

Should Firms Share Information About Customers?

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Abstract

Advances in information technology increasingly allow firms to identify expensive, high-cost customers, who are not only individually less profitable for firms but also raise the average marginal cost incurred by firms and thus impose a negative externality on inexpensive customers. Should competing firms share information that identifies such customers? The answer to this question has important implications for firm profitability, consumer welfare, and privacy laws that currently constrain firms' ability to share information.

Considering consumers to be heterogeneous in terms of the *cost* they impose on firms, this paper presents an analytical model to examine the conditions in which two differentiated Bertrand competitors prefer to share information. The firms' incentives to share information differ according to the degree of product differentiation, the relative proportion of expensive customers in the market, the relative marginal cost of selling to expensive customers and the level of noise in the information.

A Prisoner's Dilemma results when firms selling substitutable products share information identifying expensive customers. The competing firms benefit from sharing information, but the benefits from a firm individually renegeing on an information-sharing agreement are even higher; paradoxically, in equilibrium, both firms deviate and keep their information private. A third-party agency such as an industry trade association might serve to supervise and coordinate information-sharing agreements between competing firms. In contrast, when the firms sell complementary products, they always have an incentive to share information.

Importantly, this paper establishes that sharing information identifying expensive customers increases the welfare of inexpensive customers. Privacy laws thus protect expensive customers more than inexpensive customers. In certain conditions, the aggregate consumer welfare might increase, when firms share information identifying expensive customers. This research recommends relatively weaker, not stronger, privacy laws, which is counterintuitive to the recommendations of the popular press.

Keywords: Customer knowledge, Expensive customers, Information sharing, Trade association, Privacy laws, Game theory

JEL: D83, M31

1. Introduction

With the onset of the information revolution and advances in technology, companies possess increasingly detailed databases of individual-level customer information that enable them to better identify individual-level customer preferences and reveal who bought what, when, and for how much. Consistent with the recent trend of shifting from product management to customer portfolio management (Gupta and Lehmann 2005), companies often use customer information as a strategic asset to individually identify their best customers. However, not every customer is necessarily valuable, and firms can use individual-level databases to identify undesirable customers. As Selden and Colvin (2003) argue, retail markets contain a high-cost market segment, along with a typical low-cost, profitable market segment. This high-cost segment typically spends too little, complains too much, and/or ties up too many firm resources. Such an adverse impact of a minority segment of customers is widespread across markets as diverse as clothing retailers and financial services providers, with less than 20% of customers typically responsible for more than 80% of losses (MSN Money 2004). Some customers are so costly to serve that a firm may be better off by not serving them. We refer to such customers as *expensive* customers.

In the case of Best Buy, an estimated 100 million of 500 million annual customer visits are undesirable; some customers buy products, apply for rebates, return the purchases, and then buy them back at returned-merchandise discounts. Alternatively, they may load up on loss leaders, then sell the goods at a profit on eBay. Other undesirable customers present rock-bottom price quotes from Web sites and demand that Best Buy make good on its lowest-price pledge. “They can wreck enormous economic havoc,” notes Brad Anderson, CEO of Best Buy (*Wall Street Journal* 2004).

More recently, Sprint-Nextel declined future service to thousands of expensive customers, in a bid to weed out habitual complainers who clogged up their customer service lines. Sprint implemented this by sending these customers “Dear John” letters, terminating their current cell phone contracts and disbaring them from future cellular service (See Figure 1). Sprint was prompted to adopt this policy, since the cost of providing cell phone service to such expensive customers became prohibitively high. Sprint also made this decision keeping the welfare of their remaining 53 million customers in mind - the ones who routinely made less than one call a month to customer service, as compared to the terminated subscribers who called an

average of 25 times a month, a rate 40 times higher than their average customers (*Wall Street Journal* 2007).²

While many firms have experienced an increasing ability to employ their own customer databases, it is interesting to observe that some firms share individual-level customer information with their competitors. The financial services industry has a long history of using independent credit bureaus to report, monitor, and identify customers with a higher probability of financial default. Credit card providers routinely use the credit ratings provided by credit bureau's such as Experian and Equifax, to assess individual consumers' credit worthiness and deny credit to high risk customers. In the direct marketing industry, more than 600 catalog marketers exchange information about purchases of individual customers with competitors (Deighton et al. 1996). The Abacus B2B Alliance comprises 352 businesses that share 75 million customer names and 1.2 billion transactions. After paying a monthly membership fee of \$85 and contributing at least 5000 business leads from its personal database, a participating company can label undesirable customers using the shared database (Catalog Age 2003, 2004). These trends suggest that database co-ops are not uncommon, which in turn indicates that benefits may accrue from information sharing (Rendleman 2001). However, various firms also keep their customer information private. The retail giant Wal-Mart does not sell its point-of-sales data to market research companies and thereby indirectly prevents its competitors from accessing its customer information (*Information Week* 2001). Toys 'R Us has ended its practice of sharing data with the NPD Group, which produces industry analysis reports (*Playthings* 2003).

Customer information management is becoming increasingly more important. Should a firm share information that uniquely identifies and profiles individual customers, with a competitor? On the one hand, combining its competitor's customer information with its own database can help a firm lower its average costs, by improving its ability to identify and exclude expensive customers. On the other hand, sharing customer information can concede the same

² From a legal standpoint, Sprint's decision did not violate the law. The fine print of their cell phone contract stipulates that "We can, without notice, suspend or terminate any Service at any time for any reason, including, but not limited to: (a) late payment; (b) exceeding an Account Spending Limit ("ASL"); (c) harassing/threatening our employees or agents; (d) providing false information; (e) interfering with our operations; (f) using/suspicion of using Services in any manner restricted by or inconsistent with the Agreement; (g) breaching the Agreement, including our Policies; (h) providing false, inaccurate, dated or unverifiable identification or credit information, or becoming insolvent or bankrupt; (i) modifying a Device from its manufacturer specifications; or (j) if we believe the action protects our interests, any customer's interests or our network." Essentially, when customers signed up for cell phone service, they waived their legal right to contest Sprint's decision to terminate service.

benefits to the competition and thereby increase the price competition in the market over the desirable segment of inexpensive customers. It is thus not clear whether firms would be better off sharing their knowledge about the expensive customers in the market. This question also raises timely issues about privacy laws and consumer welfare. In the Best Buy example, a minority of expensive customers significantly raise the marginal cost incurred by the firm, which gets reflected in a higher equilibrium price paid by all consumers, including the inexpensive customers. That is, the inexpensive consumers subsidize the expensive consumers. If information sharing improves a firm's ability to exclude expensive customers, the overall consumer surplus may increase, even if the expensive customers are not served.

Price discrimination is one possible mechanism whereby a firm can avoid serving expensive customers. Whenever price discrimination is possible, firms can avoid serving expensive customers by charging them a very high price. However, price discrimination is not the most dominant practice. There also exist other mechanisms by which a firm can avoid doing business with expensive customers. Consider the following two examples, where firms can avoid doing business with expensive customers without explicitly price discriminating between customers: (1) A catalog manufacturer can stop sending their future catalogs to selected customers, implicitly lowering the probability of selling to consumers perceived to be unprofitable; (2) a membership club such as Costco routinely conducts a background credit check prior to issuing membership, denying undesirable customers access to their club. Our paper does not explicitly model the *different* mechanisms by which a firm can avoid serving expensive customers. We assume that these mechanisms are exogenous, industry dependent and can be feasibly implemented by the firms. We are more interested in the *impact* of not serving the expensive customers. We investigate under what market conditions is it profitable for a firm to share information identifying expensive customers with a competitor and avoid serving such customers, given that some mechanism to achieve this exclusion is available to the firms.

Despite the recent media discussions about expensive customers (Gupta and Lehmann 2005, Selden and Colvin 2003), relatively little research has addressed the incentives for firms to share customer information. The following research questions remain unanswered and are addressed in our paper:

- When do competing firms have an incentive to share information that individually identifies their expensive customers?
- When competing firms share such information, are expensive and inexpensive customers affected homogeneously?
- Do privacy laws, which limit firms from sharing customer information, protect all consumers uniformly?

To respond to these issues, we propose a model of Bertrand price competition between two firms. In our model, two firms sell competing but differentiated products to two segments of expensive and inexpensive customers. The firms, independently and ex ante, decide whether to share information about expensive customers, which leads to one of three possible pure equilibrium information-sharing scenarios: (1) both firms keep information private, (2) only one firm shares its information, or (3) both firms share information. In our model, sharing a competitor's information with its own information permits a firm to exclude expensive customers. The firms simultaneously set profit-maximizing prices, a la Bertrand, given their underlying information structure. We measure firm profits in the different equilibrium information-sharing scenarios and specifically characterize how (1) the product differentiation between the competing firms, (2) the relative proportion of the expensive and the inexpensive customers, (3) the higher marginal cost of selling to the expensive customers and (4) the noise in the firms' customer information moderates their incentives to share individual-level customer information. We also study the corresponding impact of information sharing on consumer surplus by characterizing how the surplus changes in the absence or presence of information sharing across the two market segments of expensive and inexpensive customers.

Our equilibrium analysis generates insights of interest to both academics and practitioners. First, we shed light on managing cost-related information assets in a competitive environment. We show that although a superior knowledge about the cost imposed by individual customers can be a competitive advantage, a firm should not always protect its customer information from competitors. On the contrary, firms may mutually benefit from sharing individual-level customer information in certain competitive scenarios. We find that when the competing products are substitutes, the firms keep information private, despite having an incentive to share information. We also find that when the competing products are complements

instead, the firms have an incentive to share information. Our research thus adds to the stream of literature in economics and marketing, such as Sakai (1985), Gal-Or (1986), Raith (1996), Raju and Roy (2000), and Chen et al (2001), that investigates incentives for information sharing in different market settings.

