Patent Litigation as an Information Transmission Mechanism

by

Jay Pil Choi
Discussion Paper No. 703
Patent Litigation as an Information Transmission Mechanism

by
Jay Pil Choi*

May 1994
revised, August 1994

*Department of Economics, Columbia University

I would like to thank Yeon-Koo Che and Eric Maskin for helpful discussions. The preliminary version of this paper was completed while I was visiting the Center for Economic Research, Tilburg University, whose hospitality and financial support are gratefully acknowledged.
Abstract

The literature on patent protection assumes a so-called "fencepost" system, in which there would be no need to refer to the courts over questions of interpretation. In reality, we observe a myriad of patent infringement suits through which questions of utility, novelty, and nonobviousness are independently ruled on by a court. Therefore, patent litigation accompanying initial imitations can reveal important information about the validity of the contested patents for other potential entrants. This paper explores the implications of such information revelation through patent litigation. It is shown that the payoffs for the patentee and the initial imitator are highly discontinuous in the degree of patent protection. Furthermore, strengthening intellectual property rights is not necessarily desirable for the patentee. The analysis also has implications for interpreting empirical data on imitation lags.
I. Introduction

This paper explores the implications of patent infringement litigation for the overall patent system. More specifically, I focus on the role of patent suits in conveying information regarding the validity and enforceability of the patents in dispute. It will be shown that the incorporation of patent litigation into the process of patent enforcement generates a rich set of predictions for the imitation-based entry dynamics, especially when there are multiple potential entrants. These results can have further implications for the interpretation of empirical data on imitation and the incentive to innovate.

Recognizing that knowledge is inherently a public good, the patent system purports to confer perfect appropriability by granting legal monopoly of an invention (for a limited time) to restore the incentive to engage in innovative activity. This idealization underlies most of the theoretical work concerning the economics of innovation and patents [Arrow (1962), Dasgupta and Stiglitz (1980), and Nordhaus (1969), etc.].

Empirical studies, however, revealed that patent is not perfect and that imitation is a common occurrence [Mansfield et al. (1981) and Levin et al. (1987)]. Subsequently, the possibility of imitating or "inventing around" the patent has been formally incorporated into theoretical models [Benoit (1985), Katz and Shapiro (1987), Dasgupta (1988), and Gallini (1992)]. All these papers, despite making advances over the previous literature in that they account for empirical facts, still retain the assumption that the interpretation of the patent scope is exact and, as a result, there is no need to refer to the courts over questions of interpretation; in the jargon of the legal literature on patents, the literature on patent protection assumes a so-called strict "fencepost" system.\(^1\) This assumption is typified in the recent literature on the tradeoff between the patent scope and the patent length [Gilbert and Shapiro (1990) and Klemperer (1990)]. In Klemperer's (1990) analysis, for instance, a patent's breadth measures how different competitors' products should be in order not to infringe on the patent. To this end, a notion of distance is

\(^1\)Notable exceptions are Meurer (1989) and Waterson (1990), which will be discussed below.
introduced in his formulation of patent scope: a patent of width $\omega$ prevents competing firms from producing product varieties within a distance $\omega$ from the patentholder's product in horizontal product space. An implicit assumption in his analysis is that this distance is well-defined for all relevant participants and, consequently, there is no ambiguity regarding the occurrence of infringement.

In reality, however, the scope of patent is determined by both statutory authority and judicial interpretation; issuance of the patent does no more than confer a patent right that is "presumed" valid (35 U.S.C.A. 282). Uncertainty as to the validity and coverage of many patents makes disputes inevitable. Consequently, we observe a myriad of patent infringement suits through which questions of utility, novelty, and nonobviousness are independently ruled on by a court. To illustrate the importance of court decisions on patent validity in infringement suits, I point out that of the 294 patents contested in all federal appellate court between 1966 and 1971, only 89 (about 30%) were found valid (Kintner and Lahr, 1975). Therefore, patent litigation accompanying initial imitations can reveal important information about the validity of the contested patents for other potential entrants. This paper explores the implications of information revelation through patent litigation. It is shown that the payoffs for the patentee and the initial imitator are highly discontinuous in the degree of patent protection. Furthermore, strengthening intellectual property rights is not necessarily desirable for the patentee.

The paper considers an imitation decision by potential entrants and the incumbent (patentee)'s response to entry via a potential patent infringement suit. The novelty of the paper comes from considering multiple potential entrants with endogenous entry timing. The basic premise of the paper is an observation that the outcome of a patent suit, i.e.,

---

2Issuance does not guarantee validity. In this respect, a patent is nothing but the title to sue.
3Some legal commentators characterize a patent as an invitation to a law suit or a lottery ticket (Kitti, 1979).
4See Scotchmer and Green (1990) and Scotchmer (1991) for an economic analysis of novelty requirement in a model of sequential innovations.
5Alternatively, we may assume that uncertainty lies in the amount of royalty payments the court decides that the patentee is entitled to.
how the court will interpret the law, is inherently uncertain for both the patentee and the accused infringer. For instance, the "doctrine of equivalents" entitles the patented invention to cover a certain range of equivalents. However, the exact boundary of the equivalents is impossible to draw. The matter of infringement can be reasonably assumed to be decided case by case. This point has an important implication especially when there are multiple potential entrants. The reason is that an initial imitation attempt and its corresponding suit can reveal important information regarding the validity of the patent through the litigation process.

This information revelation can have an impact on the behavior of both the patentee and the potential imitators. First of all, if the imitated patent is held invalid and the patent is revoked, it clears the deck for other potential entrants, making further entry immune from the threat of a suit. Even though an early entrant can benefit from an additional profit until other firms enter, I expect that this potential gain can be easily outweighed by the potential saving of sunk entry costs; it may be better to be a second imitator since it can save fixed sunk costs of entry in case of patent infringement. This creates an incentive to free ride on information provided by an early imitator. The consequence is a possibility of a waiting game in the imitation process.6

For the patentee, it implies that the infringement suit is a risky business to conduct. If her patent is revoked in the suit, it will facilitate further entry to the industry. This implies that the incentive to bring up a suit increases with the number of entrants already in the market since the adverse effect of further entry gets smaller. As a result, I find a set of parameters, which I call the limit entry set, where an initial entry occurs without any patent suit while further entry is deterred. In this set, the patentee initially refrains from bringing up the suit since the potential negative effect of information revelation outweighs

6In the innovation literature, it has been recognized that the possibility of imitation can convert the innovation game from a race to a waiting game [Dasgupta (1988) and Katz and Shapiro (1987)]. However, to the best of my knowledge, this paper is the first one to point out the possibility of a waiting game in the imitation game ex post innovation.
the potential positive effect of restraining competition whereas the second entry is deterred since it will trigger a patent suit. In this case, the imitation game is a preemption game in which each potential entrant strives to be the first one to imitate, knowing that he will be accommodated without inviting further entry. The existence of the limit entry set can have a dramatic effect on the overall behavior of profit functions for the patentee and potential imitators. It is shown that the payoffs for the patentee and the initial imitator are highly discontinuous in the extent of patent protection. Furthermore, strengthening intellectual property rights is not necessarily desirable for the patentee.

