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THREE ESSAYS ON FIRM STRATEGY AND PUBLIC POLICY

By

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ABSTRACT

THREE ESSAYS ON FIRM STRATEGY AND PUBLIC POLICY

By

Byung-Cheol Kim

Firms in oligopoly can take various actions for strategic reasons. Three chapters in this dissertation respectively address three different topics of consumer information sharing, preliminary injunction and tying. I am particularly interested in studying strategic incentives to such firms' behaviors, market outcome, welfare effect, and implications on public policies.

In the first chapter, I study oligopolistic firms' incentives to share customer information about past purchase history in a situation where firms are uncertain about whether a particular consumer considers the product offerings complements or substitutes. I show that both the incentives to share customer information and its effects on consumers depend crucially on the relative magnitudes of the prices that would prevail in the complementary and substitute markets if consumers were fully segmented according to their perceptions. This chapter has important implications for merger analysis in which the primary motive for merger is the acquisition of another firm's customer lists. I also find that the informational regime firms reside in can have an influence upon the choice of product differentiation. Additionally, my analysis suggests a new role of middlemen as information aggregators.

The second chapter in this dissertation offers a model of preliminary injunctions in the context of antitrust litigations. I study the role of preliminary injunctions as a noisy

information message service in addition to its role of the channel to save a plaintiff's irreparable harms. Interestingly, I find both cases such that either the plaintiff with a high damage or the one with a low damage moves for preliminary injunctive reliefs as equilibrium phenomena. I not only analyze the decision-makings about the motion for injunction, optimal settlement offers and litigation/settlement, but also discuss various issues associated with preliminary injunctions based on my model.

In the third chapter, I study a new rationale for the tying practice between complementary goods in the presence of switching costs. I find that the monopolist may strategically commit to tying in order to capture the dynamic rents associated with those who have relatively high switching costs, especially if the monopolist has an inferior complementary product to the rival firm's complementary one. I also show that the monopolist's tying may decrease both consumer surplus and social welfare, because switching costs are endogenously incurred and the consumers end up using an inferior good.

To my wife, Sangeun Lee, and my parents
for their love, patience, prayer and support.

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Chapter 1. Customer Information Sharing: Strategic Incentives and New Implications

In this paper, we study oligopolistic firms' incentives to share customer information about past purchase history in a situation where firms are uncertain about whether a particular consumer considers the product offerings complements or substitutes. We show that both the incentives to share customer information and its effects on consumers depend crucially on the relative magnitudes of the prices that would prevail in the complementary and substitute markets if consumers were fully segmented according to their preferences. This paper has an important implication for merger analysis when the primary motive for merger is the acquisition of another firm's customer lists. We also find that the informational regime firms reside in can have an influence upon the choice of product differentiation. Additionally, our analysis suggests a new role of middlemen as information aggregators.

1 Introduction

In this paper we study oligopolistic firms' incentives to share customer information about past purchase history. More specifically, we consider a situation in which the relationship (i.e., the degree of substitutability or complementarity) between the product offerings by oligopolistic firms is customer-specific, private information unknown to the firms. Goods are substitutes for some customers and complements for others. The examples abound. Air travel and rental car service, for instance, can be complements for some travelers who use both modes of transportation in the same trip.

However, they can be substitutes to others, especially for short- to medium-distance travels.[1] Another example is the relationship between printed versions of novels and motion picture adaptations. For some consumers they can be competing products whereas for other consumers they can be complements.[2]

The sharing of customer-specific transaction records allows the firms to update information about a particular consumer's preference towards the products. In such a setup, we analyze the impact of customer information sharing on market competition and the firms' incentives to share information. These questions are especially relevant in electronic commerce where consumers' records of previous purchases can be easily traced and stored by electronic "fingerprint."[3] Our study also has important implications for merger analysis in which the primary motive for merger is the acquisition of another firm's customer lists.

We consider a simple two-period model to address the issues related to interfirm information sharing. Each firm collects information about its own sales record. As a result, at the end of the first period, each firm acquires information concerning whether or not a particular individual has bought a unit of its own product through its first-period marketing. In the absence of information sharing, however, each firm remains uncertain over whether the customer has also bought a unit of the other firm's

[1] More people rent a car and drive to their destinations as airport security inspections have become more of a hassle following the 9/11 terrorist attack.

[2] Motion picture versions were initially thought to be competing against printed versions when they were first introduced. However, film adaptations and printed novels are widely perceived to be complements now. See Gentzkow (2007) for more examples.

[3] E-commerce activities have rapidly grown and play an increasingly important role for the U.S. economy. According to the most recent data from the Census Bureau of the Department of Commerce, total e-commerce sales for 2006 were estimated at $108.7 billion, accounting for 2.8 percent of total sales in 2006. The figure for e-commerce sales is an increase of 23.5 percent from 2005. In contrast, total retail sales in 2006 increased only 5.8 percent from 2005.

product. In contrast, with information sharing each firm can learn the complete history of the past transaction record of a specific consumer. The aggregation of customer lists allows the firms to infer whether that customer considers the goods substitutes or complements. We analyze how this customer-specific information concerning the relationship of the two products can be used as a basis for price discrimination in the second period.

The analysis of the effects of information sharing on market competition and each firm's incentives to share information with other firms is complicated because the other firms, with whom the customer information might be shared, could be potential rivals in the substitute market and at the same time partners in the complementary market, depending on consumer types. We show that the incentives to share customer information depend crucially on the relative magnitudes of the prices that would prevail in the complement and substitute markets if consumers were fully segmented according to their preferences for the two products. The intuition for this result is as follows. With information sharing, the firms can distinguish consumers who consider the two products complementary from those who consider them substitutes. As a result, they charge different prices depending on consumer types. For consumers who consider the two products complementary, the two firms charge *too much* overall with information sharing. This is due to the Cournot effect in the complementary monopoly problem. The two firms could have obtained a higher profit by cooperatively lowering their individual prices as if they were a merged monopolist. This inefficiency in a noncooperative equilibrium occurs because the two firms do not internalize the interdependence of their pricing strategies. In contrast, for consumers who consider the two products substitutes, the two firms charge too little with information sharing from the perspectives of joint profit maximization due to competition. Without information sharing, each firm who maximizes its expected profit must post a single price which is an (weighted) average of the prices that would have prevailed under information sharing. Suppose that the price for consumers who regard the products as substitutes is lower than that for consumers who consider them complementary under information sharing. Then, the average price mitigates the externality problem in the complementary markets. Additionally, the average pricing relaxes competition in the substitute market enabling them to extract more rents. On both accounts, the firms are better off without information sharing. Of course, if we consider the other case where the full information price in the substitute market is higher than that in the complementary market, information sharing leads to a higher profit in the opposite manner.

The effect of information sharing on consumers also differs depending on the relative magnitudes of full information prices in the complementary and substitute markets and across consumer types. For instance, when the full information price in the substitute market is higher than that in the complementary market, information sharing benefits consumers who regard the two products as complements but hurts those who regard them as substitutes. The impact on consumers is reversed if the full information price in the substitute market is lower than that in the complementary market.

The intuition for our main result also provides a new perspective on the determinants of the degree of product differentiation. Firms potentially face a trade-off between a higher profit associated with highly differentiated goods in the substitute market and the potentially aggravated externality problem in the complementary market when information sharing is banned and the firms are forced to charge one price. This implies that the informational regime firms reside in can have an influence upon the choice of product differentiation.

Our basic model analyzes *direct* exchange of customer information between the firms in the market. Our analysis, however, also has implications for other channels of information aggregation. For instance, our analysis suggests a new role of middlemen – the intermediaries between the seller of a good and its potential buyers – as information aggregators. If the direct exchange of customer information between firms is banned due to either privacy concerns or antitrust reasons, the presence of middlemen *such as Amazon, eBay, Google check-out* can benefit firms and some consumers by functioning as lawful institutions in the facilitation of information aggregation. To the best of our knowledge, this role of middlemen has not yet been addressed.[4]

In addition, our model provides a new rationale for merger in which the primary motive for merger is the acquisition of another firm's customer lists rather than its real assets.[5] Even if a merger does not lead to a higher market-power or cost-synergies by eliminating some duplications in production or marketing, it still can be a profitable strategy only due to the value of customer lists held by its merger partner. The recent

[4]See Rubinstein and Wolinsky (1987) and Yavas (1994) for an analysis of middlemen as an intermediary to reduce transaction costs in bilateral search economies with trade frictions.

[5]Customer information is one of intangible assets acquired through a merger, according to 'Antitrust division policy guide to merger remedies (October 2004)' by U.S. Department of Justice, Antitrust division (http://www.usdoj.gov/atr/public/guidelines/205108.htm). However, there is no formal analysis that recognizes customer list as a primary driver of merger.

acquisition of CDNow by Bertelsmann is a case in point. CDNow, a web-based startup company founded in February 1994, publicly announced that its cash assets were only sufficient to sustain another six months of operations in March 2000. Its major asset was its customer list of 3.29 million in June 2000; it did not have substantial physical assets like other online retailers. In July 2000, however, Bertelsmann acquired CDNow for $117 million in an all-cash deal appreciating the value of CDNow's customer base.[6] Our study can offer a theoretical foundation for the M&A of a firm whose only asset is its customer lists in the context of behavior-based price discrimination.[7]

Our paper is related to two strands of literature: information sharing and behavior-based price discrimination. There is by now an extensive literature that studies the issue of information sharing between oligopolistic firms concerning market demand and production cost. For example, Clarke (1983), Crawford and Sobel (1982), Gal-Or (1984, 1985), and Novshek and Sonnenschein (1982) address the incentives to share private information about uncertain market demand that is common to every firm. Fried (1984), Shapiro (1986) and Armantier and Richard (2003) analyze incentives to exchange information about private cost that is idiosyncratic to each firm.[8] Our paper, in contrast, considers the sharing of customer-specific transaction records and

[6]See Gupta and Lehmann (2003) for more details about CDNow case and the value of customers.

[7]See Banal-Estanol (2007) for an analysis of horizontal mergers that explicitly takes into account sharing of private information of merging parties. However, the nature of private information is about uncertain demands or costs as in the existing information sharing literature.

[8]There have also been studies for the incentives to share credit information among financial intermediaries in the finance literature. Bouckaert and Degryse (2005) and Gehrig and Stenbacka (2001), for instance, analyze the issue of credit information sharing in the context of entry-deterrence or as a collusive device.

its implications for dynamic price discrimination.[9]

As in our paper, the literature on behavior-based price discrimination considers how the information gleaned from past sales record can reveal customer-specific preferences which can be used as a basis to practice personalized pricing and its impact on market outcomes such as consumer- and producer surplus.[10] Acquisti and Varian (2005) consider a setting in which rational consumers with constant valuations for the goods purchase from a monopoly merchant who can commit to a pricing policy. They show that although it is feasible to price so as to distinguish high-value and low-value consumers from advances in information technology, the merchant will never find it optimal to do so, echoing the results from the prior literature on dynamic price discrimination.[11] They then extend their model to allow the seller to offer enhanced services to previous customers and find that conditioning prices on purchase history can be profitable.[12] Chen (1997), Fudenberg and Tirole (2000), and Taylor (2003), in contrast, consider a duopolistic setting with competition to analyze the implications of price discrimination based on purchase history. Unlike previous work on behavior-based price discrimination, our innovation in this paper is to allow the possibility that product offerings can be either substitutes or complements. The existing literature typically assumes the relationship between products is one of the two types and is known to the firms that make strategic choices. One notable excep-

[9]See Liu and Serfes (forthcoming) for several real practices of companies who participate in selling and trading of customer information.

[10]For an excellent survey of the literature on behavior-based price discrimination, see Fudenberg and Villas-Boas (forthcoming).

[11]This is due to strategic demand reduction by sophisticated consumers. See Stokey (1979).

[12]For a related issue of consumer privacy, see Taylor (2004) and Calzolari and Pavan (2005).

tion is Gentzkow (2007) who explicitly analyzes the possibility that product offerings can be either substitutes or complements as in our paper. Even though our paper and Gentzkow's share the same basic premise, the focus of his paper is very different from ours. He is mainly concerned with developing a new econometric technique to estimate the impact of new goods that accounts for the possibility that the new goods can be complements to the existing goods.

Liu and Serfes (forthcoming) is closest to our paper in that it also takes a step in the direction of examining the firms' incentives to share their customer-specific information with other firms. They consider a Hotelling model in which each firm can collect detailed customer information about their own customers, indexed by a precise location in the Hotelling model. With information sharing, firms can practice perfect price discrimination against not only their own previous customers, but also the consumers who bought from rival firms. However, there is one key difference in the man qualitative results. In Liu and Serfes, neither firm finds it profitable to share information when firms have equal customer bases. The incentive to share information arises only when there is enough *asymmetry* in their market shares. In such a case, the sharing of information takes the form of one-way transaction in which the firm with the smaller customer base sells its information to the firm with the larger customer base while the "big" firm never has incentives to sell its information to the smaller rival firm. In our model, however, the information sharing takes place between *symmetrically* positioned firms. In addition, the relationship between the two firms is always competitive and the pooling of information does not reveal any information about the relationship (complements or substitutes) between the two products, which is a key aspect in our framework. Liu and Serfes and our paper complement each other in that we explore the incentives to share information in the firms' quest for qualitative improvement of information, while they study the same issue from the firms' strategic incentives to enlarge the information base.

The remainder of the paper is organized as follows. Section 2 describes the basic model. In section 3, we derive the market equilibrium in the presence of information sharing and analyze how the information sharing can be used as a basis for behavior-based price discrimination. Section 4 analyzes the market equilibrium in the absence of information sharing. In section 5, we analyze incentives to share information and the impact of information sharing on consumer welfare. In section 6, we discuss a couple of interesting implications that can be drawn from our simple framework such as the role of middlemen and the relationship between information sharing and product differentiation. In section 7, we explore some possible extensions and check the robustness of our main results by relaxing some of our initial assumptions. Section 8 concludes. The proofs for propositions are relegated to Appendix A. An explicit analysis of the example with uniform distribution is contained in Appendix B.

2 The Basic Model

Consider two goods, A and B, respectively produced by firm A and firm B, that consumers may regard either as complements or as substitutes depending on their preferences. For simplicity and analytical tractability, we consider only two distinct groups of consumers: one group of consumers in proportion λ, called group C, regard the two goods as complements and the other group of consumers in proportion $(1-\lambda)$, called group S, consider them as substitutes. The proportion λ is common knowledge, where $\lambda \in (0,1)$.

The model is a two-period setting in which each consumer purchases at most one unit of each good per period. Each firm is able to keep track of individual transaction records of its customers. In particular, this assumption implies that at the end of the first period, each firm knows whether or not a particular consumer has bought a unit of its own good in the first period. This information allows each firm to engage in behavior-based price discrimination in the second period, that is, charging different prices to consumers with different purchase histories.

Let us denote a consumer's purchase decision by (a, b), where a and b respectively refer to decisions concerning products A and B with 1 representing the *purchase* of the relevant product and 0 representing *no purchase.* A consumer's purchase history in the first period then can be described by an element of a set $H = \{(0,0),(1,0),(0,1),(1,1)\}$. For instance, a consumer with a purchase history $(1,0)$ is the one who purchased product A, but not B in the first period.

We consider two potential information regimes. Without any sharing of customer information at the end of the first period, each firm's knowledge about each consumer's purchase history is limited to its own product. Each consumer's past purchase history concerning the other firm's product is in the dark. With partial knowledge of customer purchase history, each firm's information set is coarser than the set of potential history H. We denote firm A's information set concerning a particular consumer by $\widetilde{I}_A = \{(0,\phi),\ (1,\phi)\}$, where ϕ stands for *non-availability of information.*[13] Similarly, firm B's information set can be represented by $\widetilde{I}_B = \{(\phi,0),\ (\phi,1)\}$. If the two firms exchange customer lists at the end of the first period, both firms know the complete history of each consumer's purchase. In this case, the information set of both firms concerning each consumer is the same as the set of potential history for each consumer, that is, $I_A = I_B = H = \{(0,0),(1,0),(0,1),(1,1)\}$.

Within each group of consumers (C or S), we assume heterogeneity of preferences. More specifically, a consumer of type θ in group C has the following net surpluses from each possible choices in each period.

$$u^C(p_A, p_B; \theta) = \begin{cases} \theta - p_A - p_B & \text{both } A \text{ and } B \text{ are purchased} \\ -p_i & \text{if} \quad \text{only good } i \text{ is purchased} \\ 0 & \text{neither one is purchased} \end{cases} \tag{1}$$

where p_i denotes firm i's price for $i = A$, B and the superscript C indicates that the consumer belongs to group C. The type parameter θ represents the consumer's reservation value for the pair of products viewed as complementary. We assume that θ is distributed over an interval $[\underline{\theta},\ \overline{\theta}]$ with distribution and density functions of $F(\theta)$ and $f(\theta)$, respectively, where with $0 \leq \underline{\theta} \leq \overline{\theta}$. The consumer in group C does not derive any benefit from consuming only one good, thus earning the utility of $-p_i$ when only one good is purchased. The utility from buying neither A nor B is normalized to zero.

[13]Variables associated with the regime of no information sharing are denoted with a tilde.

On the other hand, the consumers in group S are heterogeneous with respect to their relative preferences for B over A. We capture this feature with the parameter γ. More precisely, we assume that consumer type γ's reservation values for goods A and B are given by $v_A = v - \frac{\gamma}{2}$ and $v_B = v + \frac{\gamma}{2}$, respectively. That is, $v_B = v_A + \gamma$ for $\gamma \in [\underline{\gamma}, \overline{\gamma}]$ with a positive value of γ indicating that the consumer prefers good B to good A.[14] Let $G(\gamma)$ and $g(\gamma)$ denote the distribution and the density of γ, respectively. For simplicity, we also assume that G is symmetric about zero, with $\overline{\gamma} = -\underline{\gamma} > 0$. A consumer in group S has the surplus of each possible choice as follows.

$$u^S(p_A, p_B; \gamma) = \begin{cases} \max\{v_A, v_B\} - p_A - p_B & \text{both } A \text{ and } B \text{ are purchased} \\ v_i - p_i \quad \text{if} & \text{only good } i \text{ is purchased} \\ 0 & \text{neither } A \text{ nor } B \text{ is purchased} \end{cases} \quad (2)$$

where the superscript S indicates that the consumer belong to group S. The consumer in group S, who regards two goods as substitutes, earns the net surplus of $\max\{v_A, v_B\} - p_A - p_B$ from buying both A and B; the utility of buying only good i is set to be $v_i - p_i$. We assume that v is high enough to ensure that each consumer in this group buys at least one unit of either A or B.[15] The utility from no purchase is set to zero.

Finally, we assume that a consumer belongs to the same group over the two

[14] The same framework for the horizontal product differentiation is used in Fudenberg and Tirole (2000).

[15] This model specification is somewhat restrictive in that we do not allow the consumers in group S to opt for no purchase. The qualitative results of this paper, however, are robust to the relaxation of this assumption, which will be discussed in section 7.

periods, that is, the group characteristics is a fixed trait. However, we assume that the parameters θ and γ are independently and randomly drawn from their distributions in each period. This allows us to isolate the strategic incentives to share information concerning consumers' preferences towards the products without being concerned with the issue of customer poaching and/or personalized pricing within the same group, which has been extensively studied in the literature [see Fudenberg and Tirole (2000), Taylor (2003, 2004), and Acquisti and Varian (2005)]. Both firms have the same constant unit-cost of production, d. Finally, F and G satisfy the monotone hazard rate (MHR) condition: $f(\theta)/[1 - F(\theta)]$ and $g(\gamma)/[1 - G(\gamma)]$ are strictly increasing in θ and γ, respectively,[16] which ensures the first-order condition for optimization to be sufficient for the second-order condition.

3 Sharing of Customer Information

If firms exchange their customer lists acquired through the first-period marketing, they are able to draw inferences about customers' preferences towards the two products. This implies that they are able to charge different prices depending on whether consumers consider the two products as substitutes or complements in the second-period. Consequently, the two groups of consumers are segmented and each firm plays noncooperative pricing games in two separate markets.

[16] Roughly speaking, this condition means that the density functions f and g do not grow too fast, which is satisfied with most of the well-known distribution functions including the uniform, exponential, and normal distributions.

3.1 The market for group C consumers

We first consider the consumers who consider the two goods complementary. It is a standard result that the two firms acting independently charge *too much* overall from the collective viewpoint of the firms. This is due to the externality problem, noted by Cournot(1838), with two distinct firms acting independently as a monopolist of each complementary good. The two firms could have obtained a higher profit if they had cooperatively lowered their individual prices as if they were a merged monopolist. This inefficiency arises because the independent firms do not internalize the interdependence of their pricing strategies, whereas the merged firm does.[17] Consumer surplus also increases with a merged monopolist due to a lowered total price for the goods.[18]

Let us briefly show that this classic result applies to the market for group C consumers.[19] The optimal decision for consumers in group C can be characterized by a simple cut-off rule:

$$\begin{cases} \text{Buy both A and B} & \text{if} \quad \theta \geq \theta^* \\ \text{Buy neither A nor B} & \phantom{\text{if}} \quad \theta < \theta^* \end{cases} \tag{3}$$

where $\theta^* \equiv p_A^C + p_B^C$ denotes the threshold consumer who is indifferent between the

[17]This problem occurs as a dual form in the standard Cournot quantity-setting with substitutes, which Sonnenschein (1968) noted.