Second, we identify a potential reason for competing firms to join an industry trade group or trade association that among other responsibilities also supervises and regulates information-sharing agreements. We demonstrate that firms selling substitute products keep information private, since they face a Prisoner's Dilemma like situation with respect to information-sharing agreements. Even though both firms would make higher profits by sharing information, neither firm shares information in equilibrium, because renegeing on an agreement leads to even higher profits. Given such a dilemma, a trade association can potentially help regulate and coordinate information-sharing agreements among the competing firms.

Third, our research addresses a controversial public policy implication for privacy laws, which are designed to protect consumers from economic injury and unwanted intrusions. Firms' incentives to share customer information are moderated by privacy laws that legally constrain their ability to share information. Whereas the advocates of stringent consumer privacy laws argue that consumers are adversely affected when firms share information, we propose a more balanced stance in which we note that such laws may not protect consumers equally. Our analysis establishes a heterogeneous change in the consumer surplus across the two customer segments, when competing firms share information that identifies expensive customers. Under information sharing, the consumer surplus of the inexpensive customers increases, while the expensive customers are not served. We demonstrate that the expensive customers impose a negative externality on the inexpensive customers in the market when firms keep such information private. We therefore infer that privacy laws may indirectly decrease the consumer surplus of inexpensive customers, because of the presence of expensive customers. Hence, we conclude that privacy laws may protect expensive customers more than inexpensive customers. Contrary to the popular press, we argue in favor of not more but less stringent consumer privacy laws.

The rest of this article is organized as follows: In Section 2, we review related literature in marketing and economics. In Section 3, we develop our information-sharing model, and then

in Section 4, we discuss the managerial implications and insights from our model. In Section 5, we conclude and discuss some limitations.³

2. Related Literature and Contributions

2.1. Exchange of Cost Information

Our research relates to the prior literature on the exchange of aggregate cost information in a duopolistic industry (Fried 1984; Sakai 1985; Gal-Or 1986; Shapiro 1986; Raith 1996). The key difference between this literature and our work is that we consider individual-level costs imposed by customers on firms and this enables us to generate some fresh, richer insights.

In previous work, Fried (1984) and Sakai (1985) consider various aggregate cost information structures in a Cournot duopoly and find that the firms are better-off by sharing cost information with their rivals. Gal-Or (1986) extends this idea to a Bertrand duopoly, in which each firm observes its own aggregate cost with noise and may send noisy signals to its rival. She shows that in a Bertrand duopoly with substitute goods and aggregate cost uncertainty, not revealing information is a dominant strategy.⁴

Our paper extends Gal-Or's (1986) finding that firms selling to homogeneous consumers have an incentive to keep their information private under Bertrand competition. We incorporate heterogeneity in the individual costs imposed by consumers on firms, by considering two market segments of expensive and inexpensive customers. Our model leads to a richer solution space, in which Bertrand competitors may prefer sharing information in certain scenarios but keep information private in others. Our paper also provides correspondingly richer findings with

³ Our model differs from the consumer heterogeneity models in prior literature, in that we model consumers as heterogeneous with respect to the cost they impose on the firm, an approach that enables us to consider the strategic implications of expensive customers in the market. Researchers in economics and marketing have a long history of modeling consumers as either (1) horizontally differentiated by taste, a method that dates back to Hotelling's (1929) location model, or (2) vertically differentiated by valuation for quality, beginning with Mussa and Rosen's (1978) model of product quality under a monopoly. Subsequent research has modeled consumers as simultaneously horizontally and vertically differentiated, such as in Desai (2001), Shaffer and Zhang (2002), and Tyagi (2004). Our model complements this long history of analytical modeling, because we model consumers as heterogeneous in terms of their cost rather than restricting our analysis to heterogeneity in taste and/or valuation.

⁴ Also note that we consider cost uncertainty rather than demand uncertainty. There exists an additional literature pertaining to firm incentives to share information about demand shocks, such as Novshek and Sonnenschein (1982) and Clarke (1983), who show that information-sharing incentives do not exist in a Cournot duopoly with homogeneous goods, given demand uncertainty. Vives (1984) further establishes that firms have an incentive to share information in Cournot competition with complementary goods and in Bertrand competition with substitute goods. Subsequently, Raith (1996) reconciled these previous results in a general model of information sharing in an oligopoly.

regard to consumer welfare. Unlike Sakai's (1985) model, in which the consumer surplus of homogeneous consumers always falls when firms share information, we show that overall consumer surplus may either increase or decrease, depending on consumer heterogeneity and the relative proportion of the two market segments in the market.

2.2. Information Management and Trade Associations

Our paper is related to the prior literature on information management. Advances in today's information-intensive marketing environment have prompted papers such as Chen et al.'s (2001) model of a state of imperfect targetability, in which firms' ability to predict the purchase behaviors of individual consumers to customize price or product offers is imperfect. This paper segments customers as either a firm's own loyal customers or common switchers; each firm imperfectly classifies its own loyal customers and switchers correctly; and the competing firms can improve their ability to identify price-sensitive switchers and price-insensitive loyal customers by sharing information.⁵ Similarly, Villas-Boas (1999) examines the issue of customer recognition, where firms can set different prices for their previous customers and their new customers. These papers consider consumers to be heterogeneous in their valuation and model firm's price discriminating between segments. In contrast, our research makes an important distinction. We model consumers to be heterogeneous in the marginal cost incurred by firms in serving them and consider the implications of firms sharing cost information of individual consumers.

Our work also relates to the stream of literature investigating why firms join industry trade associations or groups (Shapiro 1986; Kirby 1988; Vives 1990). Vives (1990) studies the effects of the different disclosure rules used by trade associations on the incentives for firms to share information and the welfare of consumers, firms, and society. He finds that a policy of exclusionary disclosure preserves incentives to share information and that information sharing decreases the total surplus with Bertrand competition and demand uncertainty. The key finding in both Shapiro (1986) and Kirby (1988) is also that firms always benefit by joining industry trade associations. Our paper refines this research by incorporating heterogeneity into the cost

⁵ They find that competing firms can mutually benefit from exchanging individual customer information at the nascent stage of individual marketing, when firms' targetability is low. However, as individual marketing matures and firms' targetability improves, further improvements in targetability intensify price competition and lead to a Prisoner's Dilemma.

imposed by expensive and inexpensive customers. In turn, our model is more realistic and richer, one where competing firms may or may not be better off by joining industry trade associations. In contrast to Shapiro (1986) and Kirby (1988), we find that if the proportion of expensive customers is too high and the competing products are strong substitutes, firms may benefit by choosing not to join industry trade associations.

There also exists a literature in finance and credit markets related to our work (Pagano and Jappelli 1993, Dell'Ariccia et al 1999). For instance Dell'Ariccia et al (1999) consider the case where lenders have more information about the probability of default of some borrowers than about other borrowers and investigate the effects of more private information. Similarly, Pagano and Jappelli (1993) consider the case with two types of borrower quality and investigate the information sharing effects and incentives to share information.

2.3. Information Privacy

Recent technological developments in information collection and processing have heightened privacy concerns among consumers and led to widespread concerns about the collection of personal information in various contexts. Consumers are concerned that though individual profiling by firms may benefit them if the firms can more precisely identify and cater to their needs, it also may be used by firms to price discriminate or exclude consumers with less attractive characteristics (Mussa and Rosen 1978; Moorthy 1984; Varian 1985; Tirole 1988). The use of personal information to profile individual consumers thus imposes an indirect or consequential externality, because some consumers suffer from either paying a relatively higher price or being excluded from enjoying a particular good or service. In this sense, the exploitation of personal information could lead to ex post inefficiencies. Moreover, some consumers may get priced out of the market when more information is available to the seller, even if it would be socially efficient for them to consume the item (Varian 1985; Fudenberg and Villas-Boas 2006). Furthermore, the option of sharing or selling consumer information for extra revenue may further reduce social efficiency. Taylor (2004) demonstrates that the seller may experience an excessive incentive to collect consumer information, at the expense of some of its own potential consumers, because of the loss in trade and increase in deadweight losses or the cost of compiling information. Hui and Png's (2006) review of the economics of privacy examines these issues in greater detail.

In assuming all consumers to be homogeneous in terms of their cost, the key finding from previous literature has been that consumer surplus typically decreases when competing firms share information (Sakai 1985; Shapiro 1986). We contribute to privacy literature by examining whom such privacy laws benefit, and we find a heterogeneous change in consumer surplus across our two heterogeneous cost market segments. While the consumer surplus of inexpensive consumers increases, expensive consumers are not served, and therefore, privacy laws that restrict firms' ability to share information benefit expensive customers at the cost of the dominant, inexpensive customers in a market.

3. Model

Consider a market consisting of two risk-neutral Bertrand competitors $i \in \{1, 2\}$. We assume that their inverse demand functions are downward sloping, given as follows.

$$p_i = \alpha - \beta q_i - \gamma q_{3-i}$$

The firms sell $q_i > 0$ quantities at prices $p_i > 0$ respectively. We normalize $\beta = 1$, without loss of generality, yielding $p_i = \alpha - q_i - \gamma q_{3-i}$. The competing products are substitutes or complements, depending on whether $\gamma > 0$ or $\gamma < 0$ respectively and independent when $\gamma = 0$. We assume that the demands are linear in self and cross-price effects and that self-price effects are greater than cross-price effects. This implies that, $-1 < \gamma < 1$ (McGuire and Staelin 1983). We can equivalently rewrite the demand functions as

$$q_i = a - bp_i + dp_{3-i}$$

where $a = \frac{\alpha}{1+\gamma}$, $b = \frac{1}{1-\gamma^2}$ and $d = \frac{\gamma}{1-\gamma^2}$.