This paper relates closely to the imitation literature. Katz and Shapiro (1987) Dasgupta (1988) formally consider the possibility of imitation in the patent race. Gallini (1992) improves on the previous papers by assuming costly imitation. Thereby, she endogenizes the decision to imitate through its dependence on the length and scope of patent protection. Contrary to the results of Gilbert and Shapiro (1990) and Klemperer (1990), she finds that in the presence of imitation costs, the optimal patent policy involves a broad scope of patent and a short patent life. Interestingly, as in my paper, she finds that an increase in patent life over some range may have no effect on or, paradoxically, may reduce the incentive to innovate. However, the mechanism through which this result is induced is completely different; in her analysis, increasing patent life increases the number of competing products via a zero profit entry condition while my analysis resorts to the change in the entry timing. Benoit (1985) is closest to this paper in that the effect of imitation on the innovator is generated through endogenized entry timing of the imitator. In his paper, there is uncertainty surrounding the profitability of innovation, which is revealed only over time. This creates an option value of waiting for the imitator; even though the waiting strategy entails the loss of temporary profits in the event the

---

7A recent paper by Jovanovic and MacDonald (1994) considers the process of technology diffusion in a competitive industry when a fixed number of firms reduces costs via two channels: innovating themselves or imitating their rivals' technologies.
innovation is favorable, it can save on a would-be failed investment. In contrast, the endogenized timing of entry in my paper arises from strategic interaction between multiple imitators trying either to free ride on information or to preempt each other. As pointed out earlier, all these papers assume that either imitation is immune from infringement or innovation is nonpatentable. Therefore their framework is not adequate to analyze the issues we are interested in, i.e., the information revelation role of the patent suit.

Meurer (1989) and Waterson (1990) are notable exceptions in that their models incorporate a fully structured legal process in which a "signpost" system of patents is assumed. As in this paper, they consider uncertainty about the extent of protection a patent provides. The foci of their analyses, however, are quite different: Meurer's concern is on patent licensing that is induced as part of a settlement agreement to avoid litigation regarding patent validity whereas Waterson's main contribution lies in exploring issues regarding the effects of patents on product variety selection. Both of their models contain a single entrant and, consequently, the issue of information revelation does not arise.

In focusing on the information revelation aspect of patent litigation, this paper is somewhat related to Horstman et al. (1985). They assume that an innovating firm has private information regarding the profitability of imitation. As a result, in their model the decision to patent has the potential to reveal implicitly some of the innovator's information to the competitor. In contrast, my analysis assumes a symmetric information structure between the patentee and the imitators since they are assumed to share or entertain the same assessment regarding the probability of infringement. The effect of information revelation arises only through further entry by a third party.

---

8Benoit's model also predicts the nonmonotonicity of innovator's profit in relevant parameters (cost of innovation and probability of success) if imitation is possible.

9In the "fencepost" interpretation of patent specifications, the perimeter of the patentee's claims is assumed to be clearly marked out. The "signpost" interpretation regards the patent specification as merely pointing the reader in the direction which he may not travel without a license.
Finally, in terms of the overall dynamics of entry, the paper is similar to Bernheim (1984). He argues that when there is a sequence of potential entrants, the qualitative nature of the entry deterrence decision undertaken by incumbent firms is much different from the single entrant case. In particular, the sequential aspects of entry deterrence makes it possible that government policies designed to promote entry have the opposite effect of increasing industrial concentration. The reason is that the profitability of potential entrants is in turn determined in part by the ease with which future entrants can be deterred. However, as will be explained later, the underlying mechanisms through which entry dynamics are generated are quite different across the two models.

The remainder of the paper is organized in the following way. In section II, I provide a basic two-period model in which the order of entry is exogenously fixed. Also, the informational externalities provided by the first entrant is discussed. In section III, I extend the basic model by allowing the timing of entry to be endogenously determined in an infinite horizon framework. It is shown that the nature of the entry game can be either one of waiting or preemption depending on the degree of patent protection. One important consequence is that, contrary to intuition, strengthening the patent protection can be harmful for the patentee as the entry game is changed from a waiting game to a preemption game. Section IV concludes with a discussion of possible extensions and limitations of the model.

II. The Basic Model

I consider a simple model of sequential entry. There is an incumbent who has a patent for a new product or process. He faces a sequence of potential entrants. In each period there is one potential entrant who can enter the market by imitating the patented product. Once there is an entry by an imitator, the incumbent (patentee) can take the entrant to court for patent infringement. The entry involves a sunk cost of $F$. This sunk
cost can be interpreted as a cost of imitation as in Gallini (1992) or as a fixed setup cost of tooling up necessary for a new product.

Contrary to most of the previous literature, the central feature of the present paper is that the extent to which protection is provided by the patent is not precise, and even the validity of the patent itself can be challenged in court. One important consequence of incorporating this feature into the patent enforcement mechanism is that the process of imitation and its accompanying patent litigation has a characteristic of a public good if there are multiple potential entrants; an early entrant can provide a valuable piece of information since the outcome of a patent suit reveals the profitability of entry for those who wait in the wings. This information is valuable since entry involves a sunk cost, which can be saved if the court deems an imitation product to infringe the patent.

I analyze the simplest model that is capable of addressing the issue of informational externalities among potential entrants. I consider a two-period model. There are two potential entrants, which is the smallest number allowing one to meaningfully analyze information transmission. In order to abstract from the strategic choice of entry timing, I assume that the order of entry is predetermined. The next section relaxes this assumption in an infinite horizon framework. The uncertainty of the outcome of a patent suit is captured by a probability \( \alpha \) that the patentee prevails in the suit, which is assumed to be known and shared by both parties.

The order of decisions and payoffs are summarized in Figure 1. At the beginning of the first period, the first entrant decides whether or not to enter. If he decides not to enter, the incumbent will be a monopolist for the first period. If he decides to enter, he

---

10 In a survey study of Levin et al. (1987), most respondents believed only a few firms (three to five for a major innovation, six to ten for a typical innovation) were capable of duplicating new processes and products.

