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Abstract

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. By addressing this new type of behavior-based price discrimination, we show that both the incentive 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 important implications 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 in which firms reside can have an influence upon the choice of product differentiation. Additionally, our analysis suggests a new role of middlemen as information aggregators.

JEL Classification: D43, D62, D83, L14, L51, M31

Key Words: Customer Information Sharing, Complements and Substitutes, Product Differentiation, Behavior-Based Price Discrimination, Merger and Acquisition, Middlemen

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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 air travel and rental car services, for instance, can be complements for some travelers who use both modes of transportation in the same trip. However, they can be substitutes for others, especially short- to medium-distance travelers.[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 firms' incentives to share customer information, and the impact of such sharing on market competition. These questions are especially relevant in electronic commerce, where consumers' records of previous purchases can be easily traced and stored by electronic "fingerprints."[3] Our study also has important implications for merger analysis when 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 inter-firm 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 product. In contrast, with information sharing each firm can learn the complete history of the past transaction record of a

[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.

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 incentive to share customer information depends 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 tend to set *too high* prices with information sharing from the viewpoint of joint profit maximization. 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 the (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. In addition, the average pricing relaxes competition in the substitute market enabling the firms 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 across consumer types, and depend crucially on the relative magnitudes of full information prices that would prevail in the complementary and substitute markets. 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 in which firms reside can influence 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, or Google check-out can benefit firms and some consumers by functioning as lawful institutions that facilitate 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 greater market-power or cost-synergies such as the elimination of duplicative production and marketing expenses, it still can be a profitable strategy due to the value of customer lists held by its merger partner. The recent acquisition of CDNow by

[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 the intangible assets acquired through a merger, according to 'Antitrust Division Policy Guide to Merger Remedies (October 2004)' by the U.S. Department of Justice, Antitrust Division (http://www.usdoj.gov/atr/public/guidelines/205108.htm). However, there is no formal analysis that recognizes the customer list as a primary driver of merger.

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 people 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 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

[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 the 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 on the incentives to share credit information among financial intermediaries. 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.

[9] See Liu and Serfes (2006) for several real practices of companies who participate in the 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).

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 works 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 that the relationship between products is one of the two types, and that this relationship is known to the firms that make strategic choices. One notable exception 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 (2006) 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 main 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 a 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

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

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

firms is always competitive and the pooling of information does not reveal any information about the relationship (complements or substitutes) between the two products in Liu and Serfes (2006), whereas the revelation of this relationship 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 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 and check the robustness of our main results. Section 7 concludes.

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 substitutes.[13] 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

[13] Alternatively, 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 its 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. We believe that our main intuition of this paper can work; the full analysis through this alternative framework is beyond the scope of this paper.

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.*[14] 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.

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

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

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

over an interval $[\underline{\theta}, \overline{\theta}]$ with distribution and density functions of $F(\theta)$ and $f(\theta)$, respectively, where $0 \leq \underline{\theta} \leq \overline{\theta}$. 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.

On the other hand, the consumers in group S are heterogeneous with respect to their relative preferences for B over A. We capture this consumer heterogeneity 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.[15] 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 following surplus from each possible choice.

$$u^S(p_A, p_B; \gamma) = \begin{cases} \max\{v_A, v_B\} - p_A - p_B & \text{if both } A \text{ and } B \text{ are purchased} \\ v_i - p_i \quad \text{if} & \text{if only good } i \text{ is purchased} \\ 0 & \text{if neither one is purchased} \end{cases} \tag{2}$$

where the superscript S indicates that the consumer belongs to group S. The consumer in group S, who regards the two goods as substitutes, earns a 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.[16] The utility from no purchase is set to zero.

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,[17] which ensures the first-order condition for optimization to be sufficient for the second-order condition.

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

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

[16] 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 6.