[18]Clearly, this case is still not the first-best outcome: the price with the integrated monopolist is still above the total marginal cost.

[19]In a similar vein, an integrated upstream licensor holding patents for several complementary technologies can charge a cheaper total price compared to the case of separate patent holders for each innovation. This suggests a welfare-enhancing role for patent pools in case of complementary technologies. See Lerner and Tirole (2004) for a formal discussion of this issue.

two choices. Those with $\theta \geq \theta^*$ buy both goods since their willingness to pay for a pair of complements is greater than or equal to the total price for the two goods, while those with $\theta < \theta^*$ buy neither due to a relatively low reservation value for consuming the two complementary goods. The demand for each good thus is given by $1 - F(\theta^*)$. Firm i's profit maximization problem can be written as

$$\underset{p_i^C}{Max}\ \pi_i^C = (p_i^C - d)\left[1 - F(p_i^C + p_j^C)\right]. \tag{4}$$

The first-order condition with respect to each firm's full information price, p_i^C, yields

$$\left[1 - F(p_i^C + p_j^C)\right] - (p_i^C - d) f(p_i^C + p_j^C) = 0 \tag{5}$$

for $i = A, B$ and $i \neq j$. The two first-order conditions implicitly define each firm's best-response function of which slope is smaller than negative one. This implies that two responses meet each other at most once where we find a unique, stable, symmetric Nash equilibrium that is implicitly defined by

$$p^C = d + \frac{1 - F(2p^C)}{f(2p^C)}. \tag{6}$$

On the other hand, an integrated monopolist would have solved the following profit maximization problem

$$\underset{P^m}{Max}\ \pi^m = (P^m - 2d)[1 - F(P^m)] \tag{7}$$

where P^m denotes the total price for a pair of the two goods under monopoly. The first-order condition for this problem yields

$$[1 - F(P^m)] - (P^m - 2d)f(P^m) = 0. \tag{8}$$

and thus

$$P^m = 2d + \frac{1 - F(P^m)}{f(P^m)}. \tag{9}$$

By comparing (5) and (8), we find that the left-hand-side of (8) evaluated at the price of $P^m = 2p^C$ becomes negative, which implies that the integrated monopolist charges less than the sum of prices independent firms would charge in duopoly and that the profit associated with the monopoly case is larger than the sum of two firms' profits under duopoly.[20] Figure 1-1 shows the relationship of p^C and p^m graphically.

[20]Assuming a uniform distribution of θ on [0, 1] and $d = 0$, the joint-profit maximizing price for a pair of complements is equal to $\frac{1}{2}$, and thus one firm is required to charge the price of $\frac{1}{4}$ and gets the profit of $\frac{1}{8}$. However, with two firms non-cooperatively competiing, the equilibrium price that each firm charges is $\frac{1}{3}$ and its profit becomes $\frac{1}{9}$.

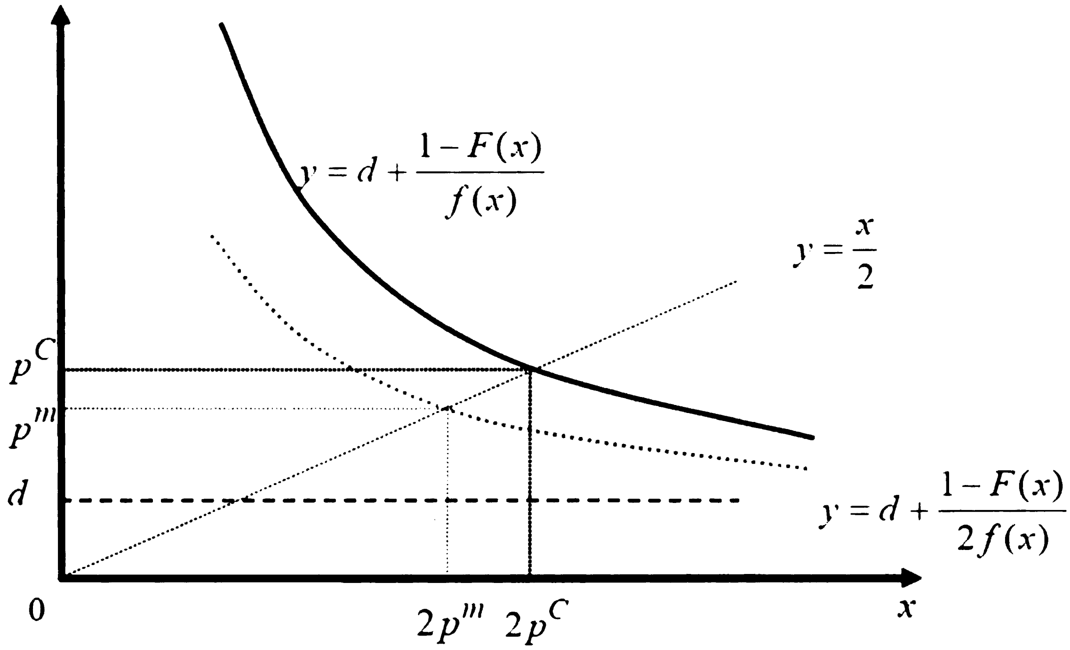

Figure 1-1. The externality problem in the complementary market

3.2 The market for group S consumers

A consumer who regards the two goods as substitutes buys a unit of either A or B.[21] The consumer will compare the net surplus of each choice and choose the good that yields a higher surplus. The optimal decision rule is given by

$$\begin{cases} \text{choose A over B} & \text{if} \quad v_A - p_A^S \geq v_B - p_B^S \quad \Leftrightarrow \quad \gamma \leq \gamma^* \\ \text{choose B over A} & \quad v_A - p_A^S < v_B - p_B^S \quad\quad\; \gamma > \gamma^* \end{cases} \tag{10}$$

[21] In the Appendix A. we show this claim rigorously.

where $\gamma^* \equiv p_B^S - p_A^S$.[22] Since the demand for firm A is $G(\gamma^*)$, the optimization problem for firm A in the market of substitutes is given by

$$\underset{p_A^S}{Max}\ \pi_A^S = (p_A^S - d)G(p_B^S - p_A^S). \tag{11}$$

The first-order condition for this problem yields

$$\partial\pi_A^S/\partial p_A^S = G(p_B^S - p_A^S) - (p_A^S - d)g(p_B^S - p_A^S) = 0. \tag{12}$$

An increment in the price of good A leads to an increase in the mark-up for the inframarginal consumers of good A, which is represented by the first term $G(p_B^S - p_A^S)$. However, firm A loses some consumers at the margin to firm B because of the increment in p_A^S, which is captured by the second term, $-(p_A^S - d)g(p_B^S - p_A^S)$. The best-response of p_A to a given p_B describes the firm A's optimal price with this trade-off considered. In a similar manner, we can derive the best-response function of firm B.

The equilibrium price is uniquely determined because the best responses have positive slopes that is less than one. The symmetric equilibrium price of $p_A^S = p_A^S = p^S$ is given by

$$p^S = d + \frac{1}{2g(0)}. \tag{13}$$

The mark-up in the market of substitutes is represented by $1/2g(0)$. Given the as-

[22]This tie-breaking rule is inconsequential because here we consider a continuum of consumers so that the point mass of critical consumers is zero.

sumption that γ is distributed symmetrically around zero, a larger value $g(0)$ indicates that consumers' preferences are more concentrated around zero and they have less diverse preferences for the goods. We thus can interpret the reciprocal of $2g(0)$ as the degree of heterogeneity in consumers' relative preferences towards the two substitute products, which plays a similar role of the transportation cost (or product differentiation) parameter in the standard Hotelling model.

The following lemma summarizes and compares the two equilibrium prices for each group, p^C and p^S.

Lemma 1 *When each consumer's group identity (C or S) is revealed to the two firms via information sharing, the full information price for consumers in group C is characterized by* $p^C = d + [1 - F(2p^C)]/f(2p^C)$ *and the full information price for consumers in group S is given by* $p^S = d + \frac{1}{2g(0)}$. *Therefore, the relative magnitudes of these two prices depend on the distributions F and G. In particular, if the two goods are perceived to be highly differentiated for group S consumers (i.e.,* $g(0)$ *is low),* p^S *will be higher than* p^C *with all other things being equal.*

Let π^C and π^S denote the equilibrium profits in markets for consumer groups C and S, respectively. With information sharing, each firm's second-period total profit from both markets is given by

$$\Pi^2 = \lambda\pi^C + (1-\lambda)\pi^S. \tag{14}$$

4 No Sharing of Customer Information

4.1 Bayesian updating about group identity

If firms do not exchange their customer lists, each firm only knows whether a particular consumer is a newcomer or a returning customer. However, each firm is unaware of whether a consumer has bought from the other firm or not. When a consumer is a newcomer, not in its customer list at the beginning of the second-period, the seller can think of two possibilities: the consumer actually considered the two goods complementary but did not buy either good because of a relatively low willingness to pay for a pair of goods, or the consumer regarded the goods as substitutes and bought a good from the other firm in the previous period. On the other hand, facing a returning consumer already registered in its present customer list, the seller also can think of two possibilities: the consumer who considered the goods complements and bought both goods, or the consumer considering the two goods substitutes chose its own product over the rival's.

Each firm will update its prior beliefs about the group identity of a particular consumer, based on his/her past purchase history. Following a Bayesian updating process, the posterior beliefs of firm A can be derived as follows.

$$\begin{aligned} \lambda_A^0 &\equiv \Pr[C|(0,\phi)] = \frac{\lambda F(\hat{\theta})}{\lambda F(\hat{\theta}) + (1-\lambda)(1-G(\hat{\gamma}))} \\ \lambda_A^1 &\equiv \Pr[C|(1,\phi)] = \frac{\lambda(1-F(\hat{\theta}))}{\lambda(1-F(\hat{\theta})) + (1-\lambda)G(\hat{\gamma})} \end{aligned} \tag{15}$$

where λ_A^0 and λ_A^1 denote firm A's conditional probability that a newcomer and a returning consumer would consider the two goods complementary, respectively, and $\hat{\theta}$ and $\hat{\gamma}$ denote the first-period thresholds for critical consumers. Similarly, firm B's posteriors are given as

$$\begin{aligned}
\lambda_B^0 &\equiv \Pr[C|(\phi,0)] = \frac{\lambda F(\hat{\theta})}{\lambda F(\hat{\theta}) + (1-\lambda)G(\hat{\gamma})} \\
\lambda_B^1 &\equiv \Pr[C|(\phi,1)] = \frac{\lambda(1-F(\hat{\theta}))}{\lambda(1-F(\hat{\theta})) + (1-\lambda)(1-G(\hat{\gamma}))}
\end{aligned} \tag{16}$$

where λ_B^0 and λ_B^1 denote firm B's posteriors that a newcomer and a returning consumer would consider the two goods complementary.

Then, obviously, the posteriors λ_i^0 and λ_i^1 typically differ from the prior λ, unless λ is either 1 or 0, for $i = A$, B. In other words, if there exist consumer heterogeneity with respect to the relationship to the product offerings, firms (sellers) will have different posterior beliefs about the group identify of a particular consumer based on the purchase history. This implies that firms may post different prices to the consumers depending on whether a particular consumer is a newcomer or a returning customer, *even without* customer information sharing. Previous studies found that the discriminatory pricing can be based on the purchase history in the presence of consumer heterogeneity with respect to reservation valuations (Taylor, 2004; Acquisti and Varian, 2005), relative preferences (Fudenberg and Tirole, 2000), or switching costs (Chen, 1997; Gehrig and Stenbacka, 2004). This paper enriches the literature of behavior-based price discrimination by introducing another possible basis for the price discrimination that has yet been addressed, to our best knowledge.

4.2 Price competition in the second period

Let us describe the firm's second-period profit maximization problem without information sharing. Denote p_i^0 and p_i^1 the prices that firm i posts for a newcomer and for a returning customer, respectively. Firm i expects a newcomer to consider the two goods complementary with probability λ_i^0 and thus be also offered the newcomer price from firm j, for $i \neq j$. In contrast, firm i expects the newcomer to regard the goods as substitutes with the remaining probability $1 - \lambda_i^0$ and thus be offered the price for a returning consumer from the other firm, p_j^1. As a result, firm A's profit maximization problem for a newcomer is given by

$$\underset{p_A^0}{Max}\ \pi_A^0 = (p_A^0 - d)\left\{\lambda_A^0[1 - F\left(p_A^0 + p_B^0\right)] + (1 - \lambda_A^0)G\left(p_B^1 - p_A^0\right)\right\}. \tag{17}$$

Similarly, the optimization problem for a returning consumer reads as

$$\underset{p_A^1}{Max}\ \pi_A^1 = (p_A^1 - d)\left\{\lambda_A^1[1 - F\left(p_A^1 + p_B^1\right)] + (1 - \lambda_A^1)G\left(p_B^0 - p_A^1\right)\right\}. \tag{18}$$

We can easily describe firm B's optimization problems as well. With the first-order conditions from these optimization problems, we can derive the symmetric equilibrium prices, $p_A^0 = p_B^0 = p^0$ and $p_A^1 = p_B^1 = p^1$, and the associated equilibrium profits per consumer, π^0 and π^1. Each firm's second-period total profit from two markets without information sharing is given by

$$\widetilde{\Pi}_A^2 = [\lambda F(\hat{\theta}) + (1-\lambda)(1-G(\hat{\gamma}))]\pi^0 + [\lambda(1-F(\hat{\theta})) + (1-\lambda)G(\hat{\gamma})]\pi^1$$
$$\widetilde{\Pi}_B^2 = [\lambda F(\hat{\theta}) + (1-\lambda)G(\hat{\gamma})]\pi^0 + [\lambda(1-F(\hat{\theta})) + (1-\lambda)(1-G(\hat{\gamma}))]\pi^1 \tag{19}$$

where the tilde denotes the case of no information sharing.

Now we are ready to discuss the relationship of the second-period equilibrium prices with and without information sharing. Intuitively, the prices without information sharing, p^0 and p^1, will be located between the full information prices. In the presence of uncertainty about the group identity of a consumer, each firm will post (weighted) average prices of two full information prices in order to maximize its expected profits. This is similar to the fact that the firms with incomplete information about demands or costs must post a weighted average price to maximize their expected profit in either Cournot or Bertrand competition.

Lemma 2 *The equilibrium prices without information sharing are between the full information prices, i.e.,* $\min\{p^C, p^S\} \leq p^0, p^1 \leq \max\{p^C, p^S\}$ *for any* λ, $0 \leq \lambda \leq 1$.

To sum up, if the firms share their customer information, they can charge two distinct full information prices, p^C and p^S, according to the group identity. Without information sharing, the firms post two different prices p^0 and p^1 that are averages of two full information prices based on consumer past purchase history. Therefore, customer information sharing provides a more precise basis for the price discrimination in the second period.

5 Incentives to Share Information and Effects on Consumers

In this section, we analyze the firms' incentives to share their customer information with the other firms. One novel feature in our model is that the firms with whom the customer information might be shared could be potential rivals in the substitutes market and at the same time partners in the complementary markets, depending on consumer types. We also study the effect of information sharing on consumers from an antitrust perspective.

5.1 To share or not

In order to investigate the firms' incentives to share information, we need to compare overall profits over the two periods with and without information sharing, not only because sophisticated consumers may strategically manipulate their demands knowing ex post discriminatory pricing, but also because the firms might adopt strategic pricing in the first period even without information sharing. In this section, let us first study ex post incentives to share information by comparing the second-period profits only, and reserve more discussion about strategic considerations for Section 7.

In the second period, we can think of two distinct cases according to the relative magnitudes of full information prices, p^C and p^S.[23] Let us first consider the case in which the full information price in the substitute market is lower than that of complementary goods, i.e., $p^S < p^C$. Then, no information sharing with the average

[23] If the prices for two groups are identical, i.e., $p^C = p^S$, the issue of information sharing is no longer interesting. Each firm has the same mark-up for both groups. The second-period profits with and without information sharing become identical.

price mitigates the externality problem in the market of complements, as long as p^S is so low that p^0 and p^C are far below the joint-profit maximizing price, p^m. Furthermore, average pricing softens competition in the substitute market where each firm can extract a more rent.[24] On both accounts, the firms are better off without information sharing.

Of course, if we consider the other case where the full information price in the substitute market is higher than that in the market of complements, information sharing leads to a higher profit in the exactly opposite manner: with information sharing, firms can avoid the aggravation of the externality problem in the complementary market and extract more rents from the consumers who consider the goods substitutes.

Proposition 1 *(Incentives to information sharing) If the full information price in the substitute market is lower than that of complementary goods, i.e.,* $p^S < p^C$*, and* p^S *is not so low that* p^0 *and* p^1 *are far below the joint-profit maximizing price,* p^m*, then firms have no incentives to customer information sharing. For the other case of* $p^C < p^S$*, firms can increase their profits with information sharing.*

The above proposition tells us that the incentives to share customer information depend crucially on the relative magnitudes of the prices that would prevail in the complementary and substitute markets if consumers were fully segmented according to their preferences towards the product offerings. If the products are not perceived as

[24] For this argument, we need to assume that those who consider the two goods as substitutes have a sufficiently high level of the intrinsic valuation of consumption, v. If not, the average prices, p^0 and p^1, that are higher than p^S may reduce the demand in the market of substitutes to such an extent that each firm earns a less profit, relative to the full information case.

highly differentiated substitutes to the extent of $p^S < p^C$, it is indeed the *uncertainty* about consumers' preferences that makes the firms better off. As far as a policy implication is concerned, our analysis shows that oligopolistic firms' commitment to no customer information sharing – possibly emphasizing privacy concerns – can arise for a strategic reason. To put it differently, we may view the commitment to no information sharing as a possible device for tacit collusion. Another interesting implication for the policy-makers is that firms may not always get worse off even if information sharing is banned, because for the case of $p^S < p^C$ the firms endogenously will reside in the regime of no information sharing so that the regulation is not binding. Of course, in the other case of $p^S < p^C$, the prohibition of customer information sharing will decrease the firms' profits.

5.2 The effects of information sharing on consumer surplus

We find that the effects of customer information sharing on consumer surplus also depend crucially on the relative magnitudes of the full information prices. If the full information price in the substitute market is lower than that of complementary goods, i.e., $p^S < p^C$, the consumers who consider the two goods complementary become beneficiaries of no sharing of customer information. This is because they pay less for a pair of both goods, relative to the full information case. In contrast, no information sharing hurts those who regard the goods as substitutes because the average prices, p^0 and p^1, are higher than the full information price, p^S. For the other case of $p^C < p^S$, those in group C prefer information sharing while those in group S do not.

Proposition 2 *(Consumer surplus) If the full information price in the substitute market is lower than that of complementary goods, i.e.,* $p^S < p^C$*, customer information sharing increases the surplus of those who regard the goods as substitutes. In contrast, the consumers who regard the goods as complements prefer no sharing of their past transactions data. For the other case of* $p^C < p^S$*, those in group* C *prefer information sharing while those in group* S *get better off under no sharing regime.*

Our analysis shows that there exist conflicts of interests between different groups of consumers. Some consumers resist customer information sharing due to its role in price discrimination, aside from privacy concerns, while others want their purchase history to be shared between the firms to get a better deal. Therefore, we cannot say that information sharing always makes all consumers worse off or better off in the presence of uncertainty about consumers' preferences. Therefore, a ban on information sharing due to antitrust concerns can be counterproductive.

6 Implications of the Model

Our innovation in this paper is to allow the possibility that product offerings can be either substitutes or complements across consumers. Fortunately, this novelty also provides interesting implications beyond the issues directly related to customer-specific information exchange. The new insights suggested in this section are to wait for further research; here we briefly provide the intuitive explanations.

6.1 Product differentiation and informational regime

The intuition for our main result provides a new perspective on the determinants of the degree of product differentiation. The standard result in the literature is that firms typically realize higher profits from more differentiated products when they compete with substitutes, because firms can mitigate competition by differentiating their product from those of their rivals.[25] When products are complementary for some consumers, however, there exists an opposing force that potentially reduces the incentives for higher product differentiation. If the full information price in the substitute market is higher than that of the complementary market and information sharing is prohibited, then greater product differentiation aggravate the externality problem in the complementary market because it causes the prices without information sharing to deviate further away from the optimum. As a result, firms face a trade-off between higher profits associated with highly differentiated goods in the substitute market and the loss of profits in the complementary market from the aggravated externality problem. This implies that the informational regime firms reside in can influence their choice of product differentiation.[26]

[25] d'Aspremont, Gabszewicz, and Thisse (1979) show this result in the Hotelling model where firms choose their locations at two ends of market segment, which characterizes the well-known "maximum differentiation" principle.