11 It is possible that the patentee has better information regarding this probability since she may know the potential weakness of the patent (Meurer, 1989). In this case, the mere decision to bring a suit can have informational content especially when out-of-court settlement is possible. This is an important agenda for future research. See Horstmann et al. (1985) for an analysis where the decision to patent can have a similar information-revealing effect.
has to sink a fixed cost of $F$. Let the profits for the monopoly, duopoly, and triopoly per period be denoted by $\Pi^M$, $\Pi^D$, and $\Pi^T$, respectively, where $\Pi^M > \Pi^D > \Pi^T$. With this notation, we implicitly assume that those profits are symmetric between the incumbent and entrants. Since the imitated product can be inferior or superior to the original patented product, duopoly and triopoly profits need not to be the same across the patentee and imitators. This assumption is only for the sake of saving notation and has no consequences for the main results.

Figure 1 - The Order of Decisions and Payoffs: I, E1, E2, and C denote Incumbent, Entrant 1, Entrant 2, and the Court, respectively. The payoffs vectors list final payoffs for I, E1, and E2 in that order. The subtree corresponding to the second period is collapsed reflecting the fact that litigation is a dominant strategy for the incumbent in the second period since there is no further entry even though she loses in the suit.
To make the analysis interesting, we maintain the following assumption throughout the paper.\(^\text{12}\)

\[ \Pi^T - F > 0 \]  \hspace{1cm} (1)

The assumption assures that if there is no danger of infringement it is profitable to enter the industry as a triopolist. Otherwise, the market can accommodate at most two firms and the issue of information transmission does not arise.

In the face of entry, the incumbent can accommodate the entrant by sharing the market or take the entrant to court for patent infringement. For simplicity, I assume that there is only one way to imitate and the probability that the entrant is deemed to infringe on the patent is given by \( \alpha \). This probability is known to both the incumbent and potential entrants. To focus on my main topic of interest, namely the information revelation aspect of patent suits, I assume away any legal costs involved in the litigation process.\(^\text{13}\) For simplicity I also assume that the outcome of the suit is determined immediately.\(^\text{14}\) There are two possible outcomes of the patent suit. If the entrant is found to infringe on the patent, a court injunction will prohibit the selling of the imitation product and, consequently, the entrant should leave the industry, forfeiting the entry cost of \( F \). In this case, the incumbent will remain a monopolist for the period. Another possible outcome of the suit is that the patent is deemed as invalid.\(^\text{15}\) If this is the case, the market will be occupied by two firms in the first period.

\(^{12}\)The corresponding assumption in the infinite horizon model of section III is \( \Pi^T/(1-\delta) - F > 0 \).\(^{13}\)In Meurer's (1989) model, the incentive to avoid legal costs plays a crucial role to the settlement process of patent litigation. Meurer's and my papers, however, should be viewed as complementary rather than competing because they highlight different aspects of patent litigation.\(^{14}\)In reality, few patent disputes are finally settled within three years (White and Jacob, 1986). In the case of Polaroid v. Kodak in which Polaroid received $985 million as a settlement, it took 14 years for the patent infringement suit to be resolved. One important topic for future research is to incorporate this empirical fact into the model.\(^{15}\)Another possibility, which I ignore, is the case in which the patent is valid but the claims of the patent specification are too narrow to cover the article the entrant is producing. In this case, everyone in the industry now knows how to get around it. Therefore, as will be clear, for my purposes this possibility can be ignored without any loss of generality since this case is equivalent to the case where the patent is found to be invalid.
The main focus of this paper is the implication of the patent suit for the other entrant in period 2. At the beginning of the second period, another potential entrant arrives on the scene and makes his own decision regarding entry. He is assumed to have observed what has happened in the first period. Particularly, the outcome of the patent suit, if there was one, is known to him. There are four possible subgames facing the second potential entrant: (i) there was an entry and a suit in which the patent was held invalid, (ii) there was entry and an infringement suit in which the patentee prevailed, (iii) there was entry but it was accommodated by the patentee, and (iv) there was no entry in the first period.

If the second entrant decides to enter, there may be another infringement suit by the patentee. However, for simplicity, I make the following observations/assumptions regarding the litigation process. If the patent is invalid, there is no patent and the other entrant can enter the market without the fear of being sued.\footnote{This doctrine is called collateral estoppel which states that a patent owner is precluded "from asserting a charge of infringement if the patent has already been found invalid in earlier litigation involving its owner and a different accused infringer (Kintner and Lahr, 1975)."} If the patentee prevails in the first period, on the other hand, her competitors are assumed to respect the patent in the future even though theoretically they can challenge it again.\footnote{In this respect, however, the doctrine of collateral estoppel does not work in reverse. "An owner whose patent has been found valid in an initial suit against one infringer may not thereafter avoid relitigation of the validity of the patent in a subsequent suit against another infringer (Kintner and Lahr, 1975)."} This assumption could be relaxed without affecting the main results of the paper as long as other potential imitators update their beliefs in a way that reduces the expected value of imitation.\footnote{For instance, in the United Kingdom legal system, if the patent is held valid, the patentee receives a "certificate of contested validity." Even though we abstract away from the legal costs in this paper, the effect of a certificate is to enable the patentee to recover the actual legal costs ("solicitor and own client costs") incurred if she wins another action on that patent, which makes the challenge more expensive for potential imitators. For an initial patent suit, the patentee is allowed to ask for only the least amount it would be possible to spend in fighting the action ("party and party costs"). The difference can be very large for a patent action. See White and Jacob (1986) for details.} Finally, I assume that if the patentee accommodates the initial imitator in the first period, she cannot charge him with patent infringement in the second period. I make this assumption by invoking the so-called "laches estoppel and the statute of limitations." This
is a special case of equitable estoppel which applies because of the patentee owner's earlier inaction. The purpose of this rule is to prevent a patentee from enforcing her patent against a party for infringement because she "slept on [her] rights while the infringer made expenditures in the belief that he was not infringing the patent or that, if infringing, he would not be sued [Kintner and Lahr (1975)]." However, delay in proceeding against the first imitator is no ground for refusing an injunction, if there has been no delay in proceeding against the second imitator. Therefore, the patentee can proceed against the second imitator even though she accommodated the first imitator and relinquished her rights for the remedy against the first imitator (Pneumatic Tyre Co. v. Warrilow, 13 R.P.C. 284).

Under these assumptions, note that it is a dominant strategy for the incumbent to sue any entrant in the second period since the incumbent can only gain by suing with no legal costs. Suing in the first period, on the other hand, carries with it a serious risk for the patentee in since it can facilitate further entry in the second period in case she loses.