[17] 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.

is, the group characteristics are a fixed trait. However, we assume that parameters θ and γ are independently 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)]. In fact, our focus in this paper is on the ex post incentive to share information and we abstract from strategic demand manipulation by consumers in the first period to elicit a better price in the second period. We will discuss conditions under which consumers behave myopically in section 6. This implies that firms can identify the group identity of each consumer if they exchange customer information at the end of the first period.

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 in the second period, depending on whether consumers consider the two products substitutes or complements. Consequently, the two groups of consumers are segmented and each firm plays noncooperative pricing games in two separate markets.

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 setting prices 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.[18] Consumer surplus also increases

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

with a merged monopolist due to a lowered total price for the goods.[19]

Let us briefly show that this classic result applies to the market for group C consumers.[20] The optimal decision for consumers in group C can be characterized by a simple cut-off rule:

$$\begin{cases} \text{Buy both A and B} & \multirow{2}{*}{if} & \theta \geq \theta^* \\ \text{Buy neither A nor B} & & \theta < \theta^* \end{cases} \tag{3}$$

where $\theta^* \equiv p_A^C + p_B^C$ denotes the threshold consumer who is indifferent between the 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 is thus 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 whose slope, dp_i/dp_j $(i, j = 1, 2,\ i \neq j)$, is negative and its absolute value is less than one.[21] 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

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

[20] 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.

[21] The total differentiation to (5) shows $dp_i/dp_j = -\left(1 + \frac{1-F}{f^2} f'\right) / \left(2 + \frac{1-F}{f^2} f'\right) > -1$ due to the fact that $1 - f'F/f^2 \geq 0$ from the MHR condition.

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.[22] Figure 1 shows the relationship of p^C and $p^m(= P^m/2)$ graphically.

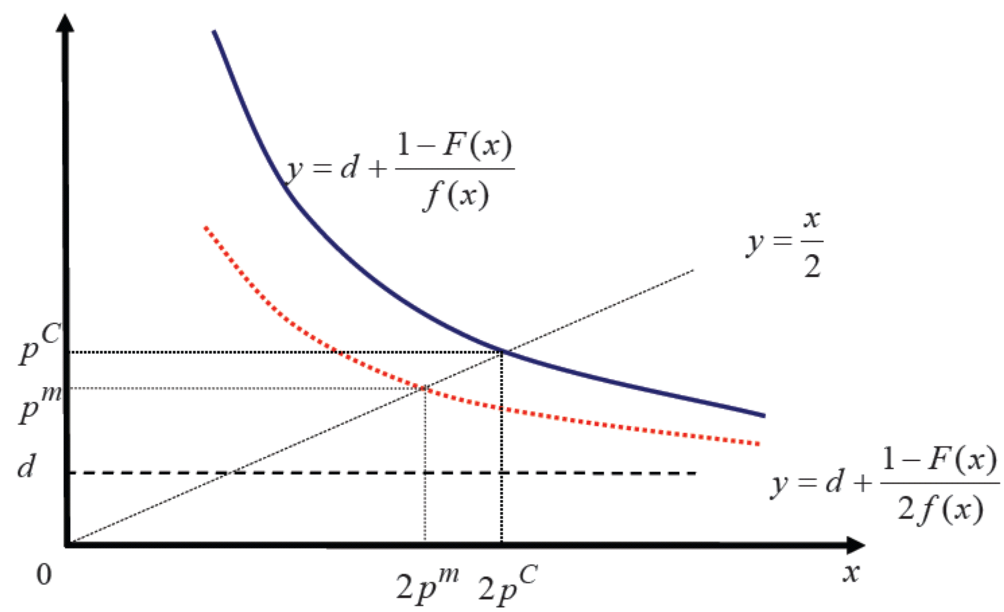

Figure 1. The externality problem in the complementary market

[22] 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 receives a profit of $\frac{1}{8}$. However, with two firms competing non-cooperatively, the equilibrium price that each firm charges is $\frac{1}{3}$ and each one's profit becomes $\frac{1}{9}$.