Information Sharing under Bertrand Competition

Each firm independently adopts a policy of either sharing its customer information with its competitor or keeping its information private. A firm also could choose to give away information unilaterally, which means one of the following three information-sharing scenarios $Z \in \{pr, sh, g\}$ may occur: Both firms keep information private ($Z = pr$); both firms share

information ($Z = sh$) ; or only one firm shares information, while the other firm keeps information private ($Z = g$). We confine our analysis to pure strategy Nash equilibria.

A firm's decision to share information is not obvious. The firm can improve its ability to identify and exclude expensive customers by gaining access to its competitor's database of expensive customers. This lowers the firm's cost and leads to potentially higher profits. However, sharing its own information grants the competitor the same benefit and potentially increases the price competition for inexpensive customers, which leads to potentially lower profits.

Consumers

The consumers impose heterogeneous marginal costs on the firms. The market has two segments - a segment of relatively high marginal cost consumers, referred to as expensive customers and a segment of relatively low marginal cost consumers, referred to as inexpensive customers. Let I denote an inexpensive customer and E denote an expensive customer. The marginal costs of serving expensive and inexpensive customers are represented by c_E and c_I respectively, with $c_E \gg c_I > 0$. These marginal costs are constant and invariant across the two firms. Our model thus explicitly incorporates consumer *cost* heterogeneity.

Suppose the probability that a given customer j is inexpensive is λ , while the corresponding probability that the customer is expensive is $1 - \lambda$, or

$$\Pr(j = I) = \lambda$$

$$\Pr(j = E) = 1 - \lambda$$

Invoking the law of large numbers, the proportion of inexpensive customers in the market is λ , while the corresponding proportion of expensive customers in the market is $1 - \lambda$.

Information Structure

The firms get private signals from the customers in the market, as being either expensive or inexpensive. Specifically, each firm $i \in \{1, 2\}$, has a privately known binary signal $s_i \in \{L, H\}$ about a given customer, concerning whether the customer is expensive ($s_i = L$) or inexpensive

$(s_i = H)$. Such a signal is based on the firm's customer database of purchase history and market research.

A firm never gets an L signal from an inexpensive customer. However, the firm may get either a correct L signal or an incorrect H signal from an expensive customer. In order to interpret this information structure, consider the following hypothetical scenario: A customer purchases an expensive evening gown from a clothing retailer on Friday and then returns it on Monday morning. The same customer purchases a pair of designer jeans from another retailer and does not return them. In this case, the first retailer has an L signal from this customer, while the second retailer has an H signal from this customer.

Let s_1s_2 represent such a pair of signals about a given customer, where s_1 refers to firm 1's signal about this customer and s_2 refers to firm 2's signal about this customer. Since each signal is binary, with $s_i \in \{L, H\}$, this implies that there are four possible pairs of signals about the customer, leading to four possible states: $s_1s_2 \in \{HH, HL, LH, LL\}$. For instance, $(s_1s_2 = HH)$ refers to the state where both firms have a H signal about this customer, while $(s_1s_2 = HL)$ refers to the state where firm 1 has a H signal about this customer, while firm 2 has a L signal about the same customer. The states $(s_1s_2 = LH)$ and $(s_1s_2 = LL)$ are analogously defined.

Conditional Probability Beliefs about Expensive Customers

The firms have potentially incorrect signals about the expensive customers in the market. For instance, a firm may incorrectly have a $(s_i = H)$ signal about a given expensive customer j . We define the conditional probability of only firm i having an incorrect H signal about customer j to be δ_i , or

$$\Pr(s_1s_2 = HL \mid j = E) = \delta_1$$

$$\Pr(s_1s_2 = LH \mid j = E) = \delta_2$$

Thus, δ_1 is equivalent to firm 1 making a Type I error and represents the probability of firm 1 having an incorrect H signal and firm 2 having a correct L signal about a given expensive

customer j . δ_2 has an analogous meaning with respect to firm 2. Note that since these are probabilities, we must have $(0 \leq \delta_i \leq 1)$.

Next, we assume that both the firms do not have incorrect H signals from a given expensive customer j , or

$$\Pr(s_1 s_2 = HH | j = E) = 0$$

Lastly, the conditional probability of both firms having a correct L signal about customer j simply follows by subtraction, as follows.

$$\Pr(s_1 s_2 = LL | j = E) = 1 - \delta_1 - \delta_2$$

Note that $(0 \leq \delta_1 + \delta_2 \leq 1)$.

The information structure implies that the competing firms are uncertain about the segment of expensive customers, particularly those expensive customers from whom the firms receive incorrect H signals. When a firm has access to only its own signals, it sells to only those customers from whom it receives H signals. However, its signals are noisy and the firm ends up selling to both inexpensive customers and some expensive customers from whom it incorrectly receives H signals. The parameter δ_i captures the probability of this misclassification and is a measure of the noise in firm i 's information.

Conditional Probability Beliefs about Inexpensive Customers

We assume that the firms do not have incorrect signals about the inexpensive customers in the market. This implies the following conditional probability beliefs about the inexpensive customers. The probability of firm i receiving an incorrect L signal about a given inexpensive customer j is zero, or

$$\Pr(s_1 s_2 = HL | j = I) = 0$$

$$\Pr(s_1 s_2 = LH | j = I) = 0$$

$$\Pr(s_1 s_2 = LL | j = I) = 0$$

This further means that the firms always correctly get a H signal from a given inexpensive customer j , or

$$\Pr(s_1 s_2 = HH | j = I) = 1$$

In other words, the firm does not face any uncertainty regarding the desirable segment of inexpensive customers in the market. We make this assumption for the following two reasons. First, this allows our model to concentrate on the firms' uncertainty regarding the expensive customers in the market and model the potential gains from sharing information about the expensive customers. Second, this keeps our model analytically tractable. Modeling Type II errors adds unnecessary complexity to our model, without offering additional significant insights.

Bayesian Updating of Beliefs

When a firm does not know its competitor's signals about the customers, it can only use its own signals about the customers. Following the information structure discussed above, when a firm has a L signal about a given customer, it correctly infers that this customer is expensive and does not sell to this customer. The firm sells to a customer, only if it has a H signal about this customer. The information structure additionally implies that a firm's signals about expensive customers are noisy and the firm may potentially misclassify expensive customers to be inexpensive. When the firm keeps information private, it ends up selling to both expensive and inexpensive customers. In contrast, when a firm learns its competitor's customer information, the firm now only sells to inexpensive customers.

Suppose firm i has a H signal about customer j . Customer j may be either expensive or inexpensive with some probability. We can use Baye's Rule to measure the posterior probability that customer j is indeed an inexpensive customer.

Let us define λ_{iH} as the probability that customer j is inexpensive, given that firm i has a H signal about customer j , or $\lambda_{iH} = \Pr(j = I | s_i = H)$.

We can apply Baye's Rule to measure λ_{iH} , as $\Pr(j = I | s_i = H) = \frac{\Pr(j=I \cap s_i=H)}{\Pr(s_i=H)}$, or

$$\Pr(j = I | s_i = H) = \frac{\Pr(s_i = H | j = I) * \Pr(j = I)}{\Pr(s_i = H | j = I) * \Pr(j = I) + \Pr(s_i = H | j = E) * \Pr(j = E)}$$

Following the information structure discussed above, the probability that firm i has a H signal, given that customer j is inexpensive is 1, or $\Pr(s_i = H | j = I) = 1$. Further, the probability that firm i has a H signal, given that customer j is expensive is δ_i , or $\Pr(s_i = H | j = E) = \delta_i$.

Substituting in Baye's rule, we get

$$\Pr(j = I | s_i = H) = \lambda_{iH} = \frac{\lambda}{\lambda + (1 - \lambda)\delta_i}$$

This gives us the probability that customer j is an inexpensive customer, given that firm i has a H signal about this customer.

Let θ_i denote the proportion of customers from whom firm i receives H signals. This includes both correctly classified inexpensive customers and incorrectly classified expensive customers. We note from above that

$$\begin{aligned}\theta_i &= \lambda + (1 - \lambda)\delta_i \\ \lambda_{iH} &= \frac{\lambda}{\theta_i}\end{aligned}$$

The corresponding probability that a customer j is expensive, given that firm i receives a H signal from this customer, or $\Pr(j = E | s_i = H)$ is simply $(1 - \lambda_{iH}) = \frac{(1 - \lambda)\delta_i}{\theta_i}$. Notice that $\lambda_{iH} > \lambda$, implying that the posterior probability of a customer being inexpensive, given that the firm receives a H signal from this customer, is higher than the prior probability $\Pr(j = I) = \lambda$.

When $\delta_i = 0$, then the firm has perfect information, $\theta_i = \lambda$ and $\lambda_{iH} = 1$. When $\delta_i > 0$, firm i receives a noisy H signal and cannot perfectly identify the customer. As the noise in the firm's signal increases, δ_i correspondingly increases.

We choose the above parsimonious information structure for analytical tractability, although the same intuition extends to a more complex information structure. We now consider the Bertrand pricing game between the two firms and compare the different information scenarios $Z \in \{pr, sh, g\}$.

Game

The firms $i \in \{1, 2\}$ play the following two-stage game.

1. In the first stage, before receiving any private information, the firms independently commit to either share or reveal their private information. Once the uncertainty is realized and private signals are received, a firm's information is revealed or not revealed to its competitor.
2. In the second stage, the firms non-cooperatively set prices that maximize individual expected profits, conditional on their available information.

4. The Impact of Information Sharing on Equilibrium Profits

We estimate the equilibrium profits made by Bertrand duopolists under the three information-sharing scenarios $Z \in \{pr, sh, g\}$, when firms keep information private, when firms share information and when one firm gives away information while the other firm keeps it private, respectively.