[26] Bester (1998) shows that consumers' imperfect information about the quality of goods may reduce the firms' incentives for product differentiation. Interestingly, our model find the source of less differentiation in the firms' uncertainty about consumer complementarity.

6.2 Middlemen as information aggregators

The model in this paper analyzes direct exchange of customer information between firms in the market. Our analysis, however, also has interesting implications for other channels of information aggregation. For example, this paper suggests a new role for middlemen[27] – the intermediaries between the seller of a good and its potential buyers – as information aggregators. If the direct exchange of customer information between firms is prohibited due to privacy concerns or antitrust regulation, the presence of middlemen such as internet retailers Amazon, eBay, Google check-out can benefit firms and consumers by functioning as lawful institutions that facilitate information aggregation. This role of middlemen, to our best knowledge, has not been addressed yet.

Middlemen are expected to play various roles in the markets with trade frictions and/or imperfect information. They can lower transaction costs or serve as experts in certifying the quality characteristics of goods.[28] In addition to these traditional roles, middlemen – especially information technology (IT)-focused, or internet-based – may well be information aggregators who are very efficient in collecting, storing, and managing customer information.

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[27] See Shevchenko (2004) for a brief literature review of recent studies on middlemen.

[28] See Biglaiser(1993), Biglaiser and Friedman(1994), and Li (1998) for the role of middlemen as expert traders.

6.3 Database co-ops and the M&A for customer information

This paper considers the situation in which consumers are heterogeneous with respect to their relationship to product offerings, and the relationship – the degree of complementarity – is consumer-specific, private information unknown to firms. In such circumstance, we have shown that each firm's customer list can become more valuable to each firm when integrated with those of other firms. In other word, the information pooling generates *informational* economies of scale. This helps us to understand how customer information can be valuable as a tradeable asset. In this aspect, our analysis provides legitimacy for a new business practice such as database co-ops. In one example, a prospective member firm is required to contribute at least 5000 names in order to join the Abacus 2B2 alliance.[29] This paper provides an explanation for *how* and *when* the benefits from such customer information exchange can arise.

In a similar vein, our study has important implications for the merger analysis in which the primary motive for merger is the acquisition of another firm's customer lists.[30] Even if a merger does not lead to higher market-power or cost-synergies by eliminating some duplications in production or marketing, it can be a profitable strategy because of the value of customer lists. In reality, we can often observe M&As arising from such a motive. The CDNow case briefly described in the Introduction

[29] See the details "Who's is Who among the B-to-B Co-op Databases," Catalog Age, May 1, 2004. We noticed this real world example from Liu and Serfers. As other articles about the exchange of databases, see the followings: "List & Data Strategies: Co-ops kick it up a notch," Aug 1, 2005 and "List and data strategies: Co-ops get down to business," Sep 1, 2005 (http://multichannelmerchant.com).

[30] Customer information is one of intangible assets acquired through a merger, according to 'Antitrust division policy guide to merger remedies (October 2004)' by U.S. Department of Justice, Antitrust division. (http://www.usdoj.gov/atr/public/guidelines/205108.htm)

is a case in point. Our study provides a theoretical foundation for the M&A of a firm whose only asset is its customer lists in the context of behavior-based price discrimination.[31]

7 Robustness and Extensions

As previously mentioned, sophisticated consumers who expect ex post price discrimination may strategically misrepresent their preferences in order to increase their overall surplus, which leads us to check the conditions under which our main results are robust with such considerations. In this section, we also discuss the assumption that the substitute market is fully-covered to check the robustness of our main results. Potential extensions include an alternative way to model our key intuition with a downward sloping demand and a continuous parameter for complementarity.

7.1 Potential strategic misrepresentation of preferences

7.1.1 Under information sharing regime

As previously shown, if the full information price in the substitute market is higher than that in the complementary market, i.e., $p^C < p^S$, then each firm has ex post incentive to share its customer past history with the other firms. Then, the sophisticated consumers who consider the two goods substitutes may strategically buy

[31] Tadelis (1999) develops a model in which the only asset a firm has is its name. He shows that there generates an active market for names if buyers cannot observe ownership shifts between sellers. His model and ours have something in common in that both find the value of intangible assets and explain their trade between sellers.

both goods or neither, instead of buying only one good, in order to avoid the expected higher second-period price p^S. Needless to say, the decision for this strategic demand manipulation hinges upon the benefit-cost analysis associated with such possible mimicries. The benefit of pretending to consider the goods complementary is a lower second-period price than the price without such a disguise, while its cost is a potential loss of utility in the first period.

More specifically, the consumer in group S can have additional benefit of $\delta(p^S - p^C)$ by strategically purchasing either both goods or neither good instead of buying only one good. By doing so, however, this consumer may enjoy less surplus in the first period because she now buys an additional good without further utility earned[32] or loses the first-period utility, $\max\{v_A, v_B\} - q_i$, that could have been earned if the consumer had not strategically chosen no purchase. As a result, the consumer will not misrepresent her preference by buying both goods if the first-period price for a unit of good is sufficiently high due to either a sufficiently large marginal cost, d, or reservation value v is sufficiently high.

7.1.2 Under no sharing regime

If the full information price in the substitute market is lower than that in the complementary market, i.e., $p^S < p^C$, the sophisticated consumers expect no information sharing in the second period. So, they know that the second period prices will be based only on whether they are newcomers or returning customers. In such a case, a consumer's consumption decision in group C will be based not only on the first period

[32] We assume away the possibility of resale.

surplus but also on its feedback effect on the second period price. The detailed analysis for this dynamics becomes complex because the marginal type of consumer will be determined by the first period prices and the expected second period prices which in turn affects on the first period pricing. We believe, however, that our qualitative results would not be changed: there would be some restriction on parameters.

On the other hand, a consumer who consider the two goods substitutes expects that she faces the price for a returning customer if she buys a good from the same firm, but the price for a newcomer if she switch to the other firm in the second period. Since she is not informed of her second-period preference, indexed by γ, at the beginning of period one, there is no dynamic effect of the ex post discriminatory prices on the first-period choice. This is similar to the case of the changing preference in the two-period poaching model of Fudenberg and Tirole (2000).

7.2 Not fully-covered substitute market

In our basic model, every consumer who regards the two goods as substitutes buys at least a unit of either A or B with the assumption that the common reservation price v is high enough to ensure that the substitute market is fully covered. Clearly, this assumption simplifies the analysis to a significant extent because the sharing of information allows firms to identify consumer preferences for the entire consumers. Apparently, this assumption may sound somewhat restrictive, but our qualitative result turns out to be robust to relaxing this assumption.

To see this point, suppose that consumers are heterogeneous in the vertical dimension – with respect to their reservation price v_i – as well so that the possibility of no purchase is open to those who have relatively low reservation values for both goods. Then, even if the firms share their customer information collected through the initial marketing period, there will be residual uncertainty about consumer preferences. Meeting a consumer who bought neither product, firms cannot tell if the consumer has considered the goods complementary but did not buy either good due to a relatively low θ or if the consumer has regarded the goods as substitutes but chose not to purchase either product due to a relatively low valuation for both goods. As a result, the firms must post a weighted average price for unidentified consumers even after information sharing. As far as identified consumers are concerned, however, the incentives to share customer information work in the same manner as the case of perfect identification.

In fact, it must be more realistic to consider this possibility of no purchase; it only comes at the expense of substantial complication. If our simplifying assumption is relaxed, the demand for those who regard the goods as substitutes depends not only on horizontal but also vertical dimensions. So, unfortunately, the model suffers from technical complexity; little additional insight is gained. The benefits associated with our simple basic model outweigh its costs.

7.3 Complementarity as a continuous variable and downward sloping demands

In our basic model, consumers are categorized into only two distinct groups and they have a unit demand per period. This simplification allows us to deliver our main intuition in a simple and tractable manner; it would be interesting to consider a downward sloping demand with the complementarity (or substitutability) embodied as a continuous variable.

In this spirit, let us suppose an individual consumer has a downward-sloping demand for good i , for instance, which is given as $D_i(p_i, p_j; \sigma) = a - p_i + \sigma p_j$, where the coefficient σ measures her complementarity or substitutability: $\sigma > 0$ is for substitutes, $\sigma < 0$ is for complements, and $\sigma = 0$ is for independent goods. If consumers are heterogeneous with respect to their complementarities that are correlated over time, then the exchange of past purchase histories may provide the firms with a better estimate for the value of the parameter σ, relative to the case where firms do not share their customer information. For example, given the demand specifications we have, information about σ can be inferred more efficiently with sharing of information between the two firms if consumers are heterogenous with respect to both a and σ. We believe that our main intuition of this paper can work through this alternative framework. The full analysis in this direction, however, is beyond of the scope of this paper.

8 Concluding Remarks

We live in a world where electronic commerce through the Internet prevails more than ever before, numerous innovations in information-technology take place rapidly, consumers' records of previous purchases can be easily traced and stored by electronic "fingerprints," and the issues related to privacy concerns are heard and discussed daily. Our analysis for customer information sharing is especially relevant in such a modern business environment. In this paper, we have investigated oligopolistic firms' incentives to share customer information about past purchase history and the effects of information sharing on consumer surplus in a situation where firms are uncertain about whether a particular consumer regards the product offerings as complements or substitutes.

The key intuition of this paper has several important implications not only for the issues directly related to customer information sharing, but also for other significant subjects such as the determinants of product differentiation and the roles of middlemen. Additionally, this paper sheds a new light on merger analysis in which the primary motive for merger is the acquisition of another firm's customer lists. Our research is an early step which we hope to encourage more research in this direction.

Appendix A

Proof of the claim: A consumer in group S (weakly) prefer buying only one product to buying both, that is, $\max\{v_A - p_A, v_B - p_B\} \geq \max\{v_A, v_B\} - p_A - p_B$.

There are four possibilities depending on the relative magnitude of terms in the maximands. If $v_A \geq v_B$ and $v_A - p_A \geq v_B - p_B$, then $\max\{v_A, v_B\} = v_A$ and $\max\{v_A - p_A, v_B - p_B\} = v_A - p_A$ so that the given statement is shown to be true as follows.

$$
\begin{aligned}
&\max\{v_A - p_A, v_B - p_B\} - (\max\{v_A, v_B\} - p_A - p_B) \\
&= (v_A - p_A) - (v_A - p_A - p_B) = p_B \geq 0
\end{aligned}
$$

If $v_A \geq v_B$ and $v_A - p_A < v_B - p_B$,then $\max\{v_A, v_B\} = v_A$ and $\max\{v_A - p_A, v_B - p_B\} = v_B - p_B$.

$$
\begin{aligned}
&\max\{v_A - p_A, v_B - p_B\} - (\max\{v_A, v_B\} - p_A - p_B) \\
&= v_B - p_B - (v_A - p_A - p_B) = v_B - (v_A - p_A) \geq (v_B - p_B) - (v_A - p_A) > 0
\end{aligned}
$$

If $v_A < v_B$ and $v_A - p_A \geq v_B - p_B$, then $\max\{v_A - p_A, v_B - p_B\} = v_A - p_A$ and $\max\{v_A, v_B\} - p_A - p_B = v_B - p_A - p_B$. In a similar manner, we can show that

$$
\begin{aligned}
&\max\{v_A - p_A, v_B - p_B\} - (\max\{v_A, v_B\} - p_A - p_B) \\
&= (v_A - p_A) - (v_B - p_A - p_B) \\
&= v_A - (v_B - p_B) \geq 0
\end{aligned}
$$

As the last case, if $v_A < v_B$ and $v_A - p_A < v_B - p_B$, then we know that $\max\{v_A - p_A, v_B - p_B\} = v_B - p_B$ and $\max\{v_A, v_B\} - p_A - p_B = v_B - p_A - p_B$.

$$\max\{v_A - p_A, v_B - p_B\} - (\max\{v_A, v_B\} - p_A - p_B)$$
$$= v_B - p_B - (v_B - p_A - p_B) = p_A \geq 0$$

Q.E.D.

Proof of Proposition 1

Consider the case of $p^S \leq p^i \leq p^C$, then profits with and without customer information sharing are arranged such that $\pi^i \geq \pi^C$ and $\pi^i \geq \pi^S$, as long as p^i is not extremely low, $i = 0, 1$. With the symmetry of distribution G, each firm has the half of the market of substitutes, i.e., $G(\widehat{\gamma}) = 1/2$. The second-period profit with no information sharing is decomposed into

$$\widetilde{\Pi}_2 = \lambda[1 - F(\widehat{\theta})]\pi^1 + \lambda F(\widehat{\theta})\pi^0 + \frac{1-\lambda}{2}\pi^1 + \frac{1-\lambda}{2}\pi^0$$

which satisfies the following inequality

$$\geq \lambda[1 - F(\widehat{\theta})]\pi^C + \lambda F(\widehat{\theta})\pi^C + \frac{1-\lambda}{2}\pi^S + \frac{1-\lambda}{2}\pi^S = \Pi_2$$

Therefore, the profit without information sharing is at least as higher as the profit with information sharing.

For the other case of $p^C \leq p^i \leq p^S$, then the relative magnitudes of prices are such that $\pi^i \leq \pi^C$ and $\pi^i \leq \pi^S$. In a similar manner, the second-period profit with no information sharing is shown to be less than or equal to that with information sharing as follows.

$$\begin{aligned}\widetilde{\Pi}_2 &= \lambda[1 - F(\widehat{\theta})]\pi^1 + \lambda F(\widehat{\theta})\pi^0 + \frac{1-\lambda}{2}\pi^1 + \frac{1-\lambda}{2}\pi^0 \\ &\leq \lambda[1 - F(\widehat{\theta})]\pi^C + \lambda F(\widehat{\theta})\pi^C + \frac{1-\lambda}{2}\pi^S + \frac{1-\lambda}{2}\pi^S = \Pi_2\end{aligned}$$

Q.E.D.

Appendix B. Example with uniform distributions

For explicit solutions, let us consider the case in which both θ and γ follow uniform distributions: $\theta \in [0, 1]$ and $\gamma \in [-\overline{\gamma}, \overline{\gamma}]$. A uniform distribution satisfies the MHR condition, so the first-order condition is sufficient for the optimization. For simplicity, let us set the production cost to zero, i.e., $d = 0$. With information sharing, the full information prices for each group in the second period are given by

$$p^C = \frac{1}{3} \qquad p^S = \overline{\gamma}. \tag{ex-3}$$

Subsequently, the second-period equilibrium profit with information sharing is given by

$$\Pi^2 = \frac{\lambda}{9} + (1-\lambda)\frac{\overline{\gamma}}{2}. \tag{ex-4}$$

Without information sharing, the firms revise their beliefs on the proportions of the consumers in each group in the process of Bayesian update. Using the first-period equilibrium price q, the posterior probabilities are given by

$$\lambda^0 = \frac{\lambda(2q)}{\lambda(2q) + (1-\lambda)/2}; \qquad \lambda^1 = \frac{\lambda(1-2q)}{\lambda(1-2q) + (1-\lambda)/2} \tag{ex-5}$$

and recall that λ^0 and λ^1 are the probabilities that a newcomer and a returner would belong to group C, respectively. As explained in Section 4, the profit-maximization problem of firm i for a newcomer is given by

$$\underset{p_i^0}{Max}\ \pi_i^0 = (p_i^0 - d)\left\{\lambda^0[1 - F\left(p_i^0 + p_i^0\right)] + (1-\lambda^0)G\left(p_j^1 - p_i^0\right)\right\}$$

and for a returning consumer firm i solves the following problem

$$\underset{p_i^1}{Max}\ \pi_i^1 = (p_i^1 - d)\left\{\lambda^1[1 - F\left(p_i^1 + p_i^1\right)] + (1-\lambda^1)G\left(p_j^0 - p_i^1\right)\right\}$$

where $i \neq j$. With some algebra, we can derive the symmetric equilibrium prices without information sharing as

$$p^0 = \frac{3\overline{\gamma}^3(1-\lambda^0)(1-\lambda^1) + 6\overline{\gamma}^2(1-\lambda^0)\lambda^1 + \overline{\gamma}(4\lambda^0 + 2\lambda^1 - 6\lambda^0\lambda^1) + 12\lambda^0\lambda^1}{3\overline{\gamma}^2(1-\lambda^0)(1-\lambda^1) + 12\overline{\gamma}(\lambda^0 + \lambda^1 - 2\lambda^0\lambda^1) + 36\lambda^0\lambda^1}$$

$$p^1 = \frac{3\overline{\gamma}^3(1-\lambda^0)(1-\lambda^1) + 6\overline{\gamma}^2(1-\lambda^1)\lambda^0 + \overline{\gamma}(4\lambda^1 + 2\lambda^0 - 6\lambda^0\lambda^1) + 12\lambda^0\lambda^1}{3\overline{\gamma}^2(1-\lambda^0)(1-\lambda^1) + 12\overline{\gamma}(\lambda^0 + \lambda^1 - 2\lambda^0\lambda^1) + 36\lambda^0\lambda^1}. \tag{ex-6}$$

For these prices, we can readily check $p^0 = p^1 = p^C = \frac{1}{3}$ if every consumer considers the goods as complements, i.e., $\lambda^0 = \lambda^1 = 1$ and $p^0 = p^1 = p^S = \overline{\gamma}$ if every consumer regards the goods as substitutes, i.e., $\lambda^0 = \lambda^1 = 0$. By substituting p^0 and p^1 into the profit expression, we can also derive the associated equilibrium profits π^0 and π^1 as

$$\pi_i^0 = p^0 \left\{ \lambda^0 (1 - 2p^0) + (1 - \lambda^0) \left(p^1 - p^0 \right) \right\} \tag{ex-7}$$

$$\pi_i^1 = p^1 \left\{ \lambda^1 (1 - 2p^1) + (1 - \lambda^1) \left(p^0 - p^1 \right) \right\}$$

Therefore, without information sharing, each firm earns the total second-period profit of

$$\tilde{\Pi}^2 = \left(\lambda(2q) + \frac{(1-\lambda)}{2} \right) \pi^0 + \left(\lambda(1-2q) + \frac{(1-\lambda)}{2} \right) \pi^1 \tag{ex-8}$$

where the tilde denotes the case of no information sharing.

Table 1-A-1 shows the equilibrium outcomes for $\theta \sim U[0,1]$ and $\overline{\gamma} = 0.2$ ($p^C = 1/3 > 1/5 = p^S$) where no sharing regime is preferred. Fig. A-1 graphically shows this result. Similarly, we summarize the equilibrium outcomes for $\theta \sim U[0,1]$ and $\overline{\gamma} = 0.5$ ($p^C = 1/3 < 1/2 = p^S$) in Table 1-A-2. Now that the full information price in the substitute market is higher that for the complementary market, information sharing will be preferred. Fig. A-2 shows this result.

Table 1-A-1. Equilibrium outcomes: No information sharing is preferred.

$\theta \sim U[0, 1]$, $\bar{\gamma}=0.2$: $p^C=1/3 > p^S=0.2$							
λ	q	λ^0	λ^1	p^0	p^1	Π	$\tilde{\Pi}$
0.0	0.200	0.000	0.000	0.200	0.200	**0.100**	**0.100**
0.1	0.233	0.094	0.254	0.305	0.320	**0.101**	**0.150**
0.2	0.257	0.205	0.426	0.319	0.327	**0.102**	**0.147**
0.3	0.275	0.320	0.554	0.325	0.330	**0.103**	**0.142**
0.4	0.289	0.435	0.655	0.328	0.331	**0.104**	**0.137**
0.5	0.300	0.545	0.737	0.330	0.332	**0.106**	**0.132**
0.6	0.309	0.650	0.806	0.331	0.332	**0.107**	**0.127**
0.7	0.317	0.747	0.864	0.332	0.333	**0.108**	**0.123**
0.8	0.323	0.838	0.915	0.332	0.333	**0.109**	**0.119**
0.9	0.329	0.922	0.960	0.333	0.333	**0.110**	**0.115**
1.0	0.333	1.000	1.000	0.333	0.333	**0.111**	**0.111**

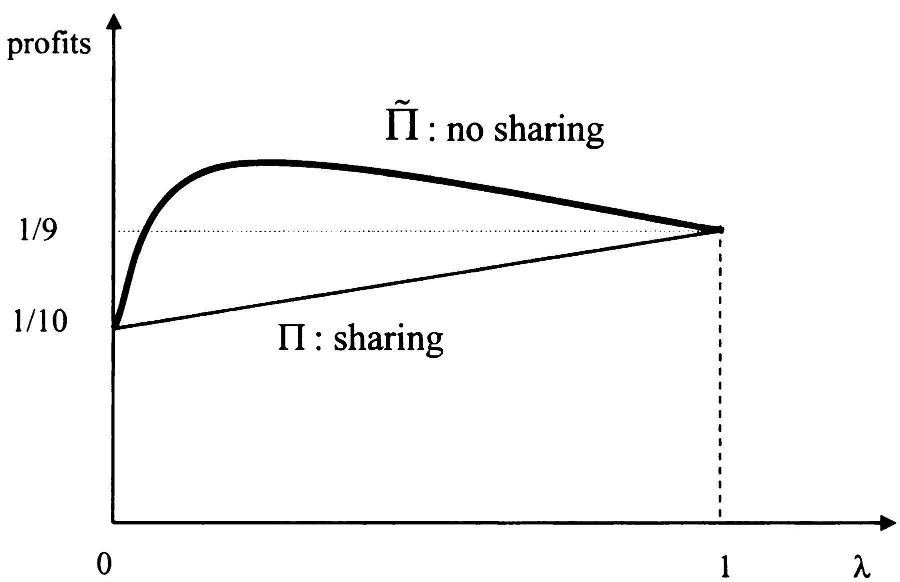

Figure 1-A-1. Comparison of equilibrium profits for **$\theta \sim U[0, 1]$, $\bar{\gamma}=0.2$**

Table 1-A-2. Equilibrium outcomes: Information sharing is preferred.