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.[23] 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

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

where $\gamma^* \equiv p_B^S - p_A^S$.[24] 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

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

A marginal increase 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 marginal increase 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 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 are less than one.[25] 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 assumption that γ is distributed symmetrically around zero, a larger value of $g(0)$ indicates that

[23] In Appendix A, we show this claim rigorously.

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

[25] Similarly to the case of complements, the application of the implicit function theorem to the first order condition yields $\frac{dp_A}{dp_B} = \frac{1-G\cdot g'/g^2}{2-G\cdot g'/g^2} > 0$ and $\frac{dp_A}{dp_B} < 1$ because the MHR condition implies $1 - G \cdot g'/g^2 \geq 0$.

consumers' preferences are more concentrated around zero and that they have less diverse preferences for the goods. We can thus interpret the reciprocal of $2g(0)$ as the degree of heterogeneity in consumers' relative preferences towards the two substitute products, which plays a role similar to 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. That is, $\pi^C = (p^C - d)(1 - F(2p^C))$ and $\pi^S = 1/4g(0)$. 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. In a similar manner, facing a returning consumer already registered in its present customer list, the seller also can think of two possibilities: the consumer considered the goods complements and bought both goods, or the consumer considered the two goods substitutes and 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 respectively denote firm A's conditional probability that a newcomer and a returning consumer would belong to group C, and $\hat{\theta}$ and $\hat{\gamma}$ denote the first-period thresholds for critical consumers, which depend on the first period prices charged by firms A and B. 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 a consumer's substitutability or complementarity between the product offerings by oligopolistic firms is customer-specific, private information, 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.

Proposition 1 *(A new type of price discrimination) Firms who are uncertain of consumers' preferences (complementarity / substitutability) can practice personalized pricing based on their customers' purchase history, regardless of the decision on 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, to our best knowledge, has not yet been addressed.

4.2 Price competition in the second period

Let us describe the firm's second-period profit maximization problem without information sharing. Let p_i^0 and p_i^1 denote the prices that firm i posts for a newcomer and for a returning customer, respectively. Let us describe the firm's second-period profit maximization problem without information sharing. Firm i expects a newcomer to consider the two goods complementary with probability λ_i^0, and thus the newcomer will also be 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 the newcomer will 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. The symmetric equilibrium prices with no information sharing, p^0 and p^1, can be derived from these optimization problems. Each firm's second-period total profit from two markets without information sharing is given by

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

where π^0 and π^1 denote the expected profit per newcomer and per returning consumer in equilibrium, respectively.

Now we are ready to discuss the relationship between 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 the two full information prices in order to maximize its expected profits. This is similar to the result that the firms with incomplete information about demands or costs 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.,* $\min\{p^C, p^S\} < p^0, p^1 < \max\{p^C, p^S\}$ *for any* λ*,* $0 \leq \lambda \leq 1$*.*

(See Appendix for the proof.)

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 the two full information prices based on the consumer's 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 who expect ex post discriminatory pricing, may strategically manipulate their demands, 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 6.

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.[26] 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 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 more rents.[27] 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 2 *(Incentives to share information) 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 incentive to share customer information. In the other case of $p^C < p^S$, firms can increase their profits with information sharing.*

(See Appendix for the proof.)

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

[26] 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.

[27] For this argument, we need to assume that those who regard 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 less profit relative to the full information case.

towards the product offerings. If the products are not perceived as 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 not sharing customer information – possibly emphasizing privacy concerns – can arise for a strategic reason. To put it differently, we may view the commitment to not sharing information as a possible device for tacit collusion. Another interesting implication for the policy-makers is that firms may not always be worse off even if information sharing is banned, because for the case of $p^S < p^C$ the firms will endogenously 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 when customer information is not shared. 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 3 *(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 are 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, aside from privacy concerns, due to its role in price discrimination, while others want their purchase history to be shared between the firms in order to receive 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 because of antitrust concerns can be counterproductive.