We focus on the scenario where the two competing firms are symmetric. The insights from our analysis also extend to the case where the firms are asymmetric. When the firms are symmetric, we let $\delta_i = \delta$. The firms' conditional probability beliefs about expensive customers can be represented as follows: $\Pr(s_1 s_2 = HL | j = E) = \delta$; $\Pr(s_1 s_2 = LH | j = E) = \delta$; $\Pr(s_1 s_2 = HH | j = E) = 0$ and $\Pr(s_1 s_2 = LL | j = E) = 1 - 2\delta$. And since we must have $1 - 2\delta \geq 0$, the noise parameter δ is constrained as follows:

$$0 \leq \delta \leq 0.5$$

When the firms are symmetric, we let $\lambda_H = \lambda_{iH}$, where λ_H measures the conditional probability of inexpensive customers giving H signals, or $\Pr(j = I | s = H)$, while $(1 - \lambda_H)$ measures the conditional probability of expensive customers giving H signals, or $\Pr(j = E | s = H)$. We also let $\theta = \theta_i$, where θ measures the fraction of consumers from whom a firm receives H signals. These parameters are related as follows:

$$\lambda_H = \frac{\lambda}{\theta} = \frac{\lambda}{\lambda + (1 - \lambda)\delta}$$

We now model how the firms' optimal decision to share or not share information gets moderated by the relative proportion of inexpensive customers in the market λ , the noise in the firms' information δ , the marginal cost of selling to expensive customers c_E , and the product differentiation between the competing firms γ .

Both Firms Keep Information Private ($Z = pr$)

We first model the firms' Bertrand pricing problem when both firms keep information private. To simplify the exposition, we focus on the case in which a firm sells only to those from whom it

receives H signals, which includes both inexpensive and expensive customers. We assume that parameters in the economy satisfy Condition A:

Condition A:

$$c_I < \alpha < c_E < c_I + \frac{(\alpha - c_I)(M + \lambda(1 - \gamma))^2}{M(M + \lambda)} \text{ when } \gamma > 0$$

$$c_I < \alpha < c_E < c_I + \frac{(\alpha - c_I)(M + \lambda)}{M}, \text{ when } \gamma < 0, \text{ where } M = \delta(1 - \lambda)(1 - \gamma^2).$$

As we show later, the first inequality of condition A ensures that it is optimal for the firm to serve inexpensive customers, the second inequality ensures that the firm will not serve expensive customers, and the third inequality ensures that the firm will serve customers from whom it receives H signals.

Given the equilibrium condition that firms will only sell to the customers from whom they have received H signals, the demand function for inexpensive customers is $q_i = a - bp_i + dp_{3-i}$, where $a = \frac{\alpha}{1+\gamma}$, $b = \frac{1}{1-\gamma^2}$ and $d = \frac{\gamma}{1-\gamma^2}$. The demand function for expensive customers is $q_i = \alpha - p_i$. Note that if we invert the inverse demand function $p_i = \alpha - q_i - \gamma q_{3-i}$, we get the demand function for inexpensive customers as $q_i = a - bp_i + dp_{3-i}$.

Note that both the firms do not receive H signals from expensive customers. Consider the expensive customers from whom the firm receives H signals and therefore sells to. The firm's competitor receives L signals from these customers and does not sell to them. Setting $q_{3-i} = 0$, their inverse demand function becomes $p_i = \alpha - q_i$, and we get the demand function for expensive customers as $q_i = \alpha - p_i$.

Suppose firm i sets a price p_i . The firms' profit functions, when both firms keeps information private, are given as follows:

$$\Pi_i = \theta[\lambda_H(p_i - c_I)(a - bp_i + dp_{3-i})] + \theta[(1 - \lambda_H)(p_i - c_E)(\alpha - p_i)]$$

The profit-maximizing problem for firm $i \in \{1, 2\}$ can thus be represented as

$$\max_{p_i} \lambda(p_i - c_I) \frac{\alpha(1 - \gamma) - p_i + \gamma p_{3-i}}{(1 - \gamma^2)} + \delta(1 - \lambda)(p_i - c_E)(\alpha - p_i)$$

We proceed by simultaneously solving the first-order conditions $\frac{\partial \Pi_i}{\partial p_i} = 0$ and verifying that the

second-order conditions $\frac{\partial^2 \Pi_i}{\partial p_i^2} < 0$ are satisfied. We find that

$$\frac{\partial \Pi_i}{\partial p_i} = \frac{\lambda(\alpha(1-\gamma) - 2p_i + \gamma p_{3-i} + c_I)}{(1-\gamma^2)} + \delta(1-\lambda)(\alpha + c_E - 2p_i)$$

$$\frac{\partial^2 \Pi_i}{\partial p_i^2} = -2 \left(\frac{\lambda}{1-\gamma^2} + \delta(1-\lambda) \right) < 0$$

Since the firms are symmetric, they set the same equilibrium price, p_{pr} , given as follows.

$$p_{pr} = \frac{\lambda(\alpha(1-\gamma) + c_I) + M(\alpha + c_E)}{\lambda(2-\gamma) + 2M}$$

where $M = \delta(1-\lambda)(1-\gamma^2)$. When firms keep information private, the equilibrium demand from inexpensive customers is given by $q_{pr,I} = \frac{\lambda(\alpha - p_{pr})}{(1+\gamma)}$, while the equilibrium demand from expensive customers is given by $q_{pr,E} = \delta(1-\lambda)(\alpha - p_{pr})$. The total equilibrium demand is given by their sum, as $q_{pr} = q_{pr,I} + q_{pr,E}$. Substituting p_{pr} , we find that $(\alpha - p_{pr}) = \left(\frac{\lambda(\alpha - c_I) + M(\alpha - c_E)}{\lambda(2-\gamma) + 2M} \right)$. Thus, we get

$$q_{pr,I} = \frac{\lambda}{(1+\gamma)} \left(\frac{\lambda(\alpha - c_I) + M(\alpha - c_E)}{\lambda(2-\gamma) + 2M} \right)$$

$$q_{pr,E} = \delta(1-\lambda) \left(\frac{\lambda(\alpha - c_I) + M(\alpha - c_E)}{\lambda(2-\gamma) + 2M} \right)$$

$$q_{pr} = \left(\frac{\lambda}{(1+\gamma)} + \delta(1-\lambda) \right) \left(\frac{\lambda(\alpha - c_I) + M(\alpha - c_E)}{\lambda(2-\gamma) + 2M} \right)$$

where $M = \delta(1-\lambda)(1-\gamma^2)$.

The equilibrium profit, when both firms keep information private, is given by

$$\Pi_{pr} = (p_{pr} - c_I)q_{pr,I} + (p_{pr} - c_E)q_{pr,E}, \text{ or}$$

$$\Pi_{pr} = (\alpha - p_{pr}) \left(\frac{\lambda(p_{pr} - c_I)}{1+\gamma} + \delta(1-\lambda)(p_{pr} - c_E) \right)$$

Substituting p_{pr} and simplifying yields the following profit function:

$$\Pi_{pr} = \frac{[M(\alpha - c_E) + \lambda(\alpha - c_I)][(\alpha - c_I)(M + \lambda(1-\gamma))^2 - M(M + \lambda)(c_E - c_I)]}{(1-\gamma^2)(2M + \lambda(2-\gamma))^2}$$

where $M = \delta(1-\lambda)(1-\gamma^2)$

Lemma 1 described below, demonstrates that the incentive of the firm is consistent with the proposed equilibrium behavior, i.e., the firm will only serve H signal customers and will not serve the L signal customers. Please see Appendix A for proofs.

LEMMA 1: Under Condition A, the firm will make a profit from serving H signal customers and will not serve the L signal customers.

The firms will enter the market only if they expect to earn positive profits. This requires that the firms make strictly positive sales ($q_{pr} > 0$) and earn a positive margin from selling to the inexpensive customers ($p_{pr} > c_l$). The inequality in Condition A is derived from these requirements. Note that Condition A implies that the firms' marginal cost of selling to expensive customers cannot exceed a threshold. We also note that $c_E < \alpha$ is a sufficient condition for market entry.

When a firm keeps information private, it sells to customers from whom the firm receives H signals. But this includes both inexpensive customers and also some expensive customers who the firm misclassifies. The firm always earns a profit from selling to the segment of inexpensive customers. However, given the conditions in the model, the firm incurs a loss from selling to expensive customers. This provides an incentive for the firm to avoid selling to this segment by sharing information with its competitor. Next, we model the firms' Bertrand pricing problem for the scenario when both firms share information.