$\theta \sim U[0, 1]$, $\bar{\gamma}$=0.5: p^C=1/3 < p^S=0.5							
λ	q	λ^0	λ^1	p^0	p^1	Π	$\tilde{\Pi}$
0.0	0.500	0.000	0.000	0.500	0.500	**0.250**	**0.250**
0.1	0.458	0.169	0.194	0.381	0.377	**0.236**	**0.172**
0.2	0.429	0.300	0.364	0.360	0.355	**0.222**	**0.153**
0.3	0.406	0.411	0.504	0.351	0.346	**0.208**	**0.143**
0.4	0.389	0.509	0.620	0.345	0.342	**0.194**	**0.136**
0.5	0.375	0.600	0.714	0.342	0.339	**0.181**	**0.131**
0.6	0.364	0.686	0.792	0.339	0.337	**0.167**	**0.126**
0.7	0.354	0.768	0.858	0.337	0.336	**0.153**	**0.122**
0.8	0.346	0.847	0.913	0.336	0.335	**0.139**	**0.118**
0.9	0.339	0.924	0.960	0.334	0.334	**0.125**	**0.114**
1.0	0.333	1.000	1.000	0.333	0.333	**0.111**	**0.111**

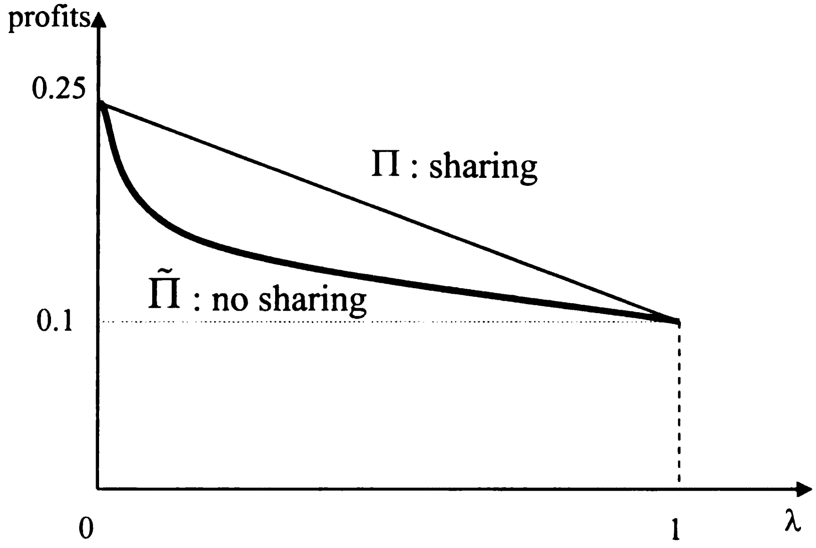

Figure 1-A-2. Comparison of equilibrium profits for **$\theta \sim U[0, 1]$, $\bar{\gamma}$=0.5**

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Chapter 2. A Theory of Preliminary Injunctions: Is it a cheap message service?

In this paper a model of preliminary injunctions is presented in the context of antitrust litigations. Following a suggestion of Lanjouw and Lerner (2001), we study the role of preliminary injunctions as a noisy information message service in addition to its role as a means to prevent irreparable harm to the plaintiff. Interestingly, we find both cases in which the plaintiff with a high damage or the one with a low damage moves for preliminary injunctive relief as equilibrium phenomena. We not only analyze the decision-making about the motion for an injunction, optimal settlement offers and litigation/settlment, but also discuss various issues associated with preliminary injunctions based on our model.

1 Introduction

A preliminary injunction is a court order prior to a final decision on a legal case based on its a priori assessed merits, in order to restrain a party from a certain activity during a period until the case will have been decided. Not surprisingly, it has substantial impact on the decisions of litigants and the outcomes of disputes.[1] In addition, we can frequently see many firms request preliminary injunctions especially in patent litigations and antitrust cases.

On Oct. 7, 1997 Sun Microsystems Inc. filed a suit against Microsoft in U.S. District Court for copyright infringement, alleging that Microsoft improperly modified

[1] Lanjouw and Lerner (2001) provides an excellent overview of preliminary injunctions.

the Java technology incorporated in Internet Explorer 4.0 and infringed Sun's trademark by distributing IE 4.0 and related products using the Java Compatible Logo, even though Microsoft's Java products failed its compatibility tests and thus violated their 1996 licensing agreement. On March 24, 1998, U.S. District Court Judge Ronald M. Whyte issued the preliminary injunction ordering Microsoft to modify all its software products that ship with Java technologies to pass Sun's Java compatibility test suite within 90 days.[2]

In a more recent case, in August 8, 2006 Sanofi-Aventis, the pharmaceutical company and the holder of a patent on the blood-thinning drug Plavix, and Bristol-Myers Squibb Co., its U.S. partner, requested a preliminary injunction against Canadian drug maker Apotex Inc. to stop its sales of a generic version of Plavix. On September 1, 2006 U.S. District Judge Sidney H. Stein granted the injunction, concluding that Sanofi-Aventis would suffer irreparable harm if Apotex were permitted to continue distributing its generic product. Bristol-Myers shares and U.S. shares of Sanofi-Aventis rose 8 percent and 3.4 percent on the NYSE, respectively, after the ruling was issued.[3]

However, despite the economic and legal significance of preliminary injunctions, there are, unfortunately, very few papers addressing this issue in a form of an economic analysis. Our analysis has been motivated in large part by two strands of early

[2]See, Summary of Sun Microsystems v. Microsoft, U.S. District Court, Northern District of California, San Jose, Case Number 97-CV-20884. For press accounts for another preliminary injunction granted in this case on November 17, 1998, see *The Wall Street Journal (Eastern edition)* Nov 18, 1998, pg. 1., "Microsoft Loses Java Decision In U.S. Court" and *Tech Law Journal* Nov 18, 1998 "Judge Whyte Issues Preliminary Injunction in Sun v. Microsoft."

[3]Refer the case number [**2] 05-CV-3965 in Southern District of New York for Apotex Inc. v. Sanofi-Aynthelabo (also known as Sanofi-Aventis). For press documents, see a report in *Townhall.com*, "Judge Halts Sales of Generic Plavix" and *Wall Street Journal (Eastern edition)* New York, N.Y.: Dec 29, 2006, "Sanofi-Aventis SA: Court Prevents Canada's Apotex From Launching Generic Plavix."

research related to this issue. Firstly, Lanjouw and Lerner (2001) suggest that

> in a world with uncertainty about case quality, a preliminary injunction hearing may be a relatively cheap way to obtain information about how a court would rule in an eventual trial. (p. 586)

As they mention, one of the reasons that lead the plaintiffs to move for a preliminary injunction could be found in the plaintiff's quest for information in the presence of uncertainty about case quality, which has not been studied yet. In our model, we incorporate this aspect of preliminary injunctions by offering a model of preliminary injunctions in which the players can revise their expected winning probability at trial through Bayesian updating once they observe the court's decision on the preliminary injunction. Also, we characterize the injunction rule as an imprecise information transmission channel, so that the cost of acquiring noisy information can be compared to its benefit.

The second motivation for our study is found in Bizjak and Coles (1995) who examine the effects of private antitrust litigation on the stock-market valuation of the firms. One conspicuous finding in their empirical study is that the request for injunctive relief is associated with a reduction in a defendant's wealth upon filing. This implies that the participants in stock markets may regard the motion for preliminary injunctive relief as a reliable signal that may impose behavioral restrictions on the defendant. In this paper we explore the plaintiff's incentives to make a motion for a preliminary injunction and attempt to identify the conditions under which the defendant's payoff is negatively related to the plaintiff's decision to ask for injunctive relief.

In general, one main reason for the plaintiff's injunction request is to avoid so-called irreparable harm. In fact, irreparable harm is also one crucial factor considered when the court rules on the injunction. For this reason the plaintiff with a higher damage is typically expected to have a stronger incentive to file the motion for preliminary injunctive relief, all other things being equal. Once we view the preliminary injunction as a noisy information transmission mechanism, however, the above logic is no longer so straightforward. This is because if the court rejects injunctive relief, then the plaintiff's expectation for the case quality can be adjusted toward an unfavorable direction so that his threat of litigation may lose its credibility or the settlement amount offered by the defendant is diminished. Thus, the incentive to ask for preliminary injunctive relief becomes more intriguing compared to the obvious trade-off between the possible avoidance of irreparable harm and the legal cost for requesting the injunction.

The literature directly concerning preliminary injunctions is quite scant, but there is by now an extensive literature on (pretrial) settlement and litigation. Bebchuk (1984) provides a model of litigation and settlement decisions under imperfect information. He studies a variety of factors that can affect the likelihood of settlement and the settlement amount such as litigation costs, the amount at stake, and legal rules.[4] Nalebuff (1987) addresses the issue of credibility in the plaintiff's threat to litigate in a framework similar to Bebchuk's. In his revised model, the settlement

[4] P'ng (1983) offers a model of settlement decisions in the presence of asymmetric information, but the settlement amount is not endogenously determined, which is endogenized in Bebchuk's model.

demand has a pronounced effect on the equilibrium outcome, as a result, the plaintiff may increase her settlement demand in order to limit the negative effect of having her offer rejected.[5] Our paper shares a similar feature with Nalebuff's in the sense that the plaintiff is concerned about an exposure to the risk that is given by the request for injunctive relief being rejected. As a paper addressing the antitrust litigation more directly, we are aware of Briggs, Huryn, and McBride (1996). They study the effects of private suits on government suits and vice versa. They show that private plaintiffs are more likely to settle following a government suit than otherwise, which is supported by data on private suits. Instead, we are particularly interested in the effect of preliminary injunction rulings on the subsequent final judgment.

On the other hand, Choi (1998) explores the implications of the information revealed in patent litigation for entry dynamics in the presence of multiple potential entrants. In his model, a patentee can be exposed to the threat of entry if he loses in the patent litigation initially launched by himself. The fear of losing in patent litigation in his model can be analogous to the plaintiff's fear of the disapproval of preliminary injunction relief.

As previously mentioned, Lanjouw and Lerner (2001) is the closest to our paper in that it also takes a step in the direction of examining the preliminary injunction. Our analysis, however, differs from theirs in the mechanism through which the injunction works. In their model, firms may request preliminary injunctions in order to impose financial stress on their rivals as well as to save irreparable harm, whereas the

[5] For the settlement of patent litigation, Meurer (1989) develops a model that analyzes the effect of the probability of patent invalidity, antitrust policy, and the rules of litigation-cost allocation on the likelihood of settlement and litigation.

ruling on preliminary injunction in ours is also an informational transmission mechanism. Recently, Boyce and Hollis (2007) study a patentee's incentive to move for a preliminary injunction and show that it may be sought in patent cases to obtain market power during the period of the injunction. Interestingly, they find that both the patentee and the alleged infringer benefit from a preliminary injunction because it may play the role of a court-ordered collusive scheme to charge monopoly prices and share profits.

The remainder of this article is organized as follows. Section 2 outlines a simple model of preliminary injunctions in which the plaintiff's incentive to file the motion for an injunction is of particular interest. Section 3 gives intuitive explanations for the analysis of our simple model. In conjunction, a few numerical examples are presented. In Section 4, we extend our basic model to include the defendant's settlement stage. Section 5 contains a variety of possible extensions and their implications. Finally, we close this paper with brief concluding remarks.

2 A Simple Model of Preliminary Injunctions

For expositional ease, we begin with a simple model which abstracts away from various aspects of preliminary injunctions. Our strategy is to study this simple version of the model, and then bring it closer to reality with additional features later.

2.1 Players and timing of the game

Consider a legal conflict that involves two risk-neutral players, a plaintiff firm and a defendant firm, in an infinite time horizon. The game begins at $t = 0$ when the plaintiff faces allegedly unlawful actions by the defendant. Before the plaintiff's filing of a suit, both parties' payoffs per period are normalized to zero. At $t = 1$, the plaintiff suffers (per period) damages of w due to an action of the defendant. The extend of the damages are private information to the plaintiff; the defendant knows only the distribution of possible damages $F(w)$ on $[\underline{w}, \overline{w}]$ with $\underline{w} < \overline{w}$.

Upon filing a suit against the defendant, the plaintiff decides whether or not to move for a preliminary injunction against the defendant's offending behaviors. Should the plaintiff file a request for an injunction, the court immediately holds hearings on the suit and announces its judgment. That is, injunctive relief is either granted or denied instantaneously. If the injunction is granted, the plaintiff goes to trial in an attempt to make the ruling permanent; if injunctive relief is denied, we assume that the plaintiff drops the suit because he expects a negative (net) payoff from going to trial.

Of course, one may consider the case where the plaintiff proceeds through to trial even after his request for a preliminary injunction is rejected. Then, however, the value of the preliminary injunction as an information service becomes zero because the purchaser of the message service, the plaintiff, does not change his action in light of what kinds of message he receives. As a result, the only reason for the motion of a preliminary injunction is restricted to prevent irreparable harm. Since the purpose of our paper is to consider the preliminary ruling as a message service the value of which is not zero, we adopt such assumption concerning the plaintiff's actions in response to the court's ruling on the request.

Finally it is worth noting that we assume that the court's ruling on the preliminary injunction is immediate, whereas it takes one time period for the court to give its final judgment in litigation, should the plaintiff proceed to trial. This reflects the fact that litigation is a more time consuming process relative to the preliminary injunction. Figure 2-1 summarizes the timing of the game that we consider.[6]

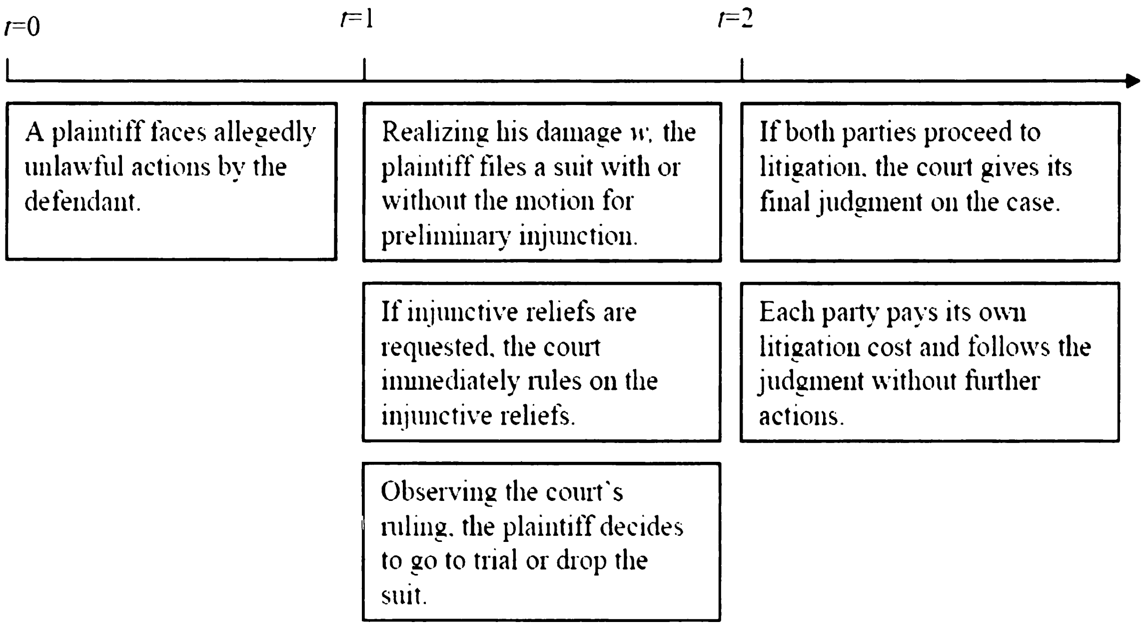

Figure 2-1. Timing of the Game

[6]The assumption that each party pays its litigation cost at the time when the court announces its judgment does not make any qualitative difference from the assumption that it occurs at $t = 1$.

2.2 Assumptions on prior beliefs

Let us assume that there are two possible underlying states concerning the case in question. In the "valid" state, the plaintiff wins the case at trial, should it come to a final ruling; whereas in the "invalid" state the court finds in favor of the defendant at trial, in the event that litigation goes through.[7] Let π denote the prior probability that the case would prove to be valid at trial, that both parties commonly hold.[8] In other words, the plaintiff's and the defendant's expected winning probabilities are π and $1 - \pi$, respectively. We assume that π is *independent* of the plaintiff's damage level w.[9] This set up reflects the fact that the primary goal of antitrust laws is not to protect *competitors* but to support *market competition*, so that the court's discretion need not depend on how much a defendant has been damaged. The court applies the same discretion for the preliminary injunction and the eventual trial, so that ex ante each party expects that the injunction will be approved with probability π.[10]

2.3 The injunction ruling as a noisy message service

The ruling on the preliminary injunction, however, may have two types of errors. Injunctive relief can be denied with probability α (≥ 0), even if the true state is valid. To put it differently, the court mistakenly can deny the requested injunction even though the court would rule in favor for the defendant at trial. Another type

[7] Here, the terms of "valid" and "invalid" are used in the sense that if the plaintiff's request for preliminary injunctive relief is valid, then the court will be in favor of the plaintiff in ruling on preliminary injunction, barring errors, and in the final judgment in litigation.

[8] Alternatively speaking, π represents the *ex ante* mean of a distribution that the variable π has.

[9] We discuss the case where this assumption is relaxed later.

[10] One interesting relaxation of this assumption is to consider a more conservative ruling in preliminary injunctions than the judgment in litigation. We discuss this later in Section 5.

of error is that the injunction can be granted with probability β (≥ 0), even if the true state is invalid so that the court should have denied it.[11] In summary, Table 2-1 shows the likelihood matrix for the ruling on preliminary injunctions, given the true state of the world.

		Ruling	
		Grant	Deny
Request for Injunctive Relief	Valid	$1-\alpha$	α
	Invalid	β	$1-\beta$

Table 2-1. Likelihood matrix for rulings on the preliminary injunction

Once injunctive relief is requested, each party revises its prior belief π into posteriors π^R, with $R \in \{G, D\}$, depending on the court's ruling, where G and D are mnemonics for the court's decision to grant (G) or deny (D) the request, respectively. The approval of an injunction occurs either when the court correctly finds a valid case or when the court mistakenly judges an invalid case to be a valid one. By Bayes' rule, the conditional winning probability at trial (for the plaintiff) given the message G is calculated as

$$\pi^G = \frac{(1-\alpha)\pi}{(1-\alpha)\pi + \beta(1-\pi)}. \tag{1}$$

In contrast, the court will not grant the injunction whenever it correctly finds an invalid case or when it makes the error of judging a valid case as an invalid one. Thus, the posterior belief that the case will prove to be valid, provided that the message D

[11] The first type or error is referred to as type-I error, false positive or α error, while the second one is called as type-II error, false negative, or β error. Our notations reflect the last alternative, α error and β error.

is received, is given by

$$\pi^D = \frac{\alpha\pi}{\alpha\pi + (1-\beta)(1-\pi)}. \tag{2}$$

Before moving to an analysis, a bit more notation is needed. Letting p and d be mnemonics for the plaintiff and defendant, respectively, let l_i denote the cost for legal proceedings associated with an injunction, for $i = p,\ d$. Let c_p and c_d be litigation costs associated with the actual trial for the plaintiff and the defendant, respectively. Each party bears its own costs regardless of the outcome in trial, that is, the American fee rule is adopted. Both parties discount their payoffs with the same discount factor, $\delta \in (0, 1)$.

The assumption that, regardless of the damages caused, a plaintiff will drop a case in light of an unfavorable ruling on the request for injunctive relief is then given by the condition that

$$c_p > \pi^D \frac{\overline{w}}{1-\delta}. \tag{3}$$

3 Incentives to file for a Preliminary Injunction

One crucial question that naturally arises when we discuss the preliminary injunction is what motivates a plaintiff to move for a preliminary injunction. That is, who asks for injunctive relief and who doesn't? Without doubt, one classic answer is that the plaintiff wants to avoid irreparable harm occurring during litigation.[12] This implies

[12]For instance, in the suit regarding Plavix it was reported that Apotex's generic drug quickly gained market share after its launch. According to Verispan LLC who collects prescription data, the generic brand captured 60.2 percent of the total prescriptions written for the week ended Aug. 19, 2006. Such changes in the market share must be a significant damage to the plaintiff, Sanofi-Aventis and Bristol-Myers.

that a plaintiff whose damage is relatively large would have a stronger incentive to move for a preliminary injunction in order to prevent irreparable losses, other things being equal. This answer, however, must potentially be adjusted to account for our second thought if we view the preliminary injunction as an information transmission mechanism, which should be another important motive for a plaintiff's choice of preliminary injunction as Lanjouw and Lerner (2001) suggest.