Now let me analyze the game by using a standard backward induction argument. Suppose that there were an entry and a subsequent patent infringement suit in the first period. The second entrant will decide to enter depending on the outcome of the suit; he enters if and only if the patent is deemed to be invalid. Suppose that there has been no patent suit brought by the patentee after an entry in the previous period. Then, the second entrant should decide to enter under uncertainty about the outcome of patent suit. Given that it is a dominant strategy for the incumbent to file a suit in the second period, he will enter if and only if

\[(1-\alpha)\Pi^T - F > 0\]

19 In North British Rubber Co. v. Gormully and Jeffrey Co. (R.S.C., Ord. 8, r.4.), Judge Chitty ruled that "the general rule of the court is that a person who comes to ask for that remedy,..., should come promptly."

20 See also Aldous et al. (1982).

21 In case of no entry in the first period, he will enter if and only if \((1-\alpha)\Pi^D - F > 0\). In equilibrium, however, there can be entry in the second period only if there has been a prior entry in the first period. The reason is that the first entrant has a bigger incentive to enter due to a longer horizon (see Eq. (7)).
Now let us analyze the decision for the patentee in case of entry in the first period. If she brings an infringement suit, her expected payoff is given by:

\[ W_S = \alpha(\Pi_M + \delta\Pi_M) + (1-\alpha) (\Pi_D + \delta\Pi_T) \]  

(3)

If she prevails in the suit, she will have monopoly profit in both periods since she can deter entry in the second period. If she loses, she will have duopoly profit in the first period and triopoly profit in the second period due to further entry. The discount factor \( \delta \) reflects the relative length of the first and second period. Consequently, we do not make any presumption on the magnitude of \( \delta \); it need not be less than 1 if the time horizon after the second entry is sufficiently long compared to the length of the first period which is meant to be a time lapse between the first and second entry.

If she does not sue, she will have a duopoly profit in the first period. The profit in the second period depends on the entry configuration. Let \( \alpha_2^* \) be defined by:

\[ (1-\alpha_2^*)\Pi_T - F = 0 \]  

(4)

If \( \alpha \geq \alpha_2^* \), i.e., condition (2) is violated, there will be no further entry and she will have a duopoly profit. If \( \alpha < \alpha_2^* \), i.e., condition (2) is satisfied, then there will be entry and there will be a suit in the second period. In this case, the second-period expected profit for the incumbent will be \( \alpha\Pi_D + (1-\alpha)\Pi_T \). I can write the expected payoff of accommodating entry in the first period as:

\[ W_A = \Pi_D + \delta [\alpha\Pi_D + (1-\alpha)\Pi_T] \quad \text{if} \quad \alpha < \alpha_2^* \]

\[ \Pi_D + \delta\Pi_D \quad \text{if} \quad \alpha \geq \alpha_2^* \]

(5)

If I rewrite Eq. (3) as \( W_S = [\alpha\Pi_M + (1-\alpha)\Pi_D] + \delta [\alpha\Pi_M + (1-\alpha)\Pi_T] \), it is immediate that \( W_S > W_A \) if \( \alpha < \alpha_2^* \); there is no adversary effect of information revelation associated with the patent infringement suit since there will be further entry anyway in the other words, whenever the condition \( (1-\alpha)\Pi_D - F > 0 \) is satisfied, the first entrant also have incentive to enter the market.

22The subscript of \( \alpha \) refers to the firm for which the critical value is relevant in order to make an entry decision.

23Note that I assume that the first entrant, who has already been accommodated, cannot be sued in the second period via laches estoppel.
second period. If $\alpha > \alpha_2^*$, the condition for accommodation to be a preferred strategy for the patentee is given by $\alpha \leq \alpha^{**}$, where $\alpha^{**} \in (0,1)$ is uniquely defined by:

$$[\alpha \Pi^M + (1-\alpha)\Pi^D] + \delta [\alpha \Pi^M + (1-\alpha)\Pi^T] = \Pi^D + \delta \Pi^T$$  \hspace{1cm} (6)

There are two cases to consider depending on the relative magnitude of $\alpha_2^*$ and $\alpha^{**}$.

**Case I. $\alpha_2^* > \alpha^{**}$.**

In this case, $W_S > W_A$ for all $\alpha \in (0,1)$, implying that the incumbent patentee will always bring an infringement suit in the face of initial entry. As long as there is entry in the first period in equilibrium (i.e., $\alpha$ is not too high to make the infringement highly likely), the model has predicted properties regarding each player's payoffs: The incumbent's profit is continuous and strictly increasing in $\alpha$ and potential imitators' profits are continuous and strictly decreasing in $\alpha$.

**Case II. $\alpha_2^* < \alpha^{**}$.**

In this case, there exists a set of parameter $J = [\alpha_2^*, \alpha^{**}]$, which I will call the "limit entry set." If $\alpha$ belongs to $J$, the first entry will be accommodated and there will be no further entry in the second period: $\alpha$ is sufficiently high to deter further entry in the second period (i.e., $\alpha \geq \alpha_2^*$), whereas it is too low for the incumbent to engage in a risky suit in the first period (i.e., $\alpha \leq \alpha^{**}$). The presence of the limit entry set generates interesting dynamics and produces many counter-intuitive predictions regarding the payoffs of the players. Since the analysis of Case I is rather trivial, hereafter I focus only on Case II to prevent the paper from becoming too lengthy.

Finally, to characterize the first entrant's decision, we need another critical value, $\alpha_1^*$, which is defined by

$$(1-\alpha_1^*) (\Pi^D + \delta \Pi^T) - F = 0$$  \hspace{1cm} (7)

---

24 $J$, can be also called the "live-and-let-live" set.
The first entrant is indifferent between entering and staying out at the critical value \( \alpha_1^* \) assuming that the entry is responded to by an infringement suit. Note that \( \alpha_1^* > \alpha_2^* \) implying that the first entrant has a bigger incentive to enter due to a longer horizon. The following proposition characterizes the equilibrium in the imitation game.

**Proposition 1.** Suppose that there exists a limit entry set \( \mathcal{L} = [\alpha_2^*, \alpha^{**}] \). Let \( \alpha# = \max(\alpha_1^*, \alpha^{**}) \). (i) If \( \alpha \leq \alpha# \), firm 1 enters the market in period 1. Confronted with an entry, the incumbent accommodates the entry and there is no further entry if \( \alpha \in \mathcal{L} \). (When \( \alpha# = \alpha^{**} > \alpha_1^* \) and \( \alpha \in (\alpha_1^*, \alpha^{**}) \) there will be no entry in the first period if the incumbent were able to commit to bringing an infringement suit. However, this threat is not credible and consequently, there will be an entry.) Otherwise (i.e., if \( \alpha \in (0, \alpha#] - \mathcal{L} \)), she brings an infringement suit. Depending on the outcome of the suit, there may be further entry in period 2; firm 2 enters if and only if the patent is held invalid. (ii) If \( \alpha > \alpha# \), there is no entry in either period. The expected equilibrium payoffs as a function of \( \alpha \) are shown in Figure 2 (assuming \( \alpha_1^* > \alpha^{**} \)).