Both Firms Share Information ($Z = sh$)

The firms' profit functions, when both firms share information, are given as

$$\Pi_i = \lambda(p_i - c_l)(a - bp_i + dp_{3-i}), \text{ where } a = \frac{\alpha}{1+\gamma}, b = \frac{1}{1-\gamma^2} \text{ and } d = \frac{\gamma}{1-\gamma^2}.$$

The profit-maximizing problem for firm $i \in \{1, 2\}$ can thus be represented as

$$\max_{p_i} \lambda(p_i - c_l) \frac{\alpha(1-\gamma) - p_i + \gamma p_{3-i}}{(1-\gamma^2)}$$

We proceed by simultaneously solving the first-order conditions $\frac{\partial \Pi_i}{\partial p_i} = 0$ and verifying that the

second-order conditions $\frac{\partial^2 \Pi_i}{\partial p_i^2} < 0$ are satisfied. We find that

$$\frac{\partial \Pi_i}{\partial p_i} = \frac{\lambda(\alpha(1-\gamma) - 2p_i + \gamma p_{3-i} + c_l)}{(1-\gamma^2)}$$

$$\frac{\partial^2 \Pi_i}{\partial p_i^2} = \frac{-2\lambda}{1-\gamma^2} < 0$$

Since the firms are symmetric, they set the same equilibrium price, given as follows:

$$p_{sh} = \frac{\alpha(1-\gamma) + c_I}{(2-\gamma)}$$

Note that the firms earn a strictly positive margin by selling to inexpensive customers, as $p_{sh} > c_I$. Also, the equilibrium sales resulting when the firms share information are given by $q_{sh} = \frac{(\alpha - p_{sh})}{(1+\gamma)}$. Since we must have $q_{sh} > 0$, we see that $\alpha > p_{sh}$. Combining these two inequalities indicates that the equilibrium price is constrained as $\alpha > p_{sh} > c_I$. Also, substituting for p_{sh} in the above expression for the equilibrium sales yields

$$q_{sh} = \frac{(\alpha - c_I)}{(1+\gamma)(2-\gamma)}$$

Notice that $q_{sh} > 0$ also implies $c_I < \alpha$ and this is consistent with Lemma 1. Substitution into the profit function yields the profit when both firms keep information private, as follows:

$$\Pi_{sh} = \frac{\lambda(1-\gamma)(\alpha - c_I)^2}{(1+\gamma)(2-\gamma)^2}$$

We now show that the incentive compatibility condition of the firm is satisfied. Please see Appendix A for proofs.

LEMMA 2: Under Condition A, the firm will make a profit from inexpensive customers and will not serve expensive customers.

When the firms share information, they have no incentive to sell to expensive customers, as they will make losses if they serve them.

LEMMA 3: When firms share information, the equilibrium price p_{sh} is lower than the equilibrium price when firms keep information private ($p_{pr} > p_{sh}$).

Lemma 3 establishes that inexpensive customers pay a lower price when the firms share information, as compared to the case where they kept information private. This lowering of the

equilibrium price has interesting welfare implications, as discussed in the next section of our paper.

Only One Firm Shares Information ($Z = g$)

We now turn our attention to the third remaining information sharing scenario, where one firm shares its information, while its competitor keeps information private. This analysis is necessary, in order to examine if either firm has any incentive to deviate from an information sharing agreement.

For example, imagine the scenario where firm 1 and 2 have an agreement to share information ($Z = sh$). Now suppose Firm 2 breaks their agreement. This leads to a situation where firm 1 does not get access to firm 2's information, while firm 2 has access to firm 1's information.

Under this scenario, the profit maximization problem of firm 1, is as follows,

$$\max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_2}{1-\gamma^2} + \delta(1-\lambda)(p_1 - c_E)(\alpha - p_1)$$

while the profit maximizing problem of firm 2 can be represented as follows:

$$\max_{p_2} \lambda(p_2 - c_I) \frac{\alpha(1-\gamma) - p_2 + \gamma p_1}{(1-\gamma^2)}$$

We proceed by simultaneously solving the first-order conditions $\frac{\partial \Pi_i}{\partial p_i} = 0$ and verifying that the second-order conditions $\frac{\partial^2 \Pi_i}{\partial p_i^2} < 0$ are satisfied, similar to the earlier cases. The first order condition for firm 1 is given by

$$\frac{\lambda}{1-\gamma^2} [\alpha(1-\gamma) - p_1 + \gamma p_2 - (p_1 - c_I)] + \delta(1-\lambda)(\alpha + c_E - 2p_1) = 0$$

Similarly, the first-order condition for firm 2 is given by

$$\frac{\lambda}{1-\gamma^2} [\alpha(1-\gamma) - p_2 + \gamma p_1 - (p_2 - c_I)] = 0$$

Let p_{g1} and p_{g2} represent the equilibrium profit-maximizing prices selected by the firms. The equilibrium prices are given as follows.

$$p_{g1} = \frac{2M(\alpha + c_E) + \lambda(2 + \gamma)(\alpha(1 - \gamma) + c_I)}{4M + \lambda(4 - \gamma^2)}$$

$$p_{g2} = \frac{M(\alpha(2 - \gamma) + 2c_I + \gamma c_E) + \lambda(2 + \gamma)(\alpha(1 - \gamma) + c_I)}{4M + \lambda(4 - \gamma^2)}$$

where $M = \delta(1 - \lambda)(1 - \gamma^2)$.

Substitution into the profit functions yields the firm profits. Firm 1's profit, given that firm 1 shares information, but firm 2 keeps information private, is as follows.

$$\Pi_{g1} = \frac{\lambda(p_{g1} - c_I)(\alpha(1 - \gamma) - p_{g1} + \gamma p_{g2})}{(1 - \gamma^2)} + \delta(1 - \lambda)(p_{g1} - c_E)(\alpha - p_{g1}),$$

where p_{g1} and p_{g2} are given as above. Substituting for p_{g1} and p_{g2} yields

$$\Pi_{g1} = \frac{\frac{\lambda}{(1 + \gamma)} J_1 J_2 + \delta(1 - \lambda) K_1 K_2}{[4M + \lambda(4 - \gamma^2)]^2}, \text{ where}$$

$$J_1 = \alpha(2M + \lambda(2 + \gamma)(1 - \gamma)) + 2Mc_E - (4M + \lambda(2 + \gamma)(1 - \gamma))c_I$$

$$J_2 = \alpha(1 - \gamma)[\delta(1 - \lambda)(3\gamma^2 + \gamma^3 - 2) + \lambda(2 + \gamma)] + (2 - \gamma^2)Mc_E - (2\gamma M - \lambda(2 + \gamma)(1 - \gamma))c_I$$

$$K_1 = \alpha(2M + \lambda(2 + \gamma)) - 2Mc_E - \lambda(2 + \gamma)c_I$$

$$K_2 = \alpha[2M + \lambda(2 + \gamma)(1 - \gamma)] - [2M + \lambda(4 - \gamma^2)]c_E + \lambda(2 + \gamma)c_I$$

Similarly, firm 2's profit, given that firm 1 shares information, but firm 2 keeps information private, is as follows.

$$\Pi_{g2} = \frac{\lambda(p_{g2} - c_I)(\alpha(1 - \gamma) - p_{g2} + \gamma p_{g1})}{(1 - \gamma^2)}$$

Substituting for p_{g1} and p_{g2} and simplifying, yields

$$\Pi_{g2} = \frac{\lambda[\alpha((2 - \gamma)M - (2 + \gamma)\lambda) + \gamma Mc_E - (2M + (2 + \gamma)(1 - \gamma)\lambda)c_I]^2}{(1 + \gamma)[4M + \lambda(4 - \gamma^2)]^2}$$

where $M = \delta(1 - \lambda)(1 - \gamma^2)$.

In the subgame in which only one firm shares information, in order for the proposed strategies to be in equilibrium, we need to make sure that the firms will make positive profits. Clearly, we have $\Pi_{g2} > 0$. Therefore, the proposed pricing strategies constitute an equilibrium in the subgame whenever $\Pi_{g1} > 0$. Thus, when $\Pi_{g1} > 0$, the firm which gives out information will serve L signal customers and the firm which does not give out information but takes

information will serve only inexpensive customers. Moreover, none of the firms will serve the expensive customers. However, as we show in the next section, in the first stage game on the decision to share information, $Z=g$, in which only one firm shares information, will never be a Nash equilibrium. We now turn to the first stage game to analyze the incentive to share information.

5. Firm Incentives to Share Information

We establish the constraints under which firms find it Pareto optimal to share information by comparing the profits made by the firms when $Z = sh$ or $Z = g$ relative to $Z = pr$. We consider the relative change in Bertrand profits when both firms share information, $\Delta\Pi_{sh} = (\Pi_{sh} - \Pi_{pr})$, relative to when both firms keep information private. We also investigate the incentive to deviate from an information sharing agreement, by examining the relative change in Bertrand profits when firm 1 shares information with firm 2 but firm 2 keeps its information private, $\Delta\Pi_{g1} = (\Pi_{g1} - \Pi_{pr})$ and $\Delta\Pi_{g2} = (\Pi_{g2} - \Pi_{pr})$, relative to when both firms keep information private.

PROPOSITION 1.

- *The firms keep information private when the competing products are substitutes. However, there exists a Prisoner's Dilemma — they would be better off if both firms shared information.*
- *The firms share information when the competing products are complements.*

Please see Appendix B for an analytical proof of Proposition 1.

We first establish the conditions necessary for a Prisoner's Dilemma to occur and also the conditions necessary for the firms to prefer sharing information to keeping information private. Next, we examine the case where the products are substitutes, separately from the case where the products are complements.

The three conditions necessary for the Prisoner's Dilemma with respect to information sharing to occur are as follows.

1. The profit when the firms share information is higher than the profit when the firms keep information private: $(\Pi_{sh} > \Pi_{pr})$ or $(\Delta\Pi_{sh} > 0)$.

2. Each firm has an individual incentive to deviate from an information sharing agreement: $(\Pi_{g2} > \Pi_{sh})$ or $(\Delta\Pi_{g2} > \Delta\Pi_{sh})$.
3. Each firm prefers keeping information private to giving information away: $(\Pi_{g1} < \Pi_{pr})$ or $(\Delta\Pi_{g1} < 0)$.

We find that such a Prisoner's Dilemma occurs when the competing products are substitutes ($0 < \gamma < 1$). The Nash equilibrium resulting from this Prisoner's Dilemma is that both firms keep information private. Interestingly, the firms would both make a higher profit if both shared information, since $(\Delta\Pi_s > 0)$. However, mutually sharing information is not a Nash equilibrium, as each firm has an independent incentive to deviate from an information sharing agreement $(\Delta\Pi_{g2} > \Delta\Pi_{sh})$. Thus, there exists a Prisoner's Dilemma regarding information sharing when the above conditions are satisfied and the resulting Nash equilibrium is that both firms keep information private.