The plaintiff may attempt to obtain the court's ruling on an injunction as a hint for the final judgment at a relatively small expense. Remarkably, the rule on the preliminary injunction is at best a noisy informative message service due to its accelerated process: The court can commit the mistake of not granting the injunction *even in the valid state*. With such informational effects taken into consideration, the incentives to file a motion for a preliminary injunction can be more intriguing rather than an obvious trade-off between the legal costs l_p and the potential aversion of irreparable harm.

3.1 Plaintiff's payoffs

Note that in our simple set-up we treat the defendant as a passive player who does not take any strategic actions. In the next section, the defendant comes on the scene as a strategic player who must decide on settlement offers.

If the plaintiff of type w does not take any action, he gets damages of w in every subsequent period. The plaintiff's payoff without a suit is thus given by $-\frac{w}{1-\delta}$, the discounted present value of damages through infinite horizon. If the plaintiff with w

goes to trial without the motion for injunction, he earns the expected payoff of

$$-w - \delta c_p - (1 - \pi)\frac{\delta w}{1 - \delta}. \tag{4}$$

He suffers damages for one period until the trial's outcome comes. At the expense of litigation cost c_p, he can avert this damage permanently if the court finds in favor of him — which occurs with probability π. From the other option — moving for a preliminary injunction — the plaintiff's expected payoff is given by

$$-l_p + \Pr(G)\left(-\delta c_p - (1 - \pi^G)\frac{\delta w}{1 - \delta}\right) + \Pr(D)\left(-\frac{w}{1 - \delta}\right); \tag{5}$$

where $\Pr(G) = (1 - \alpha)\,\pi + \beta(1 - \pi)$ gives the probability of injunctive relief being granted and $\Pr(D) = 1 - \Pr(G)$. The plaintiff must pay the legal cost l_p to move for an injunction, regardless of the court's decision. With probability $\Pr(G)$, the injunction is granted, then the plaintiff is free from the damages of w for that period. He updates his winning probability at trial to π^G and expects to win at trial with probability π^G. If injunctive relief is not granted, the plaintiff drops the suit, by our previous assumption[13] so that he ends up with the payoff of no suit at the cost of l_p.

[13] The plaintiff drops the suit if the litigation cost is too high or the posterior winning probability π^D is too low relative to the potential saving of damages.

3.2 When is the motion for an injunction filed?

By comparing (4) to (5), the plaintiff with damages w prefers moving for a preliminary injunction to going directly to trial without it, if and only if

$$\Pr(G)w + (1 - \Pr(G))\,\delta c_p \geq l_p + \alpha\pi\frac{\delta w}{1-\delta}. \tag{6}$$

The left-hand-side of (6) is the plaintiff's expected benefits from the choice of filing for preliminary injunctive relief. With probability $\Pr(G)$ the injunction will be granted. Then the plaintiff can avoid his damage w temporarily. Otherwise, he drops the suit to save the litigation cost. The right-hand-side captures the costs associated with the motion for injunction. The preliminary injunction costs the plaintiff the legal cost l_p. In addition, if the court mistakenly decides not to grant the injunctive relief even in the valid state, the plaintiff will suffer the damages that could have been avoided under an error-free ruling on the preliminary injunction.

From this benefit-cost analysis, we find that there could be two distinct cases depending on the parameters. The first possibility is that the plaintiff whose damage is relatively high chooses to move for a preliminary injunction, while the one with a smaller damage opts for going to trial without the motion for injunction. This case is not surprising, since the marginal saving from preventing irreparable damages can exceed the potential marginal cost from the court's erroneous ruling on the preliminary injunction. As illustrated in Figure 2-2, for a sufficiently low α such that $\alpha\pi\frac{\delta}{1-\delta} < \Pr(G)$ and for large enough l_p such that $l_p > \delta c_p\,(1 - \Pr(G))$, the plaintiff with $w \geq w^*$ chooses to file for a preliminary injunction.

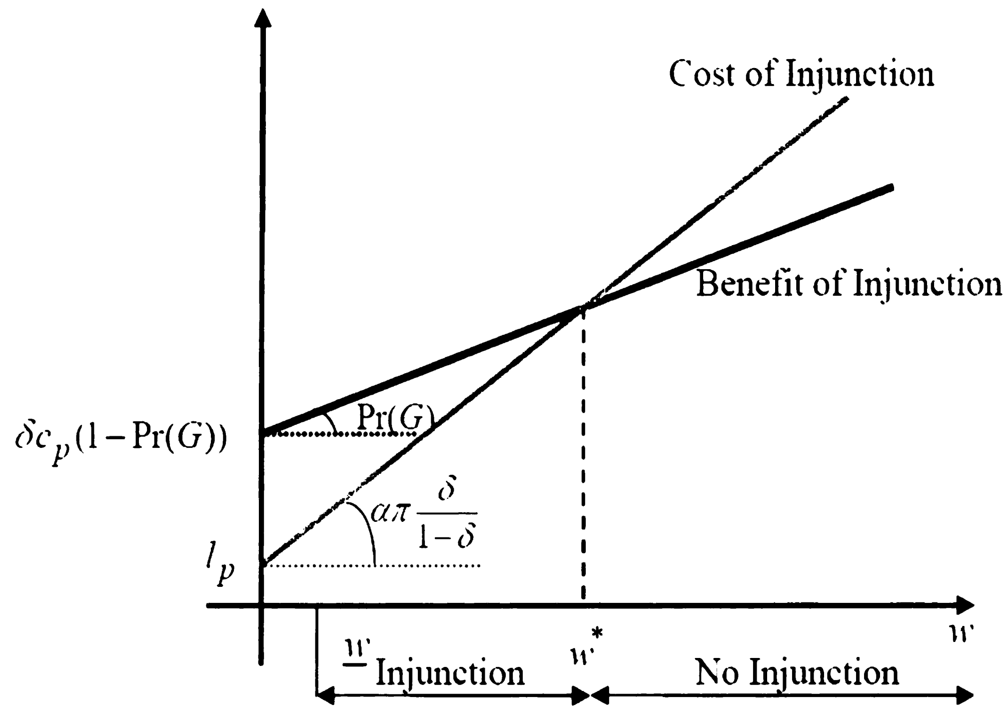

Figure 2-2. The Plaintiffs with Large Damages Move for Injunction

The numerical example below that satisfies all the assumptions and conditions listed falls into this first category of equilibrium.

Example 1 *Suppose that the parameters have the values such that* $\pi = 1/2$, $l_p = 5$, $c_p = c_d = 10$, $\delta = 0.75$, $\alpha = 0.2$ *and* $\beta = 0.1$. *Then, according to Bayesian updating process, the posteriors are derived as* $\pi^G = 8/9$ *and* $\pi^D = 2/11$. *That is, if the court grants the injunction, the plaintiff's expected winning probability increases to 8/9 from 1/2; if the court denies the injunction, it falls to 2/11 from 1/2. With simple algebra, we can verify that* $\delta c_p(1-\Pr(G)) = 33/8 < l_p = 5$ *and* $\alpha\pi\frac{\delta}{1-\delta} = \frac{3}{10} < \Pr(G) = \frac{9}{20}$ *and* $w^* = \frac{35}{6} \approx 5.83$. *The plaintiffs with* $13.75 > w \geq 5.83$ *request the preliminary injunction, while those with* $5.83 > w \geq 5$ *will go directly to trial without moving for* *injunctive reliefs. The upper- and low-bound of the damage w can take are determined by the assumptions under which the plaintiff's behavior is rationalized.*

The second possibility is that the plaintiff whose damage level is relatively low prefers asking for a preliminary injunction. This case seems to be counter-intuitive because the plaintiff with small damages should have a weaker incentive to request a preliminary injunction. The intuition for this interesting outcome is as follows. As a plaintiff's damage increases, his incentive for filing for a preliminary injunction to prevent irreparable damages gets strong. Nevertheless, given the condition that $\alpha\pi\frac{\delta}{1-\delta} > \Pr(G)$, the plaintiff's disincentive to request a preliminary injunction increases even at a faster rate because of the rate of the unfavorable error toward the plaintiff in the preliminary ruling. Graphically, we can illustrate this case as in Figure 2-3: This case happens when marginal cost of the injunction is greater than its marginal benefit, i.e., $\alpha\pi\frac{\delta}{1-\delta} > \Pr(G)$, and the legal cost of the injunction is small enough so that $l_p < \delta c_p(1 - \Pr(G))$.[14] As a result, the plaintiff with $w < w^*$ ends up preferring moving for a preliminary injunction to not doing so, where w^* is defined as

$$w^* = \frac{\delta c_p (1 - \Pr(G)) - l_p}{\pi\alpha\frac{\delta}{1-\delta} - \Pr(G)}. \tag{7}$$

[14]The typical single crossing property holds here.

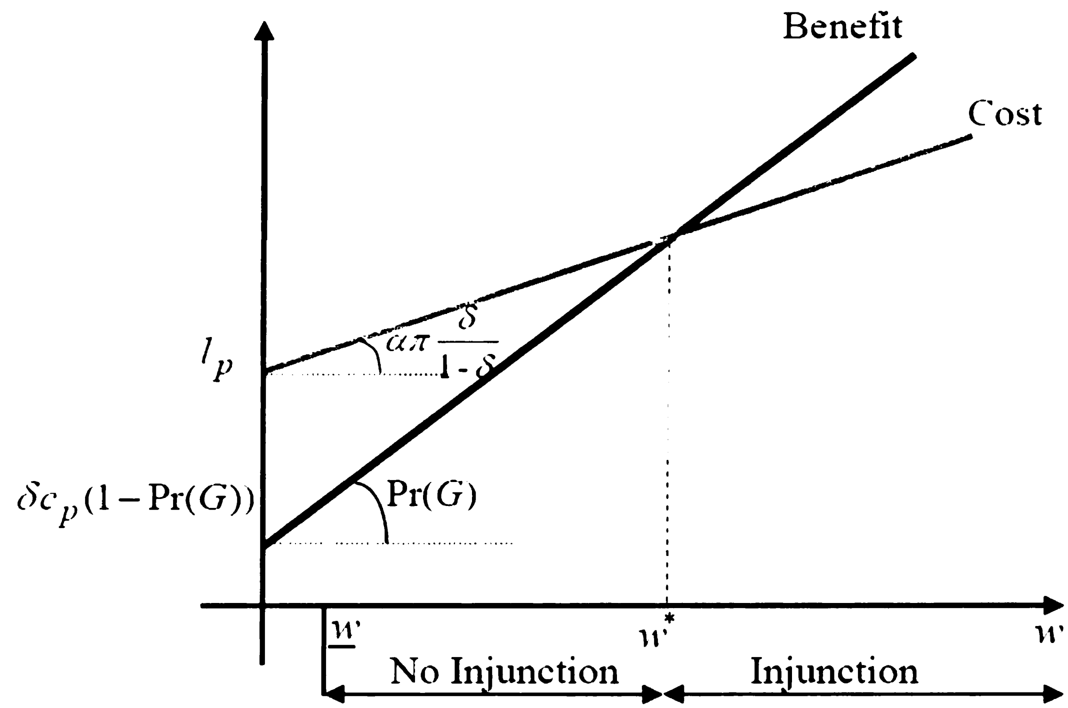

Figure 2-3. The Plaintiffs with Small Damages Move for Injunction

Finally, it is worth finding the conditions under which a plaintiff initially files a suit. In order to make the game start, one of the following two conditions must be satisfied: either a plaintiff has a higher expected payoff when he goes to trial without the motion for injunction or when he files for an injunction than when he opts for no suit. With some algebra, these two conditions simplify to

$$\pi\frac{w}{1-\delta} \geq c_p \quad \text{or} \quad \Pr(G)\left(-\delta c_p + \pi^G\frac{\delta w}{1-\delta} + \underline{w}\right) \geq l_p \tag{8}$$

We summarize the analysis so far in the following proposition. It is quite interesting to find that in equilibrium even the plaintiff whose damage is relatively large may choose not to move for preliminary injunction due to the risk of the noisiness in the judgment on the injunction.

Proposition 1 *Given the Assumptions in Equations 3 and 8, the plaintiff with* $w < w^*$ *moves for preliminary injunction if and only if* $\alpha\pi\frac{\delta}{1-\delta} > \Pr(G)$ *and* $l_p < \delta c_p(1 - \Pr(G))$, *where* w^* *is defined as in Equation 7.*

The following numerical example shows this second possiblity of equilibrium.

Example 2 *Now consider a different parameter constellation where* $\pi = 1/2$, $l_p = 6$, $c_p = c_d = 20$, $\delta = 0.9$, $\alpha = 0.2$ *and* $\beta = 0.1$. *Since the prior belief and the errors are the same as in Example 1, the updated posteriors are not changed. However, now we have such relationships that* $\delta c_p(1 - \Pr(G)) \approx 9.9 > l_p = 6$, $\alpha\pi\frac{\delta}{1-\delta} = \frac{9}{10} > \Pr(G) = \frac{9}{20}$ *and* $w^* \approx 8.67$, *under which the plaintiffs with* $11 > w^* \geq 8.67$ *will not move for the preliminary injunction, while those with* $8.67 > w \geq 6$ *will go to trial without the request for injunctive reliefs.*

4 An Extended Model

So far our simple model of preliminary injunctions has ignored the role of the defendant. A more complete model, however, must incorporate a defendant who can also take strategic actions. Thus, we extend the previous set-up to a more generalized one in which the defendant can make a take-it-or-leave-it offer for an out-of-court settlement after observing the court's ruling on the preliminary injunction.

4.1 The strategic defendant

The defendant can make a take-it-or-leave-it offer once the suit is filed against him. With the plaintiff's motion for a preliminary injunction filed and then receiving a particular message, either G or D, the defendant will offer a optimal settlement amount to maximize his own payoff. Given the defendant's settlement offer, the plaintiff decides whether to accept it or not. If the plaintiff accepts the offer, the two parties settle; if the plaintiff rejects the offer, the parties go on to trial. If the plaintiff drops the suit, then the game is over with payoffs remaining as in the status-quo. On the other hand, without the plaintiff's motion for an injunction, the defendant will also make a take-it-or-leave-it settlement offer, based on the rational expectation about which type of plaintiffs do and do not file for a preliminary injunction. When both parties go to trial, each party's payoff follows the court's final judgment.

There are three possible situations in which the defendant may consider a settlement offer. First, if the plaintiff does not seek a preliminary injunction the defendant makes a settlement offer of S^N.[15] Second, should the court grant the motion subsequent to the filing of an injunction, the defendant offers S^G to settle the case and avoid further litigation. Lastly, one may consider that case that a filing for injunctive relief has been denied by the court. In this final case, to maintain consistency with the base model, we assume that the plaintiff drops the case so that, consequently, $S^D = 0$.

In order to study the defendant's optimal decision concerning a settlement offer,

[15]The superscript N represents the case of *no* motion for injunctive reliefs. It should be noted that the offer of S^N is made after a plaintiff has decided whether or not to file for a preliminary injunction.

we need to specify the defendant's payoffs in the various situations that he could be confronted with. Suppose that the defendant's per period payoff gain from the disputed action is given by g. And note that the defendant's gain g is not necessarily equal to the plaintiff's damage w. Hence, the game being played between the defendant and the plaintiff concerning the action in questions is not a zero-sum game.

Our analysis proceeds backward from the plaintiff's decision concerning the acceptance/rejection of the defendant's settlement offer, to the defendant's decision of an optimal settlement amount, and, then, the plaintiff's decision to ask for the injunctive relief as a function of his per period damages w and expectations concerning possible forthcoming settlement offers.

4.2 Plaintiff's decision whether to settle or not

Let us first consider the case in which a plaintiff of type w moved for an injunction which the court subsequently granted. Note that at this stage the legal cost for injunction hearings l_p is a sunk cost, independent of the decision concerning settlement or trial. If the plaintiff accepts the settlement offer S^G, the case is resolved and the state in which the defendant gains the right to the present behaviors in dispute. Thus, the plaintiff's discounted present payoff at $t = 1$, net of l_p, from accepting the offer S^G is given by

$$S^G - \frac{\delta w}{1-\delta}. \tag{9}$$

If the plaintiff rejects the offer, both parties proceed to trial. Then, the plaintiff pays the litigation cost c_p, regardless of the final outcome at trial, but the plaintiff expects with probability π^G to win at trial and thus make the preliminary injunction permanent. As a result, the plaintiff's expected payoff from rejecting the offer S^G is

$$-\delta c_p - (1 - \pi^G)\frac{\delta w}{1 - \delta}. \tag{10}$$

Comparing (9) with (10), we find that the plaintiff of type w accepts the offer if and only if the offer amount is equal to or higher than S^G; where S^G is defined by

$$S^G + \delta c_p = \pi^G \frac{\delta w}{1 - \delta}. \tag{11}$$

We can intuitively interpret the above equality condition. The plaintiff's total cost of turning down the settlement offer S^G is the sum of the foregone settlement offer (S^G) and his legal costs (δc_p), which are captured by the left-hand-side of (11). By contrast, the plaintiff's benefit from this choice is the permanent avoidance of his per-period damage w by winning at trial with probability π^G. If the settlement amount is sufficiently large, the plaintiff will prefer accepting the settlement offer to turning it down. In this sense, we can see S^G as the minimum amount needed to make the type-w^G plaintiff agree to the settlement, where w^G is defined as the marginal defendant who is indifferent between agreeing to the settlement at S^G and not, which is expressed as a function of S^G:

$$w^G \equiv \frac{(1 - \delta)(S^G + \delta c_p)}{\delta \pi^G}. \tag{12}$$

Note that the marginal plaintiff w^G is uniquely — one-to-one mapping from w^G

to S^G — determined by the settlement amount, which allows us to treat w^G as the defendant's choice variable for the sake of convenience. In other words, the optimal choice of S^G is a dual problem of the optimal choice of w^G. The plaintiffs with $w \geq w^G$ will prefer rejecting the offer S^G then going to trial, while those with $w < w^G$ will accept the offer S^G.

If the plaintiff makes no motion for injunction, there is no Bayesian updating process: each party does not change its expected winning probability at trial. In a similar manner, by comparing payoffs associated with two possible choices, the marginal plaintiff of type w^N is derived as

$$w^N \equiv \frac{(1-\delta)(S^N + \delta c_p)}{\delta \pi}. \tag{13}$$

The plaintiff with $w \geq w^N$ will prefer rejecting the offer S^N and then go to trial, while the one with $w < w^N$ will accept the offer.

4.3 The defendant's optimal settlement offer

In this subsection, we study the defendant's optimal settlement offers. Needless to say, the defendant will choose the settlement amount that yields him the maximum net surplus. In order to calculate his expected payoff, the defendant first must have a belief about which types of plaintiffs filed for an injunction in the first place and which did not. As we explored in the simple model, one needs to consider two possibilities: the plaintiff with a small damage moves for preliminary injunction or the one with a high damage opts for it.