As can be seen in Figure 2, the payoffs for each player are discontinuous at the boundary of the limit entry set and constant within the set. Moreover, the imitators' payoffs need not be decreasing as the degree of patent protection, parametrized by \( \alpha \), strengthens. As \( \alpha \) increases and passes through the limit set, we have a fundamental change in the regimes. Despite this fact, the patentee's expected payoff is a weakly increasing function of \( \alpha \). The reason is that the patentee always has the option of suing in the limit entry set. Moreover, the first entrant's behavior is not affected as \( \alpha \) crosses the boundary of the limit entry set. However, this invariance of the first entrant's behavior is due to the artificial assumption of exogenous entry timing. In the next section, it will be shown that if the timing of entry is endogenized, an increase in \( \alpha \) can have a perverse effect on the expected payoffs of the incumbent.
Figure 2 - The Expected Payoffs of the Incumbent and Entrants as Functions of $\alpha$. 
In this section, I relax the artificial assumption of exogenous entry timing. As before, there are two potential entrants indexed by $i=1,2$ who can now enter at any time they desire if they have not yet entered. Entry decisions are made only at the beginning of each period which lasts for $\Delta$. In each period, if there is any entry, the patentee can respond with a patent suit if she chooses to. As before, per-period payoffs for monopolist, duopolist and triopolist are denoted by $\Pi_M$, $\Pi_D$, and $\Pi_T$, respectively. The discount factor is given by $\delta = \exp(-r\Delta)$, where $r$ is the rate of interest. Once again, I assume that the legal principle of "laches estoppel" prevents the patentee from suing if she does not bring up the suit immediately after imitation. I now analyze the entry game by two potential entrants as a simple stopping game in an infinite horizon model in which the decision for each firm is an entry timing.

In light of the results in the previous section, define the limit entry set, $\mathcal{L} = [\alpha_2^*, \alpha^{**}]$, which corresponds to the infinite horizon.\textsuperscript{25} The boundary of the limit entry set, $\alpha_2^*$ and $\alpha^{**}$, are defined analogously, taking into account an infinite horizon.

\begin{align}
(1 - \alpha_2^*) \frac{\Pi_T}{1 - \delta} - F &= 0 \quad (4') \\
\alpha^{**} \frac{\Pi_M}{1 - \delta} + (1 - \alpha^{**}) \left[ \frac{\Pi_D + \delta \frac{\Pi_T}{1 - \delta}}{1 - \delta} \right] &= \frac{\Pi_D}{1 - \delta} \quad (6')
\end{align}

Once again, to ensure that $\mathcal{L}$ is not empty, assume that $\alpha^{**} > \alpha_2^*$.

\textbf{A. Waiting Game Regime}

Now suppose that $\alpha \in \mathcal{L} = (0, 1) - \mathcal{L}$, i.e., the best response of the patentee facing an initial entry is to counter with an infringement suit. In this case, the expected payoff of the first imitator who enters in period $t$ can be written as:

\begin{footnotesize}
\textsuperscript{25} Once again, subscript 2 refers to the second entrant. In contrast to the previous section, the order of entry, however, is endogenously determined rather than exogenously fixed.
\end{footnotesize}
\[ L(t) = \delta^{t-1} \left[ (1 - \alpha) \left( \Pi^D + \delta \frac{\Pi^F}{1 - \delta} \right) - F \right] \]  
(8)

If one firm enters in period \( t \), the other firm can receive information regarding the infringement of the patent, which allows the latter's entry decision to be conditioned on the outcome of the suit. Therefore, the follower's expected payoff is

\[ F(t) = \delta^{t-1} \left[ (1 - \alpha) \left( \frac{\Pi^F}{1 - \delta} - F \right) \right] \]  
(9)

If both firms enter in the same period, we know that it is a dominant strategy for the patentee to sue since there is no further entry to be concerned about. Therefore, the expected payoff of both entrants can be written as

\[ B(t) = \delta^{t-1} \left[ (1 - \alpha) \left( \frac{\Pi^F}{1 - \delta} \right) - F \right] \]  
(10)

To make the initial entry feasible \( (L(t) > 0) \), assume that \( \alpha < \alpha^*_1 \), which is defined by

\[ (1 - \alpha^*_1) \left( \Pi^D + \delta \frac{\Pi^F}{1 - \delta} \right) - F = 0 \]  
(7)

The game is stationary before any entry and has a unique symmetric equilibrium, which is also stationary. Since we are interested in the case where delta is short, it is easy to verify that the game exhibits the payoff structure of a waiting game. The equilibrium is characterized by mixed strategies in which each potential entrant enters with probability \( p \) in each period if no player has entered before.\(^{26}\) For the stationary symmetric profile \((p, p)\) to be an equilibrium, a firm should be indifferent to entering now and waiting for one more period. When the other player enters with probability \( p \), the value of entering is given by:

\[ V_E(p) = p \left[ (1 - \alpha) \left( \frac{\Pi^F}{1 - \delta} \right) \right] + (1 - p) \left[ (1 - \alpha) \left( \Pi^D + \delta \frac{\Pi^F}{1 - \delta} \right) \right] - F \]  
(11)

The value of waiting is

\[ V_W(p) = p \left[ (1 - \alpha) \delta \left( \frac{\Pi^F}{1 - \delta} - F \right) \right] + (1 - p) \delta V \]  
(12)

where \( V \) is the equilibrium value of playing the imitation game.

\(^{26}\)There are also two asymmetric stationary equilibria: one is that firm 1's strategy is "always enter" and player 2's is "never enter"; the other is one in which the roles of firms are reversed.
The equilibrium probability of adoption \( p^* \in (0, 1) \) will be chosen so that \( V_E(p^*) = V_W(p^*) = V \). Since we are interested in the results as \( \Delta \to 0 \), it is convenient to approximate the waiting game in a continuous-time formulation. Then, the discount factor \( \delta = \exp(-r\Delta) \) reflects the time lapse between periods. We now interpret \( \Pi^M, \Pi^D, \) and \( \Pi^T \) as flow profits for monopoly, duopoly and triopoly, respectively.