We now consider the conditions necessary for the firms to prefer sharing information to keeping information private.

1. The profit when the firms share information is higher than the profit when the firms keep information private: $(\Pi_{sh} > \Pi_{pr})$ or $(\Delta\Pi_{sh} > 0)$.
2. Neither firm has an individual incentive to deviate from an information sharing agreement: $(\Pi_{g2} < \Pi_{sh})$ or $(\Delta\Pi_{g2} < \Delta\Pi_{sh})$.

We find that when the competing products are complements ($-1 < \gamma < 0$), both these conditions are satisfied. The resulting Nash equilibrium is that both firms share information.

The intuition behind Proposition 1 lies in the trade-off faced by competing firms that sell differentiated products to a heterogeneous population of inexpensive and expensive customers. Sharing information causes an increase in price competition between the firms for the desirable segment of inexpensive customers, particularly when the competing products are substitutes. At the same time, sharing information improves the firms' ability to segment and sell to inexpensive customers in the market, which lowers their marginal costs. These cost savings are a function of the relative proportion of expensive customers in the market and the uncertainty associated with identifying them. The gains from information sharing are higher when the relative proportion of expensive customers in the market is greater. The tug-of-war between lower marginal costs and higher price competition drives the equilibrium outcomes.

Insert Figure 2

We demonstrate Proposition 1 using numerical simulations. Figure 2 shows the incentive of the firms to share information, as a function of the product differentiation ($-1 < \gamma < 1$). We consider a unit demand intercept $\alpha = 1$ and normalize the marginal cost of selling to inexpensive customers as $c_I = 0$ without loss of generality. Further, we fix the level of noise in the firms' information as $\delta = 0.25$ and examine the case where the proportion of expensive customers in the market is $(1-\lambda) = 10\%$.

The left panel of Figure 2 plots the change in equilibrium price when firms share information, compared to when the firms keep information private ($p_{sh} - p_{pr}$), with respect to the product differentiation ($-1 < \gamma < 1$). We observe that the equilibrium prices when firms share information are always lower than those when the firms keep information private, or $p_{sh} - p_{pr} < 0$. This numerically illustrates Lemma 3.

The right panel of Figure 2 plots the change in profits under information sharing, when firms share information, compared to when the firms keep information private, with respect to the product differentiation ($-1 < \gamma < 1$). It illustrates that $\Delta\Pi_{g2} > \Delta\Pi_{sh} > 0 > \Delta\Pi_{g1}$ for ($0 < \gamma < 1$). This demonstrates the Prisoner's Dilemma, when the products are substitutes. The right panel of Figure 2 also illustrates that $\Delta\Pi_{sh} > 0 > \Delta\Pi_{g2}$ for ($-1 < \gamma < 0$). This demonstrates that the Nash equilibrium, when the products are complements, is that the firms share information.

Comparative Statics

We additionally numerically illustrate the comparative statics for the firms' incentive to share information, with respect to the other model parameters. Specifically, we demonstrate how the relative proportion of expensive customers in the market ($1-\lambda$); the noise in the firms' information (δ) and the relative marginal cost of selling to expensive customers c_E , moderate the incentives to share customer information.

RESULT 1: The gain from sharing information increases as the proportion of expensive customers in the market ($1-\lambda$) increases, provided their relative proportion is small.

Insert Figure 3

We numerically illustrate in the top left panel of Figure 3 that when the firms are substitutes ($\gamma=0.5$), the gains from information sharing increase, as the relative proportion of expensive customers in the market ($1-\lambda$) increases up to $\sim 60\%$. However, as the proportion of expensive customers increases beyond $\sim 60\%$, the relative sales made by the firms start decreasing so much, that they begin to overwhelm the gains from sharing information. This accounts for the decrease in gain from sharing information. Analogously, the top right panel of Figure 3 illustrates the case where the firms are complements ($\gamma=-0.5$). We observe an increase in the gains from sharing information, while the relative proportion of expensive customers is less than $\sim 75\%$ and a decrease in gains beyond that.

We also observe that the Prisoner's Dilemma exists for the entire range of proportion of inexpensive customers in the market ($0 < \lambda < 1$), when the products are substitutes ($\gamma = 0.5$). Also, the firms prefer to share information when the products are complements ($\gamma = -0.5$) for all values over the range ($0 < \lambda < 1$). This offers additional evidence in support of Proposition 1.

RESULT 2: The gain from sharing information increases as the noise in the firms' information (δ) increases.

In case firms selling substitute products ($\gamma = 0.5$) are able to coordinate and share information, we find that the benefits from information sharing increase with an increase in the noise in the firms' information, ($0 < \delta < 0.5$). We numerically illustrate this in the middle-left panel of Figure 3. When the firms sell complementary products ($\gamma = -0.5$), the middle-right panel of Figure 3 numerically illustrates a similar result, $\frac{\partial(\Delta\Pi_s)}{\partial\delta} > 0$.

We also note that the Prisoner's Dilemma exists throughout the support of the noise parameter ($0 < \delta < 0.5$), when the products are substitutes ($\gamma = 0.5$). Also, the firms prefer to share information when the products are complements ($\gamma = -0.5$) throughout the support of the noise parameter ($0 < \delta < 0.5$). This offers additional evidence in favor of Proposition 1.

RESULT 3: The gain from sharing information increases as the marginal cost of selling to expensive customers (c_E) increases.

In case firms selling substitute products ($\gamma = 0.5$) are able to coordinate and share information, we find that the benefits from information sharing increase, as the marginal cost of serving the expensive customers increase. This is clear from the bottom-left panel of Figure 3. A

similar result $\frac{\partial(\Delta\Pi_s)}{\partial c_E} > 0$ is also numerically illustrated in the bottom-right panel of Figure 3,

when the firms share information, given that the products are complementary ($\gamma = -0.5$).

We once again note that the Prisoner's Dilemma exists in the numerical simulation with respect to c_E , when the products are substitutes ($\gamma = 0.5$). Also, once again, the firms prefer to share information when the products are complements ($\gamma = -0.5$). This offers even more evidence in favor of Proposition 1.

RESULT 4: The Nash equilibria of the information-sharing game are $Z = \{pr, sh\}$ and $Z = g$ is never a Nash equilibrium. There is no asymmetric pure strategy equilibrium.

Our numerical simulations in Figures 2 and 3 illustrate that the Nash equilibrium of the information sharing game, when the firms are substitutes, is that they keep information private ($Z = pr$). Our simulations also illustrate that when the firms are complements, the Nash equilibrium of the information sharing game is that the firms share information ($Z = sh$).

6. The Impact of Information Sharing on Consumer Surplus

We measure the consumer surplus, corresponding to the profit maximizing prices set by two competing symmetric firms, as discussed above.

Consumer Surplus When Both Firms Keep Information Private ($Z = pr$)

The symmetric firms set the equilibrium price p_{pr} and sell to a fraction of λ inexpensive and $1-\lambda$ expensive customers. The demand function is given by $p_i = \alpha - q_i - \gamma q_{3-i}$. For the symmetric case, the demand function for inexpensive customers is given as $p = \alpha - (1+\gamma)q$, while the demand function for expensive customers is given as $p = \alpha - q$.

A given consumer's surplus is defined as the difference between her maximum willingness to pay and the price charged by the firm. Thus, we aggregately measure the surplus of all inexpensive customers, representing a fraction λ , of all sales, by integration. Following Tirole (1988, pp 9-12), the consumer surplus of inexpensive customers, when two symmetric firms keep information private, is given as follows.

$$CS_{pr,I} = 2 \int_{p_{pr}}^{\alpha} \frac{\lambda(\alpha - p)}{(1 + \gamma)} dp = \frac{\lambda(\alpha - p_{pr})^2}{(1 + \gamma)}$$

Analogously, the consumer surplus of expensive customers, when two symmetric firms keep information private, is given as follows.

$$CS_{pr,E} = 2 \int_{p_{pr}}^{\alpha} \delta(1 - \lambda)(\alpha - p) dp = \delta(1 - \lambda)(\alpha - p_{pr})^2$$

The aggregate consumer surplus across all consumers, when both firms keep information private, is the sum, $CS_{pr} = CS_{pr,I} + CS_{pr,E}$, given as follows.

$$CS_{pr} = \left(\frac{\lambda}{(1 + \gamma)} + \delta(1 - \lambda) \right) (\alpha - p_{pr})^2$$

Substituting for p_{pr} yields

$$CS_{pr} = \left(\frac{\lambda}{(1 + \gamma)} + \delta(1 - \lambda) \right) \left(\frac{\lambda(\alpha - c_I) + \delta(1 - \lambda)(1 - \gamma^2)(\alpha - c_E)}{\lambda(2 - \gamma) + 2\delta(1 - \lambda)(1 - \gamma^2)} \right)^2$$

Consumer Surplus When Both Firms Share Information ($Z = sh$)

The symmetric, competing firms set the equilibrium price p_{sh} and sell only to inexpensive customers and do not sell to any expensive customers. Under this scenario, the consumer surplus of expensive customers is zero, while the consumer surplus of inexpensive customers is measured by integration as follows.

$$CS_{sh} = 2 \int_{p_{sh}}^{\alpha} \frac{\lambda(\alpha - p)}{(1 + \gamma)} dp = \frac{\lambda(\alpha - p_{sh})^2}{(1 + \gamma)}$$

Substituting for p_{sh} yields

$$CS_{sh} = \frac{\lambda(\alpha - c_I)^2}{(1 + \gamma)(2 - \gamma)^2}$$

Consumer Surplus When Only One Firm Shares Information ($Z = g$)

Result 4 demonstrates that ($Z = g$) is never a Nash Equilibrium. Since this information-sharing scenario never arises in equilibrium, we do not measure the corresponding consumer surplus.

