties will always settle out of court.

6 *Concluding Remarks*

Our analysis has incorporated both time and pecuniary costs of imitation and litigation. Previous economic analysis of litigation and settlement focuses only on pecuniary costs, arguing that any transaction costs associated with time would be captured as an opportunity cost in dollar terms. As we have seen, this may be an oversimplification. While a lower imitation cost only directly benefits the imitator, a shorter imitation time lag benefits the imitator by shifting profit away from the patentee. By hurting the patentee, quicker imitation encourages *ex ante* licensing, but the lower cost only increases the imitator's bargaining power to discourage licensing. As we have seen, separation of the time factor from other costs makes clear the trade-offs associated with patent-law policies. This suggests that our approach could be applied to other economic analysis of litigation and settlement behavior.

Intellectual property has come to be seen as an increasingly important asset to firms. In e-commerce, where physical assets are minor in terms of money, one of the most important assets is intellectual property and know-how. Our analysis shows that equilibrium outcomes and hence equilibrium payoffs are very sensitive to the lengths of imitation and litigation, as well as to the various pecuniary costs involved and the legal environment. Neither factor is considered in standard methods of intellectual-property evaluation (SMITH AND PARR [1993]). In information technologies where the product cycle is very short, the relative size of T_1 or T_2 to $\bar{T}$ may differ from that in traditional industries.

Our approach can also be applied to analyze the trade and intellectual-property rights (IPR) protection issue. The Uruguay Round of GATT negotiations put trade-related IPRs (TRIPs) on the agenda. During negotiations, developed countries (the North) proposed to extend the patent length to no less than 20 years from the filing date. The article was finalized in the Final Agreement of the Uruguay Round negotiations in 1994. However, many developing countries (the South) insisted that each country should determine its own minimum patent length. Harmonization of IPR systems will change patent litigation and licensing behavior in countries all over the world. As discussed in this paper, an increase in patent length promotes the patentee's bargaining power. Therefore, the extension of patent length within TRIPs benefits developed countries, which have most of the patents across countries. Likewise, the extension of patent length decreases the bargaining power of the imitators and licensees in developing countries. Consequently, there will be less licensing, with a higher licensing fee, from the North to the South. The North can then expand its market power in the world by increasing worldwide IPR protection.

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