With the continuous time formulation, let \( G(t) \) denote the cumulative probability that firm \( i \) enters the market at or before \( t \). For \( G \) to be a stationary symmetric equilibrium, it is necessary that the players be indifferent to entering at time \( t \) and waiting until \( t + dt \) to take advantage of the informational revelation created by the other entrant. Conditional on not entering before \( t \), the marginal cost of waiting is approximated, to the first order of \( dt \), as \( [(1-a)\Pi^T - rF] \ dt \). By waiting, one loses flow profit proportional to \( dt \) in case the patent is held invalid which occurs with probability of \( (1-a) \). Since a successful entry will be followed by another entrant immediately \( (\Delta \to 0) \), the relevant profit is a triopoly profit. The second term \( (rF) \) in the square bracket is a cost saving from a deferred entry. The expected reward from waiting comes from the avoidance of fixed cost when the imitation is found to infringe the patent, which is \( \alpha F \ dg \).

Equilibrium requires that these two terms be equalized, which yields:\(^{27}\)
\[
\frac{dG}{1-G} = \frac{(1-\alpha)\Pi^T - rF}{\alpha F}.
\]

Then, the equilibrium strategies are characterized as an exponential distribution with a parameter of \( \lambda = \frac{(1-\alpha)\Pi^T - rF}{\alpha F} \). Let \( T \) denote the first entry time which is random.

Then, the incumbent has a monopoly profit until \( T \), thereafter her expected payoff is a triopoly profit:

\(^{27}\)It can be formally demonstrated that this equilibrium in continuous strategies is the limit of the equilibrium of the corresponding game in discrete time as \( \Delta \) goes to zero. To make the discrete- and continuous-time formulations comparable, we have to assume that the profits for monopolist, duopolist, and triopolist are \( \Pi^M, \Pi^D, \) and \( \Pi^T \) per unit of real time, respectively. For instance, the monopoly profit in discrete time with period length of \( \Delta \) is \( \Pi^M \Delta \). See Fudenberg and Tirole (1991) for details.
\[ W = \alpha \frac{\prod_{t=0}^{M} e^{-r t}}{r} + (1 - \alpha) E \left[ \int_{0}^{\infty} \prod_{t=0}^{M} e^{-r t} dt + \int_{t}^{\infty} \prod_{t}^{e^{-r t}} dt \right] \] (14)

It is well-known that
\[ E(e^{-r t}) = \frac{2 \lambda}{r + 2 \lambda} \] (15)

Thus the expected payoff for the incumbent is
\[ W = \alpha \frac{\prod_{t=0}^{M} e^{-r t}}{r} + (1 - \alpha) \left[ \frac{\prod_{t=0}^{M} e^{-r t}}{r + 2 \lambda} + \frac{2 \lambda \prod_{t}^{e^{-r t}}}{r(r + 2 \lambda)} \right], \text{where} \lambda = \frac{(1 - \alpha) \prod_{t}^{e^{-r t}} - r F}{\alpha F} \] (16)

By definition of \( \alpha_2^* \), we have that \( \lambda \to 0 \) as \( \alpha \to \alpha_2^* \). Consequently, the expected payoff for the incumbent approaches the monopoly profit \( \Pi^{M/r} \) as \( \alpha \to \alpha_2^* \).

B. Preemption Game Regime

Now, suppose that \( \alpha \in L \). For this parameter region, if in period \( t \) there is only one entrant, he will be accommodated whereas further entry will be deterred. Therefore, the expected payoff of the first player who enters in period \( t \) can be written as:
\[ L(t) = \delta^{t-1} \left( \frac{\Pi^{D}}{1 - \delta} \right) \] (17)

The other player refrains from entering further and gets zero. If both potential entrants enter in the same period \( t \), the expected payoffs of both players are given by Eq. (10) as before.

The game is one of preemption in which each firm strives to be the first entrant knowing that he will be accommodated without further entry. The game has a unique symmetric equilibrium. In each period, if no entry has yet occurred, each player enters the market with probability \( p \) which is given by:
\[ p = \frac{\Pi^{D} - (1 - \delta)F}{\Pi^{D} - (1 - \alpha \Pi^{T})} \] (18)

The expected payoffs of both players are zero. The reason is that there is a positive probability of coordination failure: both enter in the same period and lose \( B(t) \) which is

\[^{28}\text{Let } x \to y^+ (y^-) \text{ denote that } x \text{ approaches } y \text{ through values greater (smaller) than } y.\]
negative when $\alpha \in \mathcal{I}$. Note that $\partial p / \partial \alpha < 0$. The reason is that potential entrants become more cautious in their entry decision as the cost of mistakes for them increases with $\alpha$.

The continuous time formulation of the preemption game involves a subtlety that is not present in the waiting game since the formalization that is applied to a waiting game "entails a 'loss of information' in passing from discrete time with short periods to the continuous time limit" [see Fudenberg and Tirole (1985) for a new formulation that allows a continuous-time representation of the limits of discrete-time counterparts and discussions therein]. However, for our purposes, I need not delve into these technicalities. Let it suffice to mention the following features of the equilibrium as $\Delta \to 0$:

First, the entry game ends with probability 1 at time zero. Second, let $\beta$ denote the limiting value of the coordination failure. Then, we can write the expected payoff of the patentee as:

$$ W = \beta \left[ \frac{\alpha \Pi^M + (1 - \alpha) \Pi^T}{r} \right] + (1 - \beta) \frac{\Pi^D}{r} \tag{19} $$

Note that $\beta = p/(2-p)$, which is decreasing in $\alpha$:

$$ \frac{d\beta}{d\alpha} = \frac{\partial \beta}{\partial p} \frac{\partial p}{\partial \alpha} < 0 \tag{20} $$

Increased $\alpha$ reduces the probability of entry in every period for each entrant, which in turn reduces the probability of coordination failure (simultaneous entry).

Within the limit entry set, we can verify that the patented expected payoff increases as $\alpha$ increases.

$$ \frac{\partial W}{\partial \alpha} = \frac{d\beta}{d\alpha} \left\{ \frac{[\alpha \Pi^M + (1 - \alpha) \Pi^T] - \Pi^D}{r} \right\} + \beta \frac{(\Pi^M - \Pi^T)}{r} > 0 \tag{21} $$

First, as $\alpha$ increases, the probability of coordination failure decreases ($d\beta/d\alpha < 0$). Within the limit entry set, better coordinated entry induced by a higher $\alpha$ is also beneficial for the incumbent because she prefers to have an accommodated duopoly situation rather than a contested monopoly (the expression in the curly bracket in Eq.(21) is negative when $\alpha \in \mathcal{I}$).

---

29 Technically, the set of continuous-time equilibria is not the set of limit points of discrete-time equilibria.

30 We can also verify that $W$ is a concave function of $\alpha$ ($\partial^2 W/\partial \alpha^2 < 0$).
Second, given the probability of coordination failure, a higher \( \alpha \) translates into a higher probability of maintaining the monopoly position through litigation.