Comparing the Change in Consumer Surplus of Expensive and Inexpensive Customers

We now examine the impact of information sharing on consumer surplus across the two segments of expensive and inexpensive customers. Specifically, we compare the consumer surplus of each segment when ($Z = sh$) with that when ($Z = pr$).

Recall from Proposition 1 that the firms

PROPOSITION 2: When firms share information, the consumer surplus of inexpensive customers increases, while that of the expensive customers decreases.

Please see Appendix C for an analytical proof of Proposition 2.

The intuition behind Proposition 2 is that the segment of expensive customers in the market raises the marginal cost incurred by the firms. If information sharing improves the firms' ability to exclude expensive customers and sell to inexpensive customers, the consumer surplus of expensive customers decreases.

The expensive customers impose a negative externality on the inexpensive customers, in the sense that the increase in the firms' marginal costs translates into a higher equilibrium price for all consumers in the market. Sharing information results in lower equilibrium prices, as shown in Lemma 3. This correspondingly causes an increase in the consumer surplus of the inexpensive customers.

Insert Figures 4 and 5

We numerically illustrate Proposition 2 in Figures 4 and 5. Figure 4 demonstrates that the consumer surplus of inexpensive customers increases, while that of the expensive customers decreases, as a function of the product differentiation ($-1 < \gamma < 1$) in the market, holding other model parameters constant. The top panels of Figure 5 demonstrates a similar increase in the surplus of inexpensive customers and decrease in the surplus of expensive customers, as a

function of the proportion of expensive customers ($0 < 1-\lambda < 1$) in the market, both when the competing products are substitutes ($\gamma = 0.5$) and complements ($\gamma = -0.5$). The middle panels of Figure 5 illustrate Proposition 1, but with respect to variation in the noise ($0 < \delta < 1$) in the firms' information, both when the competing products are substitutes ($\gamma = 0.5$) and complements ($\gamma = -0.5$). Finally, the bottom panels of Figure 5 illustrate Proposition 1 with respect to variations in the marginal cost of selling to expensive customers. Figures 4-5 collectively reinforce that when firms share information, the inexpensive customers are better off, while the expensive customers are not served.

The Impact of Information Sharing on Aggregate Consumer Surplus

We examine the corresponding impact of information sharing on aggregate consumer welfare, by estimating the consumer surplus when both firms keep information private ($Z = pr$) and share information ($Z = sh$). By aggregate consumer surplus, we refer to the sum of the consumer surplus of expensive and inexpensive customers in the market. Note that once again we ignore the case when only one firm shares information while the other firm keeps information private ($Z = g$), because as per Result 4, this is never an equilibrium outcome. We examine whether $\Delta CS_{sh} = (CS_{sh} - CS_{pr}) > 0$. This investigation highlights the aggregate impact of information sharing between firms on consumers.

PROPOSITION 3: When firms share information, the aggregate consumer surplus increases when the following condition is satisfied:

$$M^2 \frac{(\alpha - c_E)^2}{(\alpha - c_I)^2} + M \left[\frac{2\lambda(\alpha - c_E)}{\alpha - c_I} + \lambda(1 - \gamma) \left(\frac{(\alpha - c_E)^2}{(\alpha - c_I)^2} - \frac{4}{(2 - \gamma)^2} \right) \right] + \lambda^2 \left[1 - 2(1 - \gamma) \left(\frac{2}{2 - \gamma} - \frac{\alpha - c_E}{\alpha - c_I} \right) \right] < 0$$

In particular, this inequality is satisfied when $\gamma < 2/3$.

We illustrate this proposition through numerical simulations in Figures 6 and 7.

Insert Figures 6 and 7

Figure 6 illustrates the change in aggregate consumer surplus, as a function of the product differentiation ($-1 < \gamma < 1$) in the market. We observe that the aggregate consumer surplus

typically increases. An exception to this is that the aggregate consumer surplus decreases for ($2/3 < \gamma < 1$).

The top panel of Figure 7 demonstrates that the aggregate consumer surplus increases, as a function of the proportion of expensive customers ($0 < 1-\lambda < 1$) in the market, both when the competing products are substitutes ($\gamma = 0.5$) and complements ($\gamma = -0.5$). The middle panel of Figure 7 illustrates Proposition 3, but with respect to variation in the noise ($0 < \delta < 1$) in the firms' information, both when the competing products are substitutes ($\gamma = 0.5$) and complements ($\gamma = -0.5$). Finally, the bottom panel of Figure 7 illustrates Proposition 3 with respect to variations in the marginal cost of selling to expensive customers. The important point to emphasize here is that consumers can be aggregately better off when firms share information.

7. Implications and Insights

7.1. Management of Information Assets

Customer information has become an increasingly important corporate asset in the modern information-intensive business environment. Our analysis examines how firms' knowledge about individual customers affects the nature of their strategic interactions and thus offers some noteworthy implications regarding the management of information assets in a competitive scenario. Should a firm share its customer information that individually identifies expensive customers with its competitors?

Our work establishes that the firm's decision to share such information is driven by a tug-of-war between a decrease in marginal costs arising from not selling to expensive customers on the one hand and a decrease in profits from increased price competition on the other hand. Whether competing firms should share their knowledge of individual customers in a market is driven critically by the product differentiation between the firms. Our research demonstrates that even though a superior knowledge of individual customers may be a competitive advantage, it does not mean that the firm always protects its customer information from its competitors. Rather, firms can benefit mutually from sharing individual customer information.

Specifically, we find support for information sharing when the competing products are complements, but find that firms keep information private when they sell substitute products. The counterintuitive outcome of our analysis is that firms selling substitute products may actually be able to increase their mutual profits by entering into an information-sharing

agreement. However, the limitation of such an agreement lies in each individual firm's incentive to deviate away from its commitment to share information. This in turn gives rise to the need for an external mechanism to regulate information sharing.

7.2. To Join or Not to Join an Industry Trade Group?

An industry trade group or trade association is one institution through which information gets collected, organized, and transmitted among firms. For example, the National Retail Federation (NRF) is the world's largest retail trade association, with membership that comprises all retail formats and channels of distribution including department, specialty, discount, catalog, Internet, grocery, and independent stores, as well as chain restaurants and the industry's key trading partners of retail goods and services. The NRF's statistical program typically involves three steps: (1) Collect individual company data, usually about production, demand, or cost; (2) compile industry wide totals; and (3) distribute aggregate reports to member firms and others (Vives 1990). The decision to join an industry trade group remains a strategic consideration for many firms that involves various micro-level considerations. For example, information sharing under the umbrella of an industry trade group may affect the degree of competitiveness in the market or increase the covariance between firms' actions. At a macro level, this issue has important implications for antitrust regulations, legislation, and public policy in terms of whether it improves efficiency and social surplus.

Should a firm join a trade association? Our research offers one noteworthy insight into this question in a competitive scenario. Our equilibrium analysis demonstrates a Prisoner's Dilemma if the competing products are substitutes. We find that the firms can increase their profits by sharing information when the decrease in marginal costs brought about by not selling to expensive customers, dominates the increase in price competition. However, the profits that the firm can accrue, if it deviates from an information-sharing agreement, are even higher than those it earns from sharing information. This situation gives rise to a Prisoner's Dilemma. Ironically, the firms are unable to sustain an information-sharing agreement without external supervision, and in equilibrium, they end up keeping information private.

We suggest that industry trade groups might oversee the sharing of market information among firms that sell competing products. In particular, they may help overcome the information-sharing Prisoner's Dilemma. (If we expand the strategy space to include the choice

of deciding to join a trade association prior to the information-sharing decision, both firms will choose to join the association to obviate the Prisoner's Dilemma due to defection.) Joining an industry trade group therefore could lead to a win-win situation for the competing firms as well as the dominant majority of inexpensive customers in the market. Although firms may have other exogenous reasons that dictate their decision to join or not join industry trade associations, our research identifies one compelling reason in support of firms joining trade associations.

7.3. Whom Do Privacy Laws Protect?

Electronic data-mining systems gather and process information about consumers 24 hours a day, tracking prior purchases, personal files and public records, and Internet surfing. They thus create overall databases of individual behavior that contain details about everything, from activities and interests to credit and product purchasing habits. Garfinkel (2001) cautions consumers to be concerned about how and where their data are collected, tracked, and stored; the laws that protect privacy; and who owns, manipulates, ensures the safety of, and manages the vast amount of individually identifiable personal data. Other advocates of stringent privacy laws argue that consumers are adversely affected when firms share their information. Privacy and security experts advise consumers about why and how to protect themselves from information predators (Sontag 2001; Luna 2004), and opinion polls consistently show that the public would prefer more privacy and is concerned about its erosion.

Our research attempts to temper the panic and mitigate the dismal picture painted by privacy experts by advocating a more neutral stance. We demonstrate that privacy laws meant to protect consumers from economic injury have instead had a heterogeneous impact on consumer welfare. For example, we find a heterogeneous change in consumer surpluses across our two customer segments when competing firms share customer information: The consumer surplus of inexpensive customers increases, while expensive customers are not served in equilibrium. We infer from this finding that the expensive customers impose an indirect negative externality on the inexpensive customers. The adverse impact of expensive customers thus has two facets: (1) These customers impose a direct cost on the firms by raising their marginal costs and lowering their profitability and (2) they impose an indirect cost on the inexpensive customers.