Let us first consider the case in which the defendant believes that a plaintiff with $w < \tilde{w}$ requests preliminary injunctive relief while those with $w \geq \tilde{w}$ do not, assuming an interior critical type $\tilde{w}$, i.e., $\tilde{w} \in (\underline{w}, \overline{w})$. Then, given a granting of the injunctive relief, the optimization problem that the defendant faces is to minimize his expected loss by choosing S^G,[16] which is given by

$$\min_{S^G} E(L) = P(S^G)S^G + \left(1 - P(S^G)\right)\left(\delta c_d + \pi^G \frac{\delta g}{1-\delta}\right); \tag{14}$$

where $P(S^G) = F(w^G)/F(\tilde{w})$ denotes the conditional probability that the plaintiff will accept the offer S^G given that the requested injunction was granted. Once the offer is accepted, the defendant pays the settlement amount S^G, so the expected settlement payment is equal to $P(S^G)S^G$. If the settlement offer is rejected, the defendant must pay the litigation cost c_d regardless of the trial's outcome and may additionally lose g each period from $t = 2$ on, if he loses at trial. The second term in (14) represents this expected payment through litigation. As previously pointed out, the above problem is a dual one with the choice variable of w^G as follows:

$$\min_{w^G} E(L) = \frac{F(w^G)}{F(\tilde{w})}\left(-\delta c_p + \pi^G \frac{\delta w^G}{1-\delta}\right) + \left(1 - \frac{F(w^G)}{F(\tilde{w})}\right)\left(\delta c_d + \pi^G \frac{\delta g}{1-\delta}\right) \tag{15}$$

The first-order condition with respect to w^G yields the following optimality con-

[16]The problem of maximizing net surplus is the same problem as the one of minimizing the expected loss.

dition:

$$F(w^G)\frac{\pi^G\delta}{1-\delta} + f(w^G)\left(-\delta c_p + \pi^G\frac{\delta w^G}{1-\delta}\right) - f(w^G)\left(\delta c_d + \pi^G\frac{\delta g}{1-\delta}\right) = 0, \quad (16)$$

which shows the trade-off that the defendant faces by adjusting his settlement offer. A marginal increment in the settlement offer (equivalently, a marginal decrease in w^G) results in not only a higher payment to the plaintiff who would accept the settlement offer without such an increase, but also to added settlement expenditures of $-\delta c_p + \pi^G\frac{\delta w^G}{1-\delta}$ with the marginal probability of $f(w^G)$. The first two terms in (16) capture these two effects of the marginal increase in the settlement offer. On the other hand, such adjustment saves the defendant the cost of going to trial with marginal probability of $f(w^G)$, which is the last term in (16). Rearranging (16), we derive the optimality condition for w^G as

$$\frac{F(w^G)}{f(w^G)} + w^G = g + \frac{1}{\pi^G}(1-\delta)(c_p + c_d). \quad (17)$$

Adopting the standard assumption that the distribution F satisfies the monotone hazard rate (MHR) condition, F/f is strictly increasing,[17] the solution for w^G is uniquely determined by (17).[18] For the closed form solution, if we consider a uniform

[17]Roughly speaking, this condition means that the density functions f do not grow too fast, which is satisfied with most of the well-known distribution functions including the uniform, exponential, and normal distributions.

[18]The uniqueness is evidently proved as we notice that the left-hand side of (16) increases in w^G while the right-hand side is a constant.

distribution of w on $[\underline{w}, \bar{w}]$, then w^G is given by a function of all other parameters as:

$$w^G = \frac{1}{2}\left(\underline{w} + g + \frac{1}{\pi^G}\left(c_d + c_p\right)(1-\delta)\right). \tag{18}$$

From either the general expression of (17) or the above closed form solution with a uniform distribution, we can easily ascertain the following intuitive comparative statics.

Proposition 2 *The plaintiff is more likely to settle as litigation costs get large, the defendant's gain from the activities in dispute increases, and the future payoffs are less valued, all other things being equal (i.e.,* $\frac{\partial w^G}{\partial c_p} > 0$, $\frac{\partial w^G}{\partial c_d} > 0$; $\frac{\partial w^G}{\partial g} > 0$; $\frac{\partial w^G}{\partial \delta} < 0$, *respectively).*

Firstly, it is obvious that a plaintiff has a stronger incentive to settle as his litigation cost (c_p) increases, because the option of going to trial gets costly. Secondly, it is interesting that the plaintiff is more likely to agree upon a given settlement offer as either the defendant's payoff gain (g) or the defendant's litigation cost (c_d) increases. The reason is very simple. As the defendant obtains a higher payoff gain from the activities in dispute, the defendant will make a larger settlement offer in order to preserve his gain. Consequently, the likelihood of settlement increases, other things being equal. This logic applies to the litigation cost in the same manner: if the defendant faces a higher litigation cost, he will offer a larger settlement amount because the trial becomes less attractive. Thirdly, if future payoffs are valued more highly (i.e., as δ increases), the plaintiff is more likely to proceed to trial because it becomes more important to win in court and thus prevent his per-period loss from being permanent. In fact, as δ increases, the defendant's settlement offer will increase. However, this channel of such impact passes through the second degree, while for the plaintiff the impact occurs as the first degree.

On the other hand, it is very interesting to study the comparative statics for the errors in the preliminary rulings.

Proposition 3 *The plaintiff is more likely to settle as the preliminary ruling is more likely to commit α error and less likely to commit β error (i.e.,$\frac{\partial w^G}{\partial \pi^G} < 0$, that is, $\frac{\partial w^G}{\partial \alpha} > 0$ and $\frac{\partial w^G}{\partial \beta} < 0$).*

If the preliminary ruling is more vulnerable to an α error that is unfavorable to the plaintiff, the plaintiff is more likely to accept the settlement offer (equivalently, less likely to go to trial). The intuition is as follows. As α error increases, the significance of the message of G as good news becomes large. Thus, the defendant's settlement offer will increase, which results in a larger settlement. In contrast, if the court is more likely to commit a β error, the message of G might have been the result of the court's mistake with a higher likelihood. Therefore, the defendant's settlement offer, other things being equal, is relatively small so that both parties are more likely to go to trial. In this aspect, one remarkable implication of our model for preliminary injunctions is that the nature of court's preliminary ruling and litigants' views on preliminary rulings are important factors that affect the likelihood of settlement and settlement amount, which has not been addressed yet to our understanding.

When we consider the case in which the defendant faces a plaintiff who does not move for injunctive relief, the defendant's optimization is given by

$$\min_{w^N} E(L) = P(S^N)S^N + \left(1 - P(S^N)\right)\left(\delta c_d + \pi \frac{\delta g}{1-\delta}\right); \tag{19}$$

where $P(S^N) = \frac{F(w^N)-F(\tilde{w})}{1-F(\tilde{w})}$ denotes the conditional probability that the plaintiff accepts the offer S^N, conditioned on the fact that the plaintiff did not move for injunction at $t = 1$. From the first-order condition for w^N, we obtain the optimality condition for w^N:

$$\frac{F(w^N) - F(\tilde{w})}{f(w^N)} + w^N = g + \frac{1}{\pi}(1-\delta)(c_p + c_d); \tag{20}$$

where a plaintiff with $\tilde{w} > w \geq w^N$ goes to trial, and otherwise accepts the settlement offer S^N. For a uniform distribution of w on $[\underline{w}, \bar{w}]$, w^N is characterized by

$$w^N = \frac{1}{2}\left(\tilde{w} + g + \frac{1}{\pi}\left(c_d + c_p\right)(1-\delta)\right). \tag{21}$$

4.4 Plaintiff's decision to seek injunctive relief

By definition, the cutoff type plaintiff, $\tilde{w}$, must be characterized by the equality of the expected payoffs with and without the motion for a preliminary injunction. Figure 2-4 shows the plaintiff's initial choice concerning the motion for a preliminary injunction and the subsequent decision whether or not to accept the settlement offer.

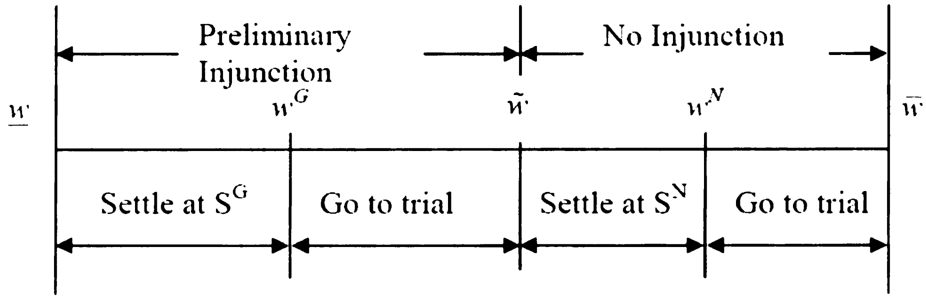

Figure 2-4. The Choices of Plaintiffs I

The choice of making the motion for injunction costs the plaintiff l_p in legal expenses, regardless of the court's eventual preliminary ruling. The injunction is granted with probability $\Pr(G)$, then the plaintiff decides to proceed through litigation to make the preliminary injunction permanent. If the court does not grant the injunction, the plaintiff drops the suit to save the litigation cost. Thus, the plaintiff of type $\tilde{w}$ obtains an expected payoff of

$$-l_p + \Pr(G)\left(-\delta c_p - (1-\pi^G)\frac{\delta \tilde{w}}{1-\delta}\right) + (1-\Pr(G))\,(-\frac{\tilde{w}}{1-\delta}) \tag{22}$$

from moving for a preliminary injunction. If the plaintiff of type $\tilde{w}$ goes directly to trial without requesting a preliminary injunction, he suffers at least the one period damage of $\tilde{w}$, but ends up accepting S^N with $\tilde{w} < w^N$. For this choice, his expected payoff is

$$-\tilde{w} + S^N - \frac{\delta \tilde{w}}{1-\delta}. \tag{23}$$

From the equality of (21) and (22), once again we can think of the trade-offs that the plaintiff faces in terms of the benefit and the cost of moving for preliminary injunctive relief.

$$\Pr(G)(\tilde{w} - \delta c_p) + (1-\alpha)\pi\frac{\delta\tilde{w}}{1-\delta} = l_p + S^N \tag{24}$$

The borderline-type plaintiff prevents his irreparable damage from occurring with probability $\Pr(G)$ when he also pays the litigation cost, because he ends up going to trial in which he can prevent his damage permanently from $t = 2$ onwards with the *ex ante* probability of $(1-\alpha)\pi$. These benefits from the motion for an injunction are captured by the left-hand-side of (24). In contrast, when he moves for a preliminary injunction, his cost is the sum of the legal cost l_p and the foregone settlement amount S^N.[19] With some algebra, we derive the critical plaintiff type to be

$$\tilde{w} = \frac{(1-\Pr(G))\delta c_p - l_p - \frac{\pi\delta}{2(1-\delta)}\left(g + \frac{1}{\pi}\left(c_d + c_p\right)(1-\delta)\right)}{\frac{\pi\delta}{(1-\delta)}\left(\alpha - \frac{1}{2}\right) - \Pr(G)} \tag{25}$$

Comparing the cutoff type of plaintiff in this extended model, $\tilde{w}$, with that in the simple model, w^*, it is easily noticeable that even after we add the stage of the defendant's settlement offer, the intuition that drives the plaintiff to take the move for the injunction works in a similar manner for both cases.

One remarkable difference is, however, that the w^*-type plaintiff — when we do not consider the defendant's settlement offer — goes to trial without the motion for a preliminary injunction, while the $\tilde{w}$-type plaintiff accepts the settlement offer S^N

[19]If we relax the assumption that the plaintiff drops the suit given the message of D, so that we allow him to go to trial, we can calculate the settlement offer S^D from the defendant. In this case, the cost of the motion for injunction is reduced to $l_p + \left(S^N - S^D\right)$. Since this possibility does not change the qualitative results of this article, we keep our present assumption.

at the stage of the defendant's settlement offer. Moreover, in the extended model, we obviously have more factors as the determinants of the critical type of plaintiff. Now the defendant's gain from the allegedly unlawful behavior, indexed by the parameter g, and the defendant's litigation cost, denoted by c_d, come into play — something that could be ignored in the simple set-up.

Proposition 4 *A plaintiff is less likely to file for the preliminary injunction as either the defendant's gain from the behaviors in dispute (g) or the defendant's litigation cost increases (i.e., $\frac{\partial \tilde{w}}{\partial g} < 0$ and $\frac{\partial \tilde{w}}{\partial c_d} < 0$).*

The comparative statics regarding the parameters of g and c_d can also be explained intuitively. As the defendant stands to gain more from the actions in dispute, he is willing to make a higher settlement offer. Knowing this, the plaintiff's incentive to file the motion for a preliminary injunction gets weakened because the settlement S^N becomes more attractive, other things being equal. In a similar spirit, as the defendant's litigation cost increases, the defendant who wants to avoid the expensive litigation process will offer a larger settlement amount. As a result, the defendant at the margin will be more inclined to choose not to move for a preliminary injunction.

One benefit from our two-step analysis from the simple version of model to a more generalized model with the strategic defendant is that it shows how the defendant's uncertainty about the plaintiff's damage level and his interests associated with the litigation are reflected on the settlement offer; and how this, in turn, affects the likelihood that a preliminary injunction is sought.

4.5 The case of high-damage plaintiffs request injunction

In Subsections 4.3 and 4.4, we analyzed the case in which a plaintiff with small damages motions for a preliminary injunction. In this Subsection, we study the other possible equilibrium in which the defendant believes that plaintiffs with $w \geq \hat{w}$ request a preliminary injunction while those with $w < \hat{w}$ do not.

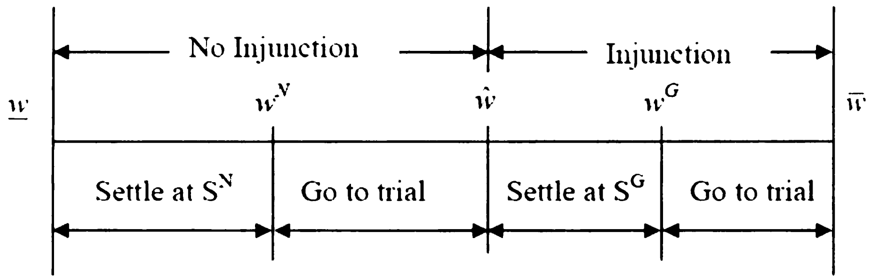

Figure 2-5. The Choices of Plaintiffs II

All the steps in the analysis are made in the exactly same manner as for the previous case. Therefore, we do not repeat all the details here. The defendant's optimization problem when the court grants the injunction is given by

$$\min_{S^G} E(L) = P(S^G)S^G + \left(1 - P(S^G)\right)\left(\delta c_d + \pi^G \frac{\delta g}{1-\delta}\right); \tag{26}$$

where one should note that $P(S^G) = (F(w^G) - F(\hat{w}))/(1 - F(\hat{w}))$. The first-order condition that must be satisfied at w^G is given by

$$\frac{F(w^G) - F(\hat{w})}{f(w^G)} + \hat{w} = g + \frac{1}{\pi^G}(1-\delta)(c_p + c_d); \tag{27}$$

and for the uniform distribution of w on $[\underline{w}, \bar{w}]$, we have the solution for w^G as

$$w^G = \frac{1}{2}\left(\hat{w} + g + \frac{1}{\pi^G}\left(c_d + c_p\right)(1-\delta)\right). \tag{28}$$

When the defendant faces a plaintiff who did not move for injunctive relief, he minimizes the expected loss by choosing w^N:

$$\min_{w^N} E(L) = P(S^N)S^N + \left(1 - P(S^N)\right)\left(\delta c_d + \pi\frac{\delta g}{1-\delta}\right); \tag{29}$$

where $P(S^N) = \frac{F(w^N)}{F(\hat{w})}$.

The optimal w^N satisfies the following condition

$$\frac{F(w^N)}{f(w^N)} + w^N = g + \frac{1}{\pi}(1-\delta)(c_p + c_d). \tag{30}$$

For the uniform distribution of w on $[\underline{w}, \bar{w}]$, we have

$$w^N = \frac{1}{2}\left(\underline{w} + g + \frac{1}{\pi}\left(c_d + c_p\right)(1-\delta)\right). \tag{31}$$

Based on this decision-rule concerning optimal settlement offers, we once again can characterize the cutoff plaintiff of type $\hat{w}$ as

$$\Pr(G)(S^G + \hat{w}) + \delta c_p = l_p + \pi\frac{\delta\hat{w}}{1-\delta}. \tag{32}$$

The borderline-type plaintiff, $\hat{w}$, prevents his per period damage $\hat{w}$ and is offered S^G when the injunction is granted. In addition, he also saves the litigation cost because he will not proceed to trial, regardless of the court's decision on the injunction.[20] These benefits from the choice of moving for an injunction are captured by the left-hand-side of (32). Clearly, the costs associated with the motion for an injunction consist of the legal cost, l_p, and the foregone potential prevention of the damages by winning at trial with probability of π, which are represented by the right-hand-side of (32). Needless to say, the plaintiff will move for the injunction if the benefit of filing for an injunction exceed the cost. The critical type $\hat{w}$ for the uniform distribution is derived as

$$\hat{w} = \frac{l_p - (1 - \Pr(G))\delta c_p - \frac{(1-\alpha)\pi\delta}{2(1-\delta)}\left(g + \frac{1}{\pi G}\left(c_d + c_p\right)(1-\delta)\right)}{\Pr(G) - \frac{\pi\delta}{2(1-\delta)}(1+\alpha)}; \tag{33}$$

where only a plaintiff with $w \geq \hat{w}$ moves for a preliminary injunction.

5 Discussion of Further Extensions

5.1 The British rule in the allocation of litigation costs

Each party bears his own litigation costs regardless of the trial's outcome under the American fee rule, which has been assumed throughout the paper. Under the alternative British rule, contrastingly, the losing party bears all the litigation costs. The change in the governing rule in the allocation of litigation costs affects on the

[20]Recall, if the injunctive relief is not granted, the plaintiff will drop the suit.

players' payoffs, which in turn has an impact on the decisions of the settlement offers and the motion for requesting a preliminary injunction.

More specifically, a plaintiff who goes directly to trial without filing for an injunction does not need to pay his litigation cost c_p if he wins the case, whereas he additionally bears the defendant's litigation cost c_d with his loss at trial. That is, the rule change—from American rule to British rule—has the net impact of $\pi^R(-\delta c_p) + (1-\pi^R)(\delta c_d)$ on the expected payoff of going to trial, where $R \in \{G, D\}$. The likelihood of a filing for a preliminary injunction and the likelihood of a settlement hinge upon the relative magnitude of litigation costs, the prior and posterior beliefs, which do not allow us to have a clear-cut way to describe the effect of the rule change for legal cost allocation.

5.2 Optimistic- and pessimistic bias

In our models we assume that both parties share the same prior belief about a case, i.e., $\pi = \pi_p = \pi_d$. However, when a party has private information containing some information to infer the distribution of π differently from the other party, the prior may differ across the agents. In addition, when we consider the optimistic or pessimistic bias toward the quality of a case when a particular message is received through the rule on the preliminary injunction, the posteriors may become different across agents. That is, we can think of the case such that $\pi_i^R \neq \pi_j^R$ for $i, j = d, p$, $i \neq j$, and $R \in \{G, D\}$. Fortunately, in even such a case, our model can be easily modified to see how these changes affect the likelihood of the motion for a preliminary injunction, the settlement amount, and litigation decisions, by just distinguishing the defendant's beliefs and the plaintiff's beliefs with the use of subscripts. Of course, this modification yields a lot of possibilities depending on the relative magnitude of each party's prior.

5.3 The judgment favoring social efficiency

So far in our models we have assumed that the court's discretion is based on only the state in which the case resides: if the state is valid, the court in principle must be favor of the plaintiff; otherwise, it must be favor of the defendant. Another interesting point is that the court (or, judge) may consider the public interest and total efficiency as important factors for judgment in addition to the case merits.[21] One way of approaching this is that the court's judgment can be described as a function of the defendant's gain and the plaintiff's damage. Specifically, we may think of a function $\pi_C = \pi_C(g - w)$ with $\pi_C' < 0$. Then, for the case with high damages and low gains, the court is more likely to be in favor of the plaintiff, while for the opposite case with low damages and high gains, the court will more likely be in favor of the defendant. Roughly speaking, this consideration may increase our social welfare because then the plaintiff's damage is better protected and possible nuisance suits are less likely to happen. Of course, once again the relative magnitude of the plaintiff's and the defendant's litigation costs will affect how such consideration impacts social welfare.

[21]For instance, the Judge Sydney H. Stein in the Plavix case wrote in his ruling that "Although there are competing and substantial public interests at stake on both sides of this litigation, the balance of those competing public interests slightly favors Sanofi. The public interest in lower-priced drugs is balanced by a significant public interest in encouraging the massive investment in research and development that is required before a new drug can be developed and brought to market."

6 Concluding Remarks

In this article, the court's ruling on a motion for a preliminary injunction is viewed as a unique (noisy) informative message concerning the likely final judgment in addition to being the only channel through which the plaintiff's irreparable damage can be prevented. In this sense, the plaintiff's motion for preliminary injunctive relief is in part an information gathering activity. In this sense, we seek a new role for understanding preliminary injunctions as methods of information transmission, which complements the work of Lanjouw and Lerner (2001) in which the preliminary injunction is a device of raising rivals' costs.

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Chapter 3. The Strategic Tying with Consumer Switching Costs

In this chapter, I study a new rationale for the tying practice between complementary goods in the presence of switching costs. I find that the monopolist may strategically commit to tying in order to capture the dynamic rents associated with those who have relatively high switching costs, especially if the monopolist has an inferior complementary product to the rival firm's complementary one. I also show that the monopolist's tying decreases both consumer surplus and social welfare relative to the decision of no tying, because switching costs are endogenously incurred and the consumers end up using an inferior good.

1. Introduction

Because of Microsoft's behavior and a series of the associated court cases, a dominant firm's tying[1] strategy has gained considerable attention in and out of economics. In recent lawsuits against Microsoft's tying between its almost monopolized Windows operating system and other application software such as Internet Explorer, Window Media Player, and Window messenger, tying allegedly impairs competition on the merits because it makes consumers bear additional costs to search, download, install, and learn other products. Unfortunately, however, little attention been has given to this issue. This paper stud-

[1] Tying refers to the behavior of selling one product (the tying product) conditional on the purchase of another product (the tied product). J. Tirole (2005, p.7) distinguishes tying and bundling as follows: "... the tied product is available on a stand-alone basis under tying, but not under bundling." Here both terms are interchangeable because this distinction is irrelevant if a tied-good is valueless without a tying-good.

ies how the monopolist can use tying strategically in the presence of consumer switching (learning, or installation) costs, and its effect on consumers and competing firms.