We can also show that as \( \alpha \to \alpha_2^*+ \), the cost of a mistake becomes closer to zero, inducing each potential entrant to enter almost surely in each period \( (p \to 1) \). As a result, the probability of coordination failure also approaches one \( (\beta \to 1) \) with the expected payoff of the incumbent being \( [\alpha \Pi^M + (1-\alpha) \Pi^T]/r \). We can conclude that due to a change in the nature of entry dynamics (infinite delay vs. immediate entry), the expected payoff of the incumbent jumps down discontinuously at the left boundary point of the limit entry set as depicted in Figure 3. In contrast, at the right boundary point of the limit entry set, the payoff jumps up to the monopoly profit level as the credibility of patent litigation is restored and entry is blockaded.

We note that \( \alpha_1^* \to \alpha_2^*+ \) as \( \Delta \to 0 \), which allows us to suppress the subscripts hereafter. Proposition 2 summarizes the equilibrium in the infinite-horizon continuous framework.

**Proposition 2.** Suppose that there exists a limit entry set \( \mathcal{L} = [\alpha^*, \alpha^{**}] \). (i) If \( \alpha < \alpha^* \), there is delay in the first entry, the timing of which is distributed exponentially with parameter \( 2\lambda \), where \( \lambda = \frac{(1-\alpha)\Pi^T - rF}{\alpha F} \). The incumbent brings an infringement suit in face of the first entrant. Depending on the outcome of the suit, there may be a further entry; firm 2 enters if and only if the patent is held invalid. (ii) If \( \alpha \in \mathcal{L} = [\alpha^*, \alpha^{**}] \), there is an immediate entry. If there is only one entrant, the incumbent accommodates the entry and there is no further entry. If both enter at the same time, the incumbent brings infringement suits. (iii) If \( \alpha > \alpha^{**} \), there is no entry. If there were one, there would be patent litigation. The expected equilibrium payoffs as a function of \( \alpha \) are shown in Figure 3.
Figure 3 - The Expected Payoffs of the Incumbent and Entrants as Functions of $\alpha$.

One important consequence of this observation is that the strengthening of intellectual property rights (captured as an increase in $\alpha$) is not necessarily desirable for the patentholder. This implies that government policies designed to encourage R&D investment by providing better protection for the innovator may have the opposite effect of retarding the speed of initial innovation.
The result is reminiscent of those of Bernheim (1984) and Benoit (1985). In a model of sequential entry, Bernheim (1984) demonstrates that the qualitative nature of the entry deterrence decision undertaken by incumbent firms is much different from the single entrant case. One implication of his analysis is that the sequential aspects of entry deterrence makes it possible for government policies designed to promote entry to have the opposite effect of increasing industrial concentration. The reason is that the profitability of potential entrants is in turn determined in part by the ease with which future entrants can be deterred.

The nonmonotonicity of comparative statics result in both Bernheim's (1984) and my paper rely on the existence of multiple potential entrants. Despite the similarities in this regard, there are also some crucial differences between the two papers. First of all, Bernheim's (1984) model is devoid of any intertemporal aspects. His concern is with the equilibrium number of firms (industrial concentration) associated with the zero profit entry condition prevailing under various entry-deterrent strategies. In contrast, my model has bite only when intertemporal aspects are considered: the driving force behind the nonmonotonicity result is the endogenized timing of entry in the form of an incentive to free-ride on information revealed by the rival firm's entry or to preempt the rival firm. Second, potential entrants in Bernheim's model are symmetric in any ex post entry configurations, whereas potential entrants in my model can have asymmetric payoffs ex post when the initial entry has a preemptive nature or reveals new information regarding the validity of the patent.

Benoit (1985) is closer to this paper in that the effect of imitation on the innovator is generated through endogenized entry timing of the imitator. In his paper, there is uncertainty surrounding the profitability of innovation, which is revealed only over time.

31It is also worth mentioning a recent paper by Helpman (1993) which analyzes the enforcement of intellectual property rights in a dynamic general equilibrium framework of international trade in which the North invents new products and the South imitates them. In his model, tightening of intellectual property rights can hurt the North due to the effect of reallocation of production. When the initial rate of imitation is sufficiently low, the loss from this effect outweighs the gains from the terms of trade effect.
This creates an option value of waiting for the imitator; even though the waiting strategy entails the loss of temporary profits in the event the innovation is favorable, it can save on a would-be failed investment.\(^{32}\) The difference is that a new flow of information arrives \textit{exogenously} in Benoit's model, whereas here new information is created \textit{endogenously} only when an action is taken by one of the parties concerned. In this respect, the delayed entry in my model is due to the \textit{strategic} option value of waiting which is nonexistent in Benoit's model of a single entrant.\(^{33}\)

Finally, my analysis has an important ramification for the interpretation of empirical data on imitation. Mansfield \textit{et al.} (1981), for instance, estimate that about 60 percent of the patented innovations in their sample were imitated within four years. The analysis of Mansfield \textit{et al.} (1981) is based on the (implicit) premise that the imitation process in itself is a race among potential imitators. My analysis suggests caution in interpreting empirical data on imitation times; the data can overestimate the difficulty of imitation since the time lag may contain a strategic waiting component.

\textbf{IV. Concluding Remarks}

I have developed a simple model of imitation with multiple entrants. The basic premise of the paper is that an initial imitation attempt and its accompanying patent infringement suit can serve as an information transmission mechanism in that other potential entrants can condition their own entry decisions on the information revealed in the process of patent suit. This informational externality can induce each potential entrant to wait for the other to take the initiative. However, this is not the only possibility. There are also cases where the so-called "limit entry set (\(L\))" exists. In these cases, if \(\alpha \in L\), the first entrant is accommodated whereas further entry is deterred. As a result, the entry

\(^{32}\)Benoit's model also predicts the nonmonotonicity of innovator's profit in relevant parameters (cost of innovation and probability of success) if imitation is possible.

\(^{33}\)Another difference is that Benoit (1985) considers nonpatentable innovations, whereas the information revelational role of patent suit in my paper applies to patentable innovations.
dynamics is that of a preemption game in which each one strives to be the first entrant. This implies that as the parameter \( \alpha \) changes and crosses the boundary of the set \( \mathcal{I} \), the imitation game undergoes a fundamental change in the nature of entry dynamics. In fact, it was demonstrated that the expected payoff of the incumbent jumps down discontinuously at the left boundary point of \( \mathcal{I} \) as the imitation game is converted from one of waiting to one of preemption; the timing of entry changes from infinite delay to immediate entry. Implications for the interpretation of empirical data on imitation were also discussed.

The model adds an important dimension to the innovation literature by considering the litigation process in the enforcement of patents. However, the model abstracts from many important details of reality, leaving many questions unanswered. I conclude by mentioning several avenues along which the current analysis can be extended.