Firm incentives to share customer information are moderated by privacy laws, which constrain their ability to share information legally. Our analysis justifies a more moderate stance

toward privacy laws. Brin (1999) supports our argument, arguing for less, not more, privacy protection. He claims that attempts to protect privacy usually benefit only a minority of the powerful or corrupt. The counterintuitive insight emerging from our research is that society as a whole may be better off with relatively weaker privacy laws. Although we acknowledge that our suggestion must be tempered, in the sense that we refer to one specific notion of private information, we hope to provoke the idea that strict privacy laws may not increase consumer welfare.

8. Conclusion and Limitations

The advancement of technology, particularly database management, data-mining techniques, and network communications, has dramatically increased firms' ability to collect, process, and share individual customer information. It is therefore more important than ever for companies to assess the individual value of their customers objectively and acknowledge the fallacy that the customer is always right. Some customers are so costly that a company may be better off by not serving them. Firms with access to progressively more comprehensive, detailed, and precise databases of micro-level customer information can use increasingly sophisticated data mining and segmentation techniques to identify expensive customers. On a related note, advancements in information collection in the modern digital age are causing increasing and widespread privacy concerns among contemporary consumers about individual profiling by firms and data sharing among firms. Policymakers and consumer protection groups actively question the current state of privacy laws and their impact on consumer welfare.

Our article addresses these issues and investigates information sharing by firms that offer differentiated products. Expensive customers, who seek a high level of service, impose a high cost on the firm, and when the firm offers a single price, inexpensive customers, who seek a lower level of service, end up subsidizing the expensive customers. We present an analytical model to examine the conditions in which two profit-maximizing Bertrand competitors become motivated to share information about the cost of serving various consumers and the identify of the expensive customers in the market. We find that the implications differ depending on the degree of product differentiation between the competing firms in the market. In particular, when the competing products are substitutes, our model predicts a Prisoner's Dilemma. The competing firms are better off by sharing information as opposed to keeping it private, but the benefits from

reneging on an information-sharing agreement are even higher, so paradoxically, both firms keep their information private in equilibrium.

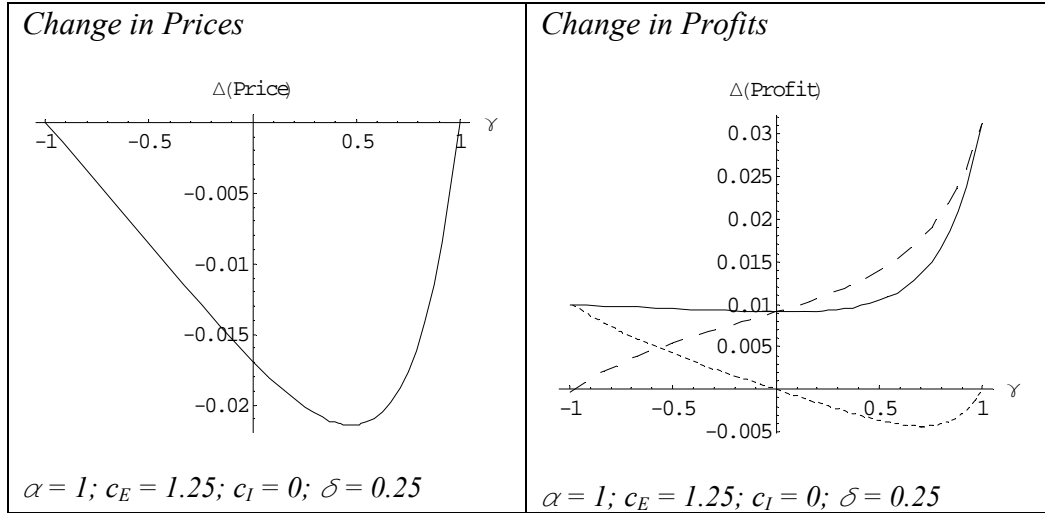
We infer that syndicates, such as industry trade associations, can play a supervisory role in coordinating joint information-sharing agreements between competing firms. On a related note, the sharing of customer information among firms remains constrained by privacy laws. Whereas advocates of stringent privacy laws claim that consumers are always adversely affected when firms share information, we question the validity of this hypothesis. Our analysis shows that information sharing increases the welfare of the firms' inexpensive customers, whereas, the expensive customers are not served. Therefore, privacy laws that limit firms from legally sharing customer information heterogeneously affect consumers, such that they protect and benefit the expensive customers more than they do inexpensive customers. This inference is counterintuitive to the comments published in the popular press. Furthermore, our research recommends relatively weaker, not stronger, privacy laws.

Our analysis contains some limitations and constraints. First, in practice, information sharing enhances firms' ability to identify and exclude expensive customers. However, we consider a limiting case of this improvement, in which information sharing allows firms to identify and exclude expensive customers perfectly. Therefore, our results should be interpreted as a useful benchmark and solution to this limiting case. Second, we model a duopoly market that sells to two market segments, which are heterogeneous in the cost they impose on the firms. In practice, markets have many firms and a continuum of consumers. Nevertheless, we expect our key insights to extend to more general settings. Third, we model Bertrand price competition, in which firms simultaneously decide what price to charge. We do not consider any asymmetry that may result from order of entry effects or the sequence of decision-making. Therefore, our model insights might to be affected if we were to consider a Stakelberg market setting. For example, a new entrant may benefit more than an incumbent from information sharing and joining a trade association. We leave this issue for further research.

Figure 1: The 'Dear John' letter issued by Sprint to customers whose contracts were terminated.



Figure 2: Incentive to share information, as a function of product differentiation ($-1 < \gamma < 1$)
 %Expensive Customers ($1 - \lambda$) = 10%



Legend: — $\Delta\Pi_s$; $\Delta\Pi_{g1}$; - - - $\Delta\Pi_{g2}$

Figure 3: Incentive to share information as a function of (a) the fraction of expensive customers; (b) the noise in the information; (c) the marginal cost of serving expensive customers.

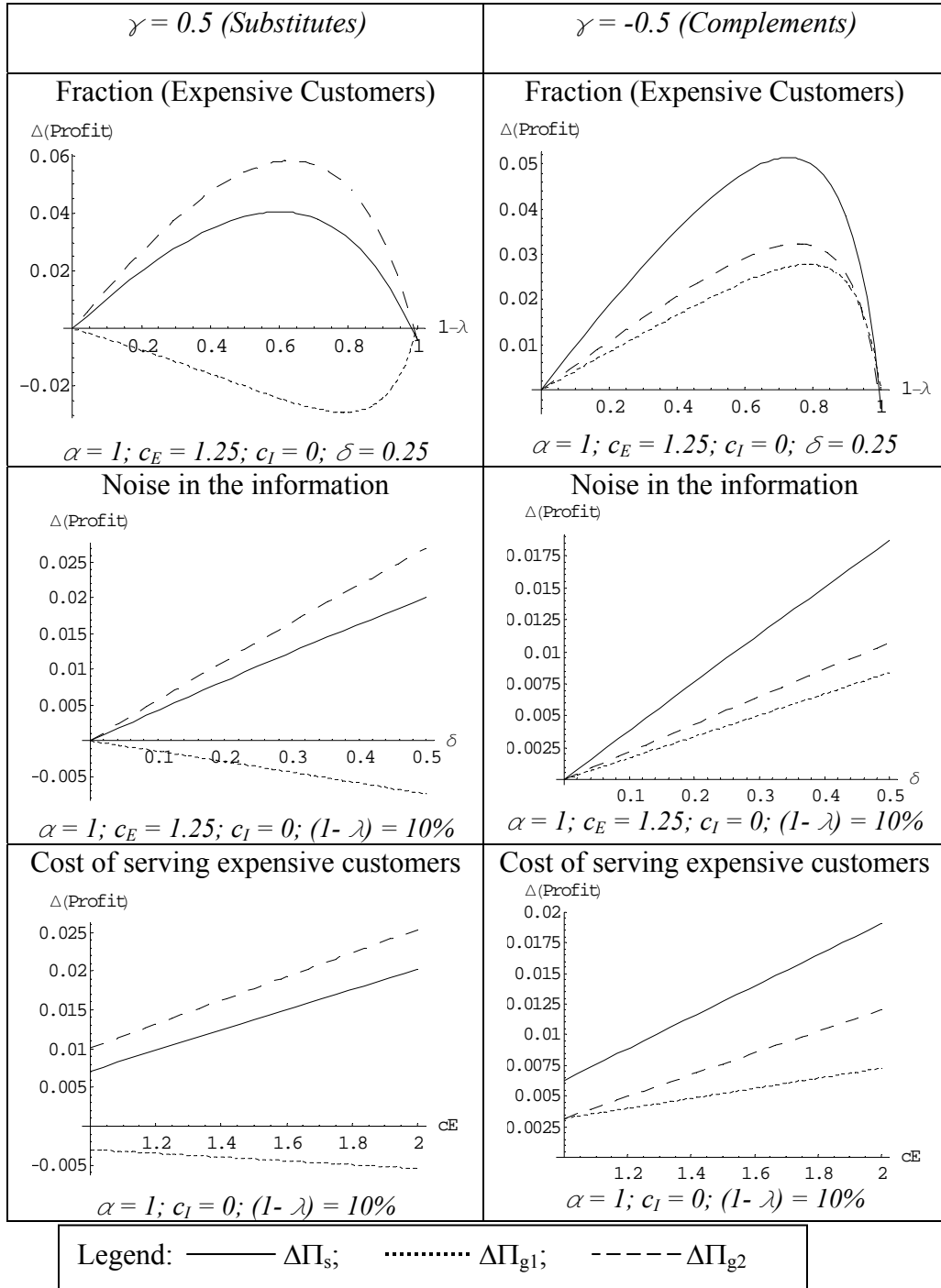


Figure 4: Change in consumer surplus of inexpensive and expensive customers, when firms share information, as a function of product differentiation, ($-1 < \gamma < 1$).

%Expensive Customers ($1 - \lambda$) = 10%