6 More Implications and Robustness Check

6.1 More Implications of Our Research

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 await further research; here we briefly provide the intuitive explanations.

6.1.1 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.[28] 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 in which firms reside can influence their

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

choice of product differentiation.[29]

6.1.2 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[30] – 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, and 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.[31] 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.

6.1.3 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 circumstances, 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 new business practices such as database co-ops. In one example, a prospective member firm

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

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

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

is required to contribute at least 5000 names in order to join the Abacus 2B2 alliance.[32] 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. 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 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.[33]

6.2 The Robustness of the Results

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. We also discuss the assumption that the substitute market is fully-covered to check the robustness of our main results.

6.2.1 Potential strategic misrepresentation of preferences by Group S Consumers

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 purchase history with the other firms. Then, the sophisticated consumers who consider the two goods substitutes may strategically buy both goods or neither, instead of buying only one good, in order to avoid the expected higher second-period price p^S. Needless

[32] For the details, see "Who's is Who among the B-to-B Co-op Databases," Catalog Age, May 1, 2004. We borrow this real world example from Liu and Serfes (2006). For 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).

[33] 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.

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 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 a large marginal cost, d. Similarly, the consumer will not engage in the misrepresentation of her preference by opting for no purchase if the potential loss of utility in the first period is large enough due to a sufficiently high reservation value v.

6.2.2 Potential strategic misrepresentation of preferences by Group C Consumers

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 surplus but also on its subsequent effect on the second period price. Specifically, the consumer with θ have overall expected surplus of $(\theta - 2q) + \delta E_\theta \max\{\theta - 2p^1, 0\}$ from buying both goods in the first period and will then face the price for a returning consumer in the second period, while $\delta E_\theta \max\{\theta - 2p^0, 0\}$ from not purchasing in the first period and then receiving the newcomer price in the second period.

With these dynamics taken into account, the first-period price in equilibrium — and thus the two firms' overall profits — may differ from that with myopic consumers. Since two firms post a weighted average price between p^S and p^C, it is no wonder that there exist two forces that influence the firms' first period profits in the opposite direction. An increase in the first-period price aggravates the externality problem in the complementary market, but allows more rent extraction from the substitute market; a decrease in the first-period price diminishes the externality problem, but it also reduces the rent from the substitute market. Due to these countervailing effects, we cannot unabmiguously assert how the potential strategic misrepresentation of preferences by the consumers in group C would affect first-period pricing and, subsequently, the firms' ex ante incentive to share customer information. We believe, however, that our qualitative results derived from ex post perspective also extend to the case where we consider such strategic concerns, with some restrictions on distributions, the proportion parameter, or the discount factor.

On the other hand, a consumer who considers the two goods substitutes knows that she will face the price for a returning customer if she buys a good from the same firm, but the price for a newcomer if she switches 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).

6.2.3 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 all consumers. 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 also heterogeneous in the vertical dimension — with respect to their reservation price v_i — 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 in 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 of those who regard the goods as substitutes depends not only on horizontal, but also vertical, dimensions. The model incorporating this feature suffers from technical complexity without gaining any significant additional insight. The benefits associated with our simple basic model outweigh its costs.

7 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 will encourage more research in this direction.

Appendix

Proof of the claim: A consumer in group S (weakly) prefers 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 in 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 $\max\{v_A, v_B\} - p_A - p_B = v_B - p_A - p_B$.

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

Q.E.D.

Proof of Lemma 2.