First of all, I have assumed that there is only one way to design around the patented invention. Realistically, there are many ways to "invent around" with associated probabilities of infringement. The Trade-off facing the imitator will be between a lower probability of infringement vs. a higher cost of inventing around in the choice of imitative research strategy. In other words, the probability of infringement can be reduced by spending more on searching for less obvious ways of inventing around. I can think of the imitators' strategy as a choice of infringement probability. In this case, imitation efforts can create another public good since the benefit of successful imitation is shared by everyone else while the cost is borne by the first imitator. From the perspectives of potential imitators as a team, the noncooperative equilibrium choice of infringement probability will be suboptimally high.

A more serious deficiency of the current paper is that it does not allow the possibility of the out-of-court settlement between the patentee and the accused infringer. In fact, a large proportion of infringement suits are settled out of court in the form of licensing (White and Jacob, 1986). An important question in this case is what kind of
informational implications the out-of-court settlement entails. We expect that the extent of information transmission is greater through trials than through the out-of-court settlement since the latter deprives other potential entrants of the opportunity to uncover critical information regarding the profitability of their own entry [Che and Yi (1990)]. If there is private information held by either disputing party regarding the validity of the patent, litigation behavior in court can have signaling value and potentially influence the terms of licensing as predatory behavior of the incumbent can affect the terms of merger with the entrant [Saloner (1987), Meurer (1989)]. Another discrepancy with reality is that we have assumed a timeless trial. However, protracted legal battles can be strategically used by the incumbent to retard the speed of further entry. On-going uncertainty about the outcome of litigation can leave other potential imitators' entry decisions in limbo, thereby allowing the incumbent extra time to come down along the learning curve.

Finally, my analysis has been limited to the post-innovation incentive to imitate. It is important to embed the analysis in the overall innovation game. For instance, it is not an unreasonable assumption that the participation in the race can reduce the cost of imitation when the innovation race is lost. Then, the progress made by the losers in the innovation race can position them asymmetrically as potential imitators in the imitation game. A full analysis of this possibility awaits future research. I believe, however, that none of the extensions mentioned above will alter the basic intuition of the paper.

---

34 Friendly settlement of law suits between rivals may induce inherently invalid patents to remain in effect to the date of expiration, resulting in restraint of trade.
35 Burns (1986) estimates that predatory pricing significantly reduced the acquisition costs of American Tobacco Company both for victims of predation and, through reputation effects, for competitors who sold peacefully.
36 Levin et al. (1987) report that the effectiveness of lead time and learning curve advantages was consistently rated high by high-level R&D managers among alternative means of appropriating the returns from R&D.
References


Che, Yeon Koo and Yi, Jong Goo, "Litigation with Multiple Plaintiffs: the Case of Effort Externality," mimeo., 1990.


1993-94 Discussion Paper Series
Department of Economics
Columbia University
420 W. 118 St., Room 1022
New York, N.Y., 10027
Librarian: Angie Ng

The following papers are published in the 1993-94 Columbia University Discussion Paper series which runs from November 1 to October 31. Domestic orders for discussion papers are available for purchase at $5.00 (U.S.) each and $140.00 (U.S.) for the series. Foreign orders cost $8.00 (U.S.) for individual paper and $185.00 for the series. To order discussion papers, please send your check or money order payable to Department of Economics, Columbia University to the above address. Please be sure to include the series number for the paper when you place an order.

671. Investment in U.S. Education and Training
Jacob Mincer (Nov. 1993)

672. Freer Trade and the Wages of the Unskilled: Is Marx Striking Again?
Jagdish Bhagwati and Vivek Dehejia

673. Employer Size and Labor Turnover
Todd Idson

674. Less Crime May Be Worse
Brendan O'Flaherty

675. Team Production Effects on Earnings
Todd Idson

David Bloom and Gilles Grenier

677. The Impact of Performance Incentives on Providing Job Training to the Poor: The Job Training to the Poor: The Job Training Partnership Act (JTPA)
Michael Cragg

678. The Demands to Reduce Domestic Diversity among Trading Nations
Jagdish Bhagwati

679. Mass Layoffs and Unemployment
Andrew Caplin and John Leahy
680. The Economics of Adjustment
   Andrew Caplin and John Leahy

681. Miracle on Sixth Avenue: Information Externalities and Search
   Andrew Caplin and John Leahy

682. Arbitrage, Gains from Trade and Social Diversity: A Unified Perspective on
   Resource Allocation
   Graciela Chichilnisky

683. Who should abate carbon emissions?
   Graciela Chichilnisky, Geoffrey Heal

684. Believing in Multiple Equilibria
   Graciela Chichilnisky

685. Limited Arbitrage, Gains from Trade and Arrow’s Theorem
   Graciela Chichilnisky

686. International Emission Permits: Equity and Efficiency
   Graciela Chichilnisky, Geoffrey Heal and David Starrett

687. Do Vehicle Emissions Testing Program Improve Air Quality?
   Matthew Kahn

688. Sources of Real Exchange Rate Fluctuations: How Important Are Nominal Shocks?
   Richard Clarida and Jordi Gali

689. Modeling Soviet Agriculture for Assessing Command Economy Policies
   Padma Desai and Balbir Sihag

690. The Changing Labor Market Position of Canadian Immigrants
   David Bloom, Gilles Grenier and Morley Gunderson

691. Herd Behavior, the "Penguin Effect", and the Suppression of
   Informational Diffusion: An Analysis of Informational Externalities
   and Payoff Interdependency
   Jay Pil Choi

692. Shock Therapy and Russia: Was It Tried? Why Did It Fail? What Did It
   Do? What Now?
   Padma Desai
693. Changes in the Structure of Family Income Inequality in the United States and Other Industrial Nations during the 1980s
McKinley L. Blackburn and David E. Bloom

Pravin Krishna and Jagdish Bhagwati

695. The Effect of Household Characteristics on Household-Specific Inflation Rates: An Application to Trends in Child Poverty and Educational Real Wage Differentials
Todd Idson and Cynthia Miller

Jagdish Bhagwati

697. Intraindustry Trade: Issues and Theory
Jagdish Bhagwati and Donald R. Davis

698. A Characterization of Cointegration
Phoebus Dhrymes

699. The Production of Human Capital and the Lifecycle of Earnings: Variation on a Theme
Jacob Mincer

700. The Philosophy of Locational Competition
Ronald Findlay

701. Size, Sunk Costs, and Judge Bowker's Objection to Free Trade
John McLaren

702. Identification and Kullback Information in the GLSEM
Phoebus Dhrymes

703. Patent Litigation as an Information Transmission Mechanism
Jay Pil Choi

704. On the Meaning of Certain Cointegration Tests
Phoebus J. Dhrymes