In a simple two-period model, I find that the monopolist may strategically commit to tying his two complementary goods especially if his own non-monopolized product is inferior to alternatives. The monopolist must offer a more attractive price to sell his own inferior non-monopolized good on a stand-alone basis because he needs to compensate for expectedly higher switching costs as well as for product inferiority. As a result, if the price after the monetary compensation falls into negative, then tying becomes the only effective way for the monopolist to sell its products in earlier marketing.

By doing so, the monopolist can earn more profits from those who have relatively high switching costs in repeated sales. If the dynamic rents from these "loyal" consumers[2] exceeds the loss from not allowing a superior complementary product used together, the monopolist will have the incentive to tying its products.

In addition, I show that the tying decision may decrease both consumer surplus and social welfare because it endogenously raises switching costs and makes the consumers use an inferior good. Of course, we must be extremely cautious in interpreting this result because such prediction is from the specific framework posited in this paper: it involves several crucial assumptions and controls for many other factors possibly driving the tying decision. However, ceteris paribus, this study provides a theoretical support for the concern about the negative effects of tying on the rivals and consumers with switching costs.

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[2] "Switchers" are in a sense penalized relative to "loyal" consumers, those who repeatedly purchase from the same firm. See Chen (1997) and Klemperer (1987a, 1987b, 1995), etc. for references.

In fact, there have been various justifications for why a firm wants to tie its products: for examples, tying may increase efficiency and assure quality better; a firm may use tying to evade price controls or to exercise price discrimination. Nevertheless, tying has been one of the most controversial strategic actions that a dominant firm can take to manipulate the competitive environment in its favor. This has been mainly due to the "leverage theory," which contends that a monopolist in one market can use its monopoly power to monopolize other markets as well. This logic has played against monopolists in the history of U.S. antitrust cases.[3]

However, a group of economists known as the Chicago School[4] successfully showed that such an argument is logically vulnerable. Their intuition is that a monopolist cannot have more profits with tying because it can already extract the entire monopoly rent through adjusting the price of its monopolized primary product.[5]

To this criticism, Whinston (1990) showed that a monopolist can increase its profit with the commitment to tying for independent, differentiated goods in oligopoly market structure. The commitment to tying leads to the more intensified competition in the tied good market, because with tying the monopolist cannot sell the monopolized tying-good on a stand-alone without the non-monopolized tied-good. Therefore, the potential entrant would rather choose not to enter the market because of the decreased post-entry profit. This mechanism has been known as strategic foreclosure.

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[3] Such cases include *United States* vs. Terminal Railroad Association of St. Lewis, 224 U.S. 383 (1912); International Business Machines vs. *United States*, 298 U.S. 131 (1936); Standard Oil vs. *United States*, 337 U.S. 293(1949).

[4] As well-known references, see Director and Levi (1956), Bowman (1957), Posner (1976), and Bork (1978), etc.

[5] This argument has also been known as "one monopoly profit theory."

It is noteworthy that the intuition of the strategic foreclosure does not directly invalidate the Chicago School's logic. As emphasized in Whinston (1990), the Chicago School's criticism generally holds for complementary goods if the monopolized good is essential for all uses of the non-monopolized good.[6] Certainly, if there is any use for the non-monopolized good without the monopolized good, tying once again can emerge as a profitable strategy even for complementary goods.

For such examples, Whinston suggested two situations: when there exists an inferior and competitively supplied alternative primary component in the market, when there is a second use for the non-monopolized product such as replacement parts market. He showed that the monopolist once again might prefer strategic foreclosure in such circumstances.

This paper contributes to this literature by providing another situation where tying can be a profitable strategy even for complementary goods. Remarkably, however, tying in this paper does not necessarily result in strategic foreclosure. In other words, the rival firm can sell its product in period two even under tying regime.[7] In this sense, this paper complements other studies showing the incentive to tying without resorting to strategic foreclosure.

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[6] Carlton and Waldman (2005) show that this is not true for durable-goods where product upgrades can be important issue. Interestingly, they show consumer switching costs amplify the incentive to tying. This paper and theirs have something in common in that both study the tying incentive for complementary goods in the present of consumer switching costs.

[7] If the monopolist is the sole producer in the primary market in both periods, then it is only twice repetition of the one-stage game where the Chicago School's one monopoly profit theory exactly fits. That is, if the rival firm cannot produce the primary component in period two, the monopolist will not tie its products.

Choi (2004) showed that we can see tying as a strategic commitment to a more aggressive R&D investment, which reduces rivals' R&D incentives in the tied good market. The monopolist can make a higher overall profit because of a higher dynamic rent in the tied-good market in spite of the loss from initially intensified price competition.

Church and Gandal (2000) studied the possibility of a profitable vertical integration in the hardware-software system market. In their model, vertical integration and the firm's decision to make its software incompatible with its rival's hardware can occur without monopolizing the hardware market. They showed that if hardware technologies are sufficiently differentiated and the marginal value of a software variety is small enough, the rival hardware firm has a positive market share because of the consumers who have relatively strong preference for its differentiated hardware. Since we can regard the irreversible tying as a firm's vertical integration with a subsequent incompatibility decision, their study provides another case of a profitable tying without excluding rivals.[8]

The remainder of this paper proceeds as follows. Section 2 describes the model. Section 3 analyzes the market equilibrium with tying and without it. Then, Section 3 explains why and when the monopolist has the incentive to the commitment to tying, and how tying affects on the rival. Section 5 offers the welfare analysis and discusses related implications. Lastly, Section 6 closes the paper. Proofs of lemmas and propositions are in Appendix.

[8] Note that the same term "foreclosure" has different meaning in their paper. They defined that foreclosure occurs when an integrated firm – a merged hardware-software firm – makes its software incompatible with a rival hardware. In contrast, in this paper "foreclosure" means the situation where one firm is excluded from the market because of its low profitability.

2. The Model

Consider two products, A and B, which must be used together as a system in one-to-one proportion. There are two periods. A continuum of consumers, whose measure is one, has a unit demand for each component in each period: each consumes either one or zero unit of the system good. That is, each consumer faces a repeated purchase in period two.

In period one, there is a sole producer in market A; two firms compete in prices in market B. In period two, however, the rival firm in market B enters market A.[9] The monopolist in market A and the other firm are denoted as firm 1 and firm 2, respectively. As natural notations, A1 and A2 refer to the primary component produced by firm 1 and firm 2, respectively. Similarly, B1 and B2 refer to the complementary component of firm 1 and firm 2, respectively. Assume that both firms have the same constant unit-production cost c_A and c_B for each component.

Assume that A1 and B1 are inferior to A2 and B2 by the monetary value of Δ_A ($\geq$0)[10] and Δ_B ($\geq$0), respectively. Each consumer derives a value V from consuming A1 and B1 together. Obviously, he/she enjoys a higher value $V+\Delta_B$, $V+\Delta_A$, or $V+\Delta_A+\Delta_B$ from the consumption of A1+B2, A2+B1, or A2+B2, respectively. The value V is sufficiently high to ensure that every consumer ends up consuming at least one system in equilibrium.

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[9] We can think of the case in which the monopolist's primary good is protected by patents that expire at the beginning of the second period. Unlike Carlton and Waldman (2002), the entry and exit of a rival primary good producer are not issue in this model.

[10] The qualitative result of this paper is robust to relaxing the superiority of A2 over A1. I make this assumption for more general description of the model and the ease of explaining the intuition.

Each consumer faces an individual switching cost s, uniformly distributed over [0, 1], when he/she uses the product that was not used previously.[11] I assume that each consumer has the same switching cost for both components, A and B. That is, if a consumer switches both components in the second period, he/she needs to bear the switching cost twice.[12] Following the switching-cost literature, the consumers realize their switching costs only after the first period.[13] This assumption implies that all the consumers are identical in period one; they become heterogeneous in the repeat-purchase according to their personal switching costs.

The timing of the game is as follows. At the beginning of period one, the monopolist makes a decision whether to tie its products irreversibly through technological arrangements in the production process or in product design. That is, with tying the consumer cannot use B2 with A1 together. After tying decision, two firms engage in price competi-

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[11] For instance, it is costly to try different software and attain a similar level of skill as for the previous one. For example, a consumer having previously used MS Word and MS Excel will pay some costs in switching to Word Perfect and Lotus. This cost may vary across consumers (or users) because of they differ in the rate and effort level in learning process. See Klemperer (1995) for abundant examples and various interpretations for switching costs.

[12] More generally, switching costs for each product can be independent so that we can think of the total switching cost as s_A+s_B, where s_A, $s_B \in [0, 1]$. Then, the demand for each consumer must be represented two-dimension in the space of s_A and s_B, which drives the analysis much complicated. In my opinion, the simple specification in the model serves to avoid such complexity with the key intuition still alive.

[13] For references, Chen (1997), Gehrig and Stenbacka (2004), Klemperer (1987), etc. In fact, if consumers are aware of their own switching cost before the first transaction, the analysis becomes severely complicated. This is because firms' choice of tying and pricing are affected by the consumers' strategic motives, which in turn has influence upon consumers' choices. Aside from these analytical complications, consumers may not know their ex post switching costs due to the presence of uncertain factors in the learning process.

tion. In period two, once again the firms compete with prices under the same tying decision made in period one. This assumption reflects that tying decision is a long-term consideration compared to the sales in each period. Finally, consumers and firms have the same discounting factor normalized to one. As a rule, the analysis proceeds backwardly for the subgame-perfect Nash equilibrium.

3. The Equilibrium Analysis: with tying and without tying

3. 1 Tying regime

To begin with, let me analyze the case in which the monopolist commits to an irreversible tying between A1 and B1 so that every consumer buys the system (A1+B1) in period one. Assuming that tying decision is effective throughout both periods, neither A1 nor B1 is available on a stand-alone basis even when consumers make a repeat purchase. Thus, each consumer faces two choices in period two: buying the same bundle (A1+B1) from firm 1 or buying (A2+B2) from firm 2.

Consumers can avoid their switching costs if they use the same system as in period one, while by doing so they end up using the inferior system. The marginal type of consumer, denoted by $\tilde{s}$, who is indifferent between the two choices must satisfy the following equation

$$V - P_1 = V + \Delta_A + \Delta_B - P_2 - 2\tilde{s} \qquad (1)$$

where P_i denotes the total price of a system composed of two components produced by firm i, for i=1, 2.[14] The left-hand side in equation (1) measures the net utility from the choice of (A1+B1), while the right-hand side is for switching to the choice of (A2+B2) that yields better quality with doubled switching costs. By solving the equation (1) for $\tilde{s}$, the threshold consumer $\tilde{s}$ is given by

$$\tilde{s} = \frac{\Delta_A + \Delta_B + P_1 - P_2}{2}. \qquad (2)$$

Since the consumers with $s \le \tilde{s}$ will prefer switching to the choice of (A2+B2), the demands for firm 1 and firm 2 are $1-\tilde{s}$ and $\tilde{s}$, respectively. Substituting these demand functions into each firm's profit expression, then maximizing with respect to each firm's bundle price yields the following reaction functions

$$P_1 = \frac{2 - \Delta_A - \Delta_B + c_A + c_B + P_2}{2} \qquad P_2 = \frac{\Delta_A + \Delta_B + c_A + c_B + P_1}{2}. \qquad (3)$$

By simultaneously solving two response functions, we get the equilibrium prices as

$$\tilde{P}_1 = c_A + c_B + \frac{4 - \Delta_A - \Delta_B}{3} \qquad \tilde{P}_2 = c_A + c_B + \frac{2 + \Delta_A + \Delta_B}{3}. \qquad (4)^{15}$$

For such equilibrium prices, the marginal consumer is

$$\tilde{s} = \frac{1}{3} + \frac{\Delta_A + \Delta_B}{6} \qquad (5)$$

[14] P_2 is equivalent to the sum of the price of A2 and that of B2, i.e., $p_{A2} + p_{B2} = P_2$. Two components virtually constitute a unit of bundled-product because consumers always need both to consume one system.

[15] Variables with a tilde denote the tying regime.

where the interiority of the solution is ensured with the condition $\Delta_A + \Delta_B < 4$. As expected, $\tilde{s}$ increases in Δ_A and Δ_B: more consumers will switch to the highly superior system.

Finally, we can compute the second period profit for each firm as

$$\tilde{\pi}_1 = \frac{(4-\Delta_A-\Delta_B)^2}{18} \qquad \tilde{\pi}_2 = \frac{(2+\Delta_A+\Delta_B)^2}{18}. \tag{6}$$

which shows the intuitive result that firm 1's profit decreases in Δ_A and Δ_B, but firm 2's profit increases in either Δ_A or Δ_B, or both.

The monopolist, firm 1, can exploit the entire surplus from the consumers in period 1 and earns the profit of $(V - c_A - c_B)$, because we consider two complementary products. Consequently, firm 2 earns no profit in period one because it cannot offer the component A until the second period. Summing the profits over both periods, the total profits for each firm are given by

$$\tilde{\Pi}_1 = (V - c_A - c_B) + \frac{(4-\Delta_A-\Delta_B)^2}{18} \qquad \tilde{\Pi}_2 = \frac{(2+\Delta_A+\Delta_B)^2}{18}. \tag{7}$$

3. 2 No Tying Regime

Now let me study the case in which the monopolist did not commit to tying arrangement. Then, consumers can freely consume any available combination in both periods.

3. 2. 1 The subgame with B1 sold in period one

Suppose that the monopolist sold his inferior product B1 in period one. Then, a consumer facing the repeated transaction will have three choices: repeating the same consumption, (A1+B1); changing either product A or product B, (A1+B2) or (A2+B1); or changing both brands, (A2+B2). Let me assume $\Delta_B \geq \Delta_A$ in order to reduce the number of cases to analyze. Then, consumers will prefer (A2+B1) to (A1+B2) because they never switch to an inferior system at the same switching cost.

Once again, we can characterize the threshold types by comparing the utilities for each choice. The consumer who is indifferent between (A2+B2) and (A1+B2), denoted by $\hat{s}$, satisfies the following equation

$$V + \Delta_A + \Delta_B - p_{A2} - p_{B2} - 2\hat{s} = V + \Delta_B - p_{A1} - p_{B2} - \hat{s}. \tag{8}$$

The left-hand-side of equation (8) is the net surplus when a consumer switches to (A2+B2) from (A1+B1), while the right-hand-side captures the net surplus when a consumer switches to (A1+B2). Similarly, the consumer who is indifferent between (A1+B2) and (A1+B1), denoted by $\breve{s}$, is characterized by the equation

$$V + \Delta_B - p_{A1} - p_{B2} - \breve{s} = V - p_{A1} - p_{B1}. \tag{9}$$

From (8) and (9), two thresholds are

$$\hat{s} = \Delta_A + p_{A1} - p_{A2} \qquad \breve{s} = \Delta_B + p_{B1} - p_{B2}. \tag{10}$$

Assuming $\hat{s} \leq \breve{s}$ that is indeed satisfied in equilibrium, we can derive the demands of the consumers in period two: those with $s \leq \hat{s}$ choose (A2+B2) by changing both components, those with $\hat{s} < s \leq \breve{s}$ choose (A1+B2) by changing only the complementary component, and those with $s > \breve{s}$ do not change either product because of their relatively high costs of switching.

3. 2. 2 The subgame with B2 sold in period one

Suppose the consumers bought the superior product B2 in period one. Then, they can make any choice in period two: repeating the same choice (A1+B2), buying (A2+B2) with changing the primary component, the choice of (A1+B1) by switching back to the *inferior* B1, or changing both brands with doubled switching costs into (A2+B1). However, the option of (A1+B1) is never chosen with the condition $\Delta_B \geq 1$, and the choice of (A2+B1) is also dominated by other choices in equilibrium.[16] Since these two options are not interesting – besides, the analysis becomes much simple – hereafter we restrict our attention to the first two cases, assuming $\Delta_B \geq 1$.

The consumer who is indifferent between (A1+B2) and (A2+B2), denoted by s^*, satisfies the condition of

$$V + \Delta_B - p_{A1} - p_{B2} = V + \Delta_A + \Delta_B - p_{A2} - p_{B2} - s^* . \quad (11)$$

The left-hand-side in equation (10) measures the net surplus of repeating the choice of (A1+B2), and the right-hand-side captures the net surplus of switching the primary component to A2. The marginal consumer, s^*, is given by

$$s^* = \Delta_A + p_{A1} - p_{A2} . \quad (12)$$

Since those with $s \leq s^*$ will choose (A2+B2), the demands for firm 1 and firm 2 are $1 - s^*$ and s^*, respectively. The left- and right panels in Figure 3-1 show the choices of the consumers when B1 and B2 are sold in period one, respectively.

[16] Specifically, in equilibrium no consumer would switch back to the inferior combination (A1+B1) if and only if $\Delta_B \geq 1$. The explanation for this outcome is as follows. Note that the monopolist is still a "dormant" seller in market B who can produce B1 at cost c_B, even if B2 sold in period one. The consumer who is indifferent between keep buying B2 and switching to B1 is the type $p_{B2} - c_B - \Delta_B$ in terms of its switching cost. Thus, the demand for B2 is $1 - p_{B2} + \Delta_B + c_B$. The profit maximization problem for this case yields the equilibrium price for B2 as $c_B + (1 + \Delta_B)/2$, the according marginal type is $(1 - \Delta_B)/2$. Consequently, no consumer will switch to B1 if and only if $\Delta_B \geq 1$.

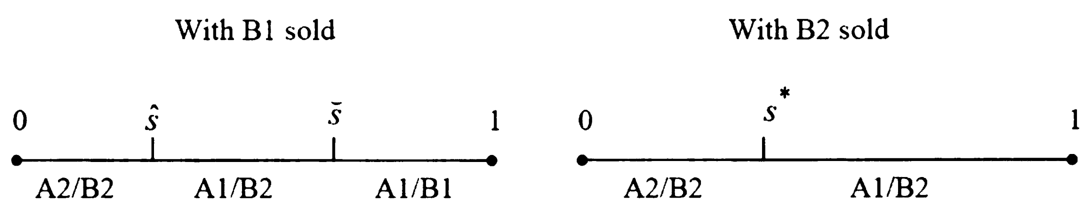

Figure 3-1. Consumer choices in period two

3. 2. 3 The prices and profits in equilibrium

Now we are ready to derive the equilibrium prices in period two. Let σ denote the share of consumers who bought B1 from firm 1, the monopolist in market A in period one. The second-period profit expression for firm 1 follows as

$$\pi_1 = \sigma[(p_{A1} - c_A)(1-\hat{s}) + (p_{B1} - c_B)(1-\breve{s})] + (1-\sigma)(p_{A1} - c_A)(1-s^*). \quad (13)$$

Firm 1 will sell his primary component A1 to those with $s > \hat{s}$ who bought B1 previously, while he will sell A1 to those with $s > s^*$ who did not buy B1 in period one.[17] In addition, firm 1 earns the profit by selling his B1 to those with $s > \breve{s}$ who bought B1 in period one. In a similar manner, firm 2's profit expression when the monopolist did not commit to tying is given by

$$\pi_2 = \sigma[(p_{A2} - c_A)\hat{s} + (p_{B2} - c_B)\breve{s})] + (1-\sigma)[(p_{A2} - c_A)s^* + (p_{B2} - c_B)]. \quad (14)$$

Substituting demand functions into each firm's profit function, then maximizing with respect to each firm's prices, we have following reaction functions for the primary prices

$$p_{A1} = \frac{1 - \Delta_A + p_{A2} + c_A}{2} \qquad p_{A2} = \frac{\Delta_A + p_{A1} + c_A}{2}, \quad (15)$$

[17] As shown in (19), $\hat{s}$ and s^* become equal. Thus, the expression (13) can be simplified into $\pi_1 = (p_{A1} - c_A)(1-\hat{s}) + \sigma(p_{B1} - c_B)(1-\breve{s})$.

which are independent of σ. By solving response functions, we can find the Nash equilibrium prices as

$$p_{A1}^{*} = c_A + \frac{2-\Delta_A}{3} \qquad p_{A2}^{*} = c_A + \frac{1+\Delta_A}{3} \tag{16}$$

Recall that all the consumers are *ex ante* homogeneous so that there would be either $\sigma = 1$ or $\sigma = 0$, unless both firms post the same price for the complementary product in period one.[18] For the case of $\sigma=1$, we can derive the response functions for the complementary prices as

$$p_{B1} = \frac{1-\Delta_B + p_{B2} + c_B}{2} \qquad p_{B2} = \frac{\Delta_B + p_{B1} + c_B}{2} \tag{17}$$

The equilibrium prices are easily derived and given by

$$p_{B1}^{*} = c_B + \frac{2-\Delta_B}{3} \qquad p_{B2}^{*} = c_B + \frac{1+\Delta_B}{3} \tag{18}$$

Let me assume $\Delta_A \le 2$ and $\Delta_B \le 2$ so that the profit margin is nonnegative in (16) and (18). The thresholds in equilibrium are identified as

$$s^{*} = \frac{1+\Delta_A}{3} \qquad \hat{s} = \frac{1+\Delta_A}{3} \qquad \hat{\hat{s}} = \frac{1+\Delta_B}{3}. \tag{19}$$

Finally, the equilibrium profit for the case of $\sigma=1$ are derived as

$$\pi_1^{*} = \frac{(2-\Delta_A)^2}{9} + \frac{(2-\Delta_B)^2}{9} \qquad \pi_2^{*} = \frac{(1+\Delta_A)^2}{9} + \frac{(1+\Delta_B)^2}{9} \tag{20}$$

where the single asterisk is for the case of $\sigma=1$.

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[18] This is because firms are asymmetric in period one in that firm 1 is the monopolist in market A. This differs from other articles that analyze a symmetric interior solution for the market share in period one, i.e., $\sigma \in [0, 1]$. See e.g. Caminal and Matutes (1990), Chen (1997), Gehrig and Stenbacka (2004), Klemperer (1987a, 1987b), Marinoso (2001), and Fudenberg and Tirole (2000) for two symmetric firms.

Similarly, for the case of σ=0 we can derive the following equilibrium prices

$$p_{B1}^{**} = c_B \qquad p_{B2}^{**} = c_B + \frac{1+\Delta_B}{2}. \tag{21}$$

For these equilibrium prices, each firm has the profit as followings:

$$\pi_1^{**} = \frac{(2-\Delta_A)^2}{9} \qquad \pi_2^{**} = \frac{(1+\Delta_A)^2}{9} + \frac{1+\Delta_B}{2} \tag{22}$$

where the double asterisk denotes the case of σ=0.

3. 2. 4 Total profits without tying

To identify when the monopolist has the incentive to tying, we need to compare the overall profits in two-period total with and without tying. Note that the monopolist can always claim the entire surplus in period one through the price of his monopolized good. That is, the intensified price competition in market B does not make the monopolist worse off. [19] However, the monopolist cannot capture the surplus Δ_B generated by the superiority of B2 if he sells the inferior product B1. Remarkably, I deliberately assume that the monopolist can capture the entire surplus Δ_B generated by the presence of B2 in order to make the most disadvantageous situation for the monopolist's tying decision.

Using the previous derivations, we can specify the overall profits of firm 1 when B1 and B2 are sold in period one respectively as

[19] This result is quite different from the outcome of standard switching cost literature in that the monopolist firm does not compete away his surplus in the form of a low price in the initial competition.

$$\Pi_1^* = (V - c_A - c_B) + \left[\frac{(2-\Delta_A)^2}{9} + \frac{(2-\Delta_B)^2}{9}\right]$$

$$\Pi_1^{**} = (V - c_A - c_B) + \Delta_B + \left[\frac{(2-\Delta_A)^2}{9}\right]. \tag{23}$$

Firm 2 cannot earn any profit in period one under the assumption that the monopolist captures the entire surplus, even if it successfully sold B2 product. However, firm 2 can sell its B2 to the entire consumer in period two, which was not the case if B1 sold in the previous sales. The overall profits of firm 2 when B1 and B2 are sold in period one is respectively given by

$$\Pi_2^* = \left[\frac{(1+\Delta_A)^2}{9} + \frac{(1+\Delta_B)^2}{9}\right] \qquad \Pi_2^{**} = \left[\frac{(1+\Delta_A)^2}{9} + \frac{1+\Delta_B}{2}\right] \tag{24}$$

4. The Incentive to tie and its effect on the competitor

The monopolist had no reason for tying its complementary products if there had been only one transaction, which is the Chicago School's argument. With tying, the monopolist only loses the benefit from a superior complementary product used together with his monopolized good A1. However, we cannot apply this logic to a two-period setting with consumer switching costs where the early sales of B1 may cause the consumers who have relatively high switching costs to choose B1 over B2 in repeat transactions. That is, now the monopolist can earn some benefits from inducing the consumers to buy his inferior complementary good B1.

More specifically, the monopolist additionally earns $\pi_1^* - \pi_1^{**} = (2-\Delta_B)^2/9$ in period two if he sells B1 in period one. Since, for this case, the monopolist cannot capture the surplus Δ_B generated by the superiority of B2 in period one, the monopolist would like to sell his own complementary product B1 unless Δ_B – the cost of tying – is enough large, which is summarized in the following lemma.

Lemma 1. The monopolist has a higher profit by selling his own inferior product B1 in period one than when the rival firm sells B2, if and only if $\Delta_B \leq \overline{\Delta}_B = (13 - 3\sqrt{17})/2 \approx 0.315$.

It is noteworthy that the monopolist's *willingness* to sell his product B1 does not necessarily imply that he *can* do so. It is the consumers who decide to buy which firm's complementary product with no tying. Accordingly, the monopolist must compensate for any utility loss associated with the inferiority of his product B1 to induce the consumers to choose B1 over B2.

If the consumers are *myopic* (naïve, or short-sighted) in the sense that their purchase decision is based on the first period utility only, the monopolist could induce them to buy B1 with a price cut of Δ_B relative to the rival. On the other hand, if the consumers are *rational* (sophisticated) so that they consider the effect of the switching costs on later choices, he needs to compensate for expectedly higher switching costs as well as for product inferiority.

In order to compute how much the monopolist has to lower its price of B2 relative to the price of B1, let me compare the expected total payment per consumer for two distinct subgames.

If a consumer purchased B1, he/she will switch to B2 with probability of $(1+\Delta_B)/3$ but buy B1 repeatedly with probability $(2-\Delta_B)/3$. Thus, the expected (second period) total payment is given by

$$\frac{(2-\Delta_B)}{3}\left(c_B+\frac{2-\Delta_B}{3}\right)+\frac{(1+\Delta_B)}{3}\left[\left(c_B+\frac{1+\Delta_B}{3}\right)+\int_0^{(1+\Delta_B)/3} s\,ds-\Delta_B\right]. \quad (25)$$

The first term (including the parenthesized term) in expression (27) represents the expected payment for the repeat purchase of B1, the product of the probability for that case and the equilibrium price of B1. The second term measures the expected payment when a consumer switches to B2. For this event, we must consider three factors: the price of B2, the first term in the bracket; the expected switching cost, the second integrated term; and the quality difference, the last term. Note that we need to subtract Δ_B to assess the *effective* payment for B2 since a consumer switching to B2 can use a superior product.

In contrast, if a consumer purchases B2 in period one, recall that he/she will not switch back to B1 with the assumption of $\Delta_B \geq 1$. For this case, the total payment is

$$c_B+\frac{1+\Delta_B}{2}-\Delta_B \quad (26)$$

where we subtract Δ_B for the same reason explained above. With some algebra, we can compute the difference between (22) and (23) as $(\Delta_B^3-3\Delta_B^2+4)/54$ denoted by Z hereafter for notational brevity. We can interpret Z as the additional compensation needed for inducing the sophisticated consumers to choose B1 over B2. In summary, the monopolist must set the price of B1 lower than that of B2 by at least $Z+\Delta_B$ to sell his inferior complementary product initially on a stand-alone basis.

Lemma 2. The monopolist will sell his inferior product B1 if $q_1 < q_2 - Z - \Delta_B$ where q_i denotes the price of Bi in period one for $i = 1, 2$.

The next question that arises naturally is what pricing strategy firm 2 will take for its complementary product. Recall that firm 2 will have the higher profit by $\Delta\pi_2 = \pi_2^{**} - \pi_2^{*} = (5\Delta_B - 2\Delta_B^2 + 7)/18$ in period two by selling its B2 product in period one. As a result, firm 2 is willing to offer up to the price $c_B - \Delta\pi_2$ for B2. This implies that the monopolist must lower the price of B1 even below the level of

$$(c_B - \Delta\pi_2) - Z - \Delta_B = c_B - \frac{(\Delta_B^3 - 9\Delta_B^2 + 69\Delta_B + 25)}{54} \tag{27}$$

to become the first-period complementary seller.

Interestingly and importantly, the price of B1 needed for the sales of B1 in period one may fall into a negative level. This means that if we do not allow negative pricing[20], then the monopolist may not be able to sell his B1 without resorting to tying practice.

This result explains the real-world behavior of the monopolist. As easily noticed, if firm 2 can decrease the price of B2 at near-zero or zero (give-away), the monopolist has no choice but to provide his inferior complementary good for free in order to sell it without tying. In reality, Microsoft's web-browser Internet Explorer has been provided at zero price. If the give-away is not enough, the monopolist may offer other benefits to capture

[20] The assumption that prices must be non-negative has been widely adopted. For examples, Farrell and Gallini (1988) justify the non-negativity assumption by mentioning the problem of opportunism that people could take products at a negative price and use them for landfill. As for more closely related literature, Carlton and Waldman (2005) also analyze the monopolist's incentive to use tying in durable goods with non-negative prices assumed.

the initial market share. Therefore, we can predict that the monopolist will resort to tying that allows him to sell B1 effectively in period one.

As a special case in the analysis, let me consider the case where the marginal production cost is zero, i.e., $c_B = 0$, which fits to computer software industry. Then, we can easily see that the value in (24) is always negative for any $1 \le \Delta_B \le 2$. By the continuity argument, the monopolist's price-cutting cannot make any sales of B1 for a sufficiently low c_B without tying.

Lemma 3. For a sufficiently low production cost of c_B, tying is the only effective way to sell both products A1 and B1 to all consumers in the first period.

The reason is that the rival firm will decrease its price enough to make the consumers choose B2 over B1, even if B1 is a give-away product. Of course, in reality we often pay for superior goods and services even if there are give-away ones.

Based on the lemmas we have discussed, we can derive the following result.

Proposition 1. (a) The monopolist has no reason for tying its products if he can sell its B1 without commitment to tying. (b) If the monopolist cannot sell B1 without tying because of the non-negativity constraint, then tying can be more profitable than no tying: precisely, if and only if $\Delta_B < 13 - \Delta_A - \sqrt{2\Delta_A^2 - 26\Delta_A + 161}$ (which is the solution for $\tilde{\Pi}_1 > \Pi_1^{**}$).

The part (a) in the above proposition tells us that the monopolist will not use a tying strategy if he can sell his B1 product without tying. This is because tying is a commitment to more aggressive competition so that the firm who decides to tie its products also suffers from the intensified competition. As part (b) says, however, the monopolist will use a tying strategy if consumers do not choose his inferior product B1 even at a near-zero or zero price because there exists an alternative B2 which could be also available at a low or zero price.

How does the tying decision affect firm 2? This question can be easily addressed with the comparison of $\tilde{\Pi}_2$ and Π_2^{**}.

Proposition 2. The rivial, firm 2, prefers no tying to tying regardless of the size of the quality superiorities.

Under tying regime, firm 2 faces more aggressive bundle vs. bundle competition in the second period and at the same time it loses the opportunity to sell its superior product B2 in period one. Therefore, firm 2's profit always decreases with tying.

So far, the entry-deterrence issue has been purposely suppressed because this paper shows another mechanism for a profitable tying without the exclusion of rival firms unlike Whinston (1990), Choi and Stefanadis (2001), and Carlton and Waldman (2002). It is noteworthy, however, that the monopolist strategically also uses tying to stifle the potential entry of the rivals in market A. In other words, the strategic foreclosure revives in this model with switching costs.

Suppose that firm 2 needs to bear a cost of K for entry in market A due to possibly R&D investment. If the cost of entry is sufficiently high to the extent of $K > \tilde{\Pi}_2$, tying would emerge as an entry-deterrence device. In that case, the monopolist will enjoy monopoly rent in both periods.

5. The Welfare Analysis

In this section, I study the effect of tying on consumer surplus and social welfare. To say the conclusion first, the model set up in this paper predicts the negative effects of tying on consumers and society as a whole. Intuitively, this is because tying forces the consumers to use an inferior product and thus leads to the higher switching costs.

With or without bundling, the consumer surplus in period one is zero because the monopolist in the primary market will exploit the entire surplus, assuming there is no waiting option for the consumers in this model.

Since we consider the case where the market is fully covered, the consumer surplus with tying is calculated from the following expression

$$\tilde{C} = \int_0^{\tilde{s}} (V + \Delta_A + \Delta_B - \tilde{P}_2 - 2s)ds + \int_{\tilde{s}}^{1} (V - \tilde{P}_1)ds. \qquad (25)$$

where the bundle prices and the marginal type $\tilde{s}$ follow the analysis in the subsection 3.1. The first integration term measures the consumer surplus of those switching to firm 2's system in period two, while the second term is for those attached to firm 1's system.

In a similar manner, we can compute the consumer surplus for no tying with the sales of B2 in period one as follows.

$$C^{**} = \int_0^{s^*} (V + \Delta_A + \Delta_B - p_{A2}^{*} - p_{B2}^{**} - s)ds + \int_{s^*}^{1} (V + \Delta_B - p_{A1}^{*} - p_{B2}^{**})ds \qquad (26)$$

where the prices and the thresholds follow the analysis in the subsection 3.2. The first integration term measures the consumer surplus of those who switch from (A1+B2) to (A2+B2). The second term captures that of those repeating the same consumption pattern (A1+B2).

The economic total welfare is the sum of the consumer surplus and the firms' profits. With some algebra, I present the consumer surplus and the social welfare for each case in Table 3-1.

Table 3-1. Consumer surplus and social welfare with and without tying

	Without tying	With tying
CS	$C^{**} = V - c_A - c_B + \frac{1}{18}(\Delta_A^2 + 8\Delta_A + 9\Delta_B - 20)$	$\tilde{C} = V - c_A - c_B + \frac{1}{36}\left[(\Delta_A + \Delta_B)^2 + 16(\Delta_A + \Delta_B) - 44\right]$
SW	$S^{**} = 2(V - c_A - c_B) + \frac{1}{18}(5\Delta_A^2 + 4\Delta_A + 36\Delta_B - 1)$	$\tilde{S} = 2(V - c_A - c_B) + \frac{1}{36}\left[5(\Delta_A + \Delta_B)^2 + 8(\Delta_A + \Delta_B) - 4\right]$
$\tilde{C} - C^{**}$	$\frac{1}{36}\left[-\Delta_A^2 + \Delta_B^2 + 2\Delta_A\Delta_B - 2\Delta_B - 4\right]$	
$\tilde{S} - S^{**}$	$\frac{1}{36}\left[-5\Delta_A^2 + 5\Delta_B^2 + 10\Delta_A\Delta_B - 64\Delta_B - 2\right]$	

By examining the signs of the differences in consumer surplus and social welfare under two regimes, i.e., $\tilde{C} - C^{**}$ and $\tilde{S} - S^{**}$, we can see how tying affects consumer surplus and total welfare.

Proposition 3. The monopolist's tying decreases both consumer surplus and social welfare.

Of course, we must be extremely cautious in interpreting this result because such prediction is from the specific framework posited in this paper: it involves several crucial assumptions and controls for many other factors possibly driving the tying decision. In fact, tying can save consumers the transaction costs associated with shopping twice for two separate products and assembling them. As manufacturers often emphasize, the reliability of a bundled package may be relatively higher. However, ceteris paribus, this study provides a theoretical support for the concern about the negative effects of tying on the rivals and consumers with switching costs. Keeping that in mind, in my opinion, this study supports the concern about the negative effects of tying on the rivals and consumers with switching costs.

6. Concluding Remarks

The firms who can wield the market power take a variety of strategic actions to influence the competitive environment in their favor. Tying is the most controversial one among them in antitrust history and economics. This paper studies a new rationale for the tying practice between complementary goods in the presence of switching costs.

I find that the monopolist may strategically commit to tying in order to capture the dynamic rents associated with those who have relatively high switching costs, especially if the monopolist has an inferior complementary product to the rival firm's complementary one. I also show that the tying decision decreases both consumer surplus and social welfare.

I believe that we can extend this simple model in several directions. One extension is to consider independent switching costs for each component. To highlight key intuition in the simplest manner, I have assumed that all the consumers have identical switching costs in both products. However, it would be more realistic and interesting to study the case where some consumers have a very high switching cost in one product but a relatively low one in the other product.

Remarkably, the welfare analysis was quite simple because I assume that a consumer has a unit demand for each product. Thus, it is a natural extension to consider a downward-sloping demand and see how the welfare result changes.

It may also be interesting to interpret the present framework in the context of co-branding (or co-marketing). We can reasonably interpret the level of switching costs as the degree of brand loyalty that varies across consumers. In this vein, we may see tying as a firm's strategic behavior to raise the loyalty level. Since the co-branding literature has been paid little attention by researchers compared to its widespread pervasiveness in the business and marketing realm, I expect this paper to stimulate more research in this direction.

Appendix

Proof of Lemma 1.

Compare the cost of tying, Δ_B, and its benefit $\pi_1^* - \pi_1^{**} = (2-\Delta_B)^2/9$. Solving the inequality $(2-\Delta_B)^2/9 \geq \Delta_B$, we can easily derive the condition $\Delta_B \leq \overline{\Delta}_B = (13-3\sqrt{17})/2 \approx 0.315$.

Proof of Proposition 1.

(a) The comparison of $\widetilde{\Pi}_1$ and Π_1^* shows $\Pi_1^* - \widetilde{\Pi}_1 = \dfrac{(\Delta_A - \Delta_B)^2}{18} \geq 0$. This implies that the monopolist's bundling is not a profitable strategy when it can sell both products separately.

(b) If the monopolist cannot sell its B1, the relevant comparison is between $\widetilde{\Pi}_1$ and Π_1^{**}. Solving the inequality of $\widetilde{\Pi}_1 > \Pi_1^{**}$ with respect to Δ_B, we can find the condition of $\Delta_B < 13 - \Delta_A - \sqrt{2\Delta_A^2 - 26\Delta_A + 161}$.

Proof of Proposition 2.

In order to compare firm 2's profit $\widetilde{\Pi}_2$ and Π_2^{**}, let me study such a condition that satisfying $\widetilde{\Pi}_2 - \Pi_2^{**} = \dfrac{(2+\Delta_A+\Delta_B)^2}{18} - \left[\dfrac{(1+\Delta_A)^2}{9} + \dfrac{1+\Delta_B}{2}\right] \geq 0$. We can rearrange this expression as $\dfrac{1}{18}\left\{-(\Delta_A - \Delta_B)^2 + 2(\Delta_B - 1)^2 - \Delta_B - 9\right\}$, which always proves to be negative for $0 \leq \Delta_A \leq 2$ and $1 \leq \Delta_B \leq 2$.

Proof of Proposition 3.

The welfare analysis can be done by studying the sign of $\widetilde{C} - C^{**}$ and $\widetilde{S} - S^{**}$ in Table 1. Let me prove this proposition by illustrating the relevant areas graphically for easier understanding. Firstly, we can present the areas where $\widetilde{C} - C^{**} \geq (<) 0$ and $\widetilde{S} - S^{**} \geq (<) 0$ in the space of Δ_A and Δ_B. Then, for the area in which the assumptions we made for the analysis are satisfied, we can see $\widetilde{C} < C^{**}$ and $\widetilde{S} < S^{**}$. That is, the following Figure 3-A-1 shows that tying decreases consumer surplus and social welfare[21].

[21] Detailed mathematical proofs are available upon a request to the author.

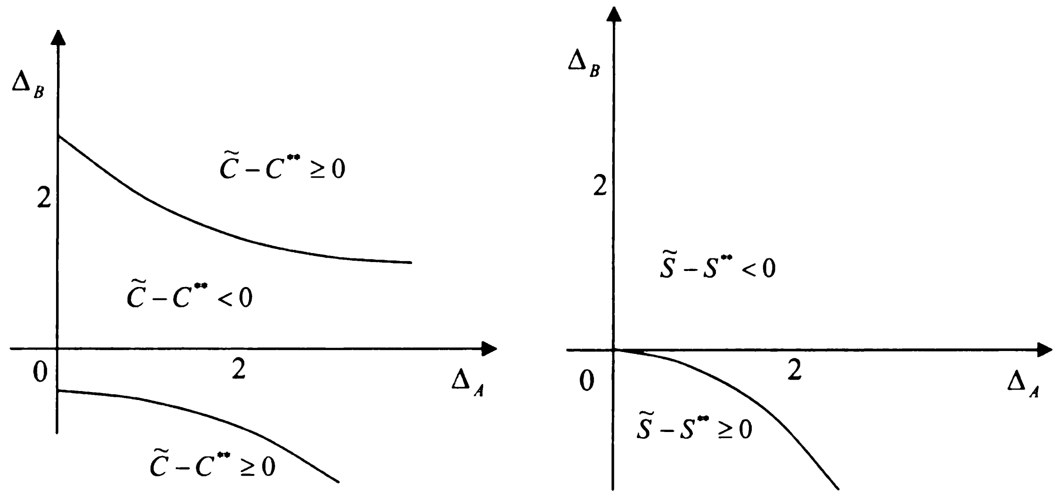

Figure 3-A-1. The welfare comparison with and without tying

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