Preliminaries for proof. Recall the first-order conditions for p^C and p^S which are respectively given by

$$\left[1 - F(2p^C)\right] - (p^C - d)f(2p^C) = 0 \tag{P1}$$

and

$$G(0) - (p^S - d)g(0) = 0. \tag{P2}$$

The first-order condition for p_A^0, given firm B's equilibrium prices p^0 and p^1, yields

$$\frac{\partial \pi_A^0}{\partial p_A^0} = \lambda_A^0[(1 - F(p_A^0 + p^0)) - (p^0 - d)f(p_A^0 + p^0)] + (1 - \lambda_A^0)[G(p^1 - p_A^0) - (p^0 - d)g(p^1 - p_A^0)]$$

which, if evaluated at $p_A^0 = p_0$, is given by

$$\left.\frac{\partial \pi_A^0}{\partial p_A^0}\right|_{p_A^0 = p^0} = \lambda_A^0[(1 - F(2p^0)) - (p^0 - d)f(2p^0)] + (1 - \lambda_A^0)[G(p^1 - p^0) - (p^0 - d)g(p^1 - p^0)]. \tag{P3}$$

Similarly, the first-order condition with respect to firm A's price for a returning consumer, if we evaluate at $p_A^1 = p^1$, is given by

$$\left.\frac{\partial \pi_A^1}{\partial p_A^1}\right|_{p_A^1=p^1} = \lambda_A^1[G(p^0-p^1)-(p^1-d)g(p^0-p^1)]+(1-\lambda_A^1)[\left(1-F\left(2p^1\right)\right)-(p^1-d)f\left(2p^1\right)]. \tag{P4}$$

Note also that the MHR condition for the distribution G with its symmetry about zero implies

$$\frac{d}{dx}\left(\frac{G(x)}{g(x)}\right) > 0.^{34} \tag{P5}$$

Proof. For the equilibrium prices without sharing of customer information, p^0 and p^1, to be between the two full information prices, several conditions must be satisfied simultaneously. Let us first consider the case $p^C < p^S$. Then, for $p^C < p^0$ and $p^C < p^1$, the first bracketed term in (P3) and the second bracketed term in (P4) are negative due to (P1) and $\frac{\partial^2 \pi^C}{\partial (p^C)^2} < 0$. For p^0 and p^1 to be equilibrium prices, we need both $\left.\frac{\partial \pi_A^0}{\partial p_A^0}\right|_{p^0} = 0$ and $\left.\frac{\partial \pi_A^1}{\partial p_A^1}\right|_{p^1} = 0$, which in turn necessiates the positive second bracketed term in (P3) and the positive first bracketed term in (P4). These conditions are mathematically put as:

$$p^0 < d + \frac{G(p^1-p^0)}{g(p^1-p^0)} \quad \text{and} \quad p^1 < d + \frac{G(p^0-p^1)}{g(p^0-p^1)}. \tag{P6}$$

Given the above, we need to show that both p^0 and p^1 are below p^S, that is, $\max\{p^0, p^1\} < p^S$.

If $p^0 < p^1$, the following inequalities hold:

$$\left(p^C < p^0 <\right) p^1 < d + \frac{G(p^0-p^1)}{g(p^0-p^1)} < d + \frac{G(0)}{g(0)} = p^S$$

because of (P6), (P5), and (P2), which consequently verifies that the equilibrium prices without information sharing are between the two full information prices.

For the other case of $p^0 < p^1$, we have the following result:

$$\left(p^C < p^1 <\right) p^0 < d + \frac{G(p^1-p^0)}{g(p^1-p^0)} < d + \frac{G(0)}{g(0)} = p^S,$$

once again because of (P6), (P5) and (P2). Symmetrically, it can be shown that the equilibrium prices without information sharing are between the two full information prices for the other possibility of $p^S < p^C$. *Q.E.D.*

Proof of Proposition 2.

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

[34] The similar assumption and result is also found in Fudenberg and Tirole (2000, p.637 Assumption 1 and footnote 10).

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:

$$\widetilde{\Pi}_2 \geq \lambda[1 - F(\widehat{\theta})]\pi^C + \lambda F(\widehat{\theta})\pi^C + \frac{1-\lambda}{2}\pi^S + \frac{1-\lambda}{2}\pi^S = \Pi_2.$$

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

For the other case of $p^C \leq p^i \leq p^S$, 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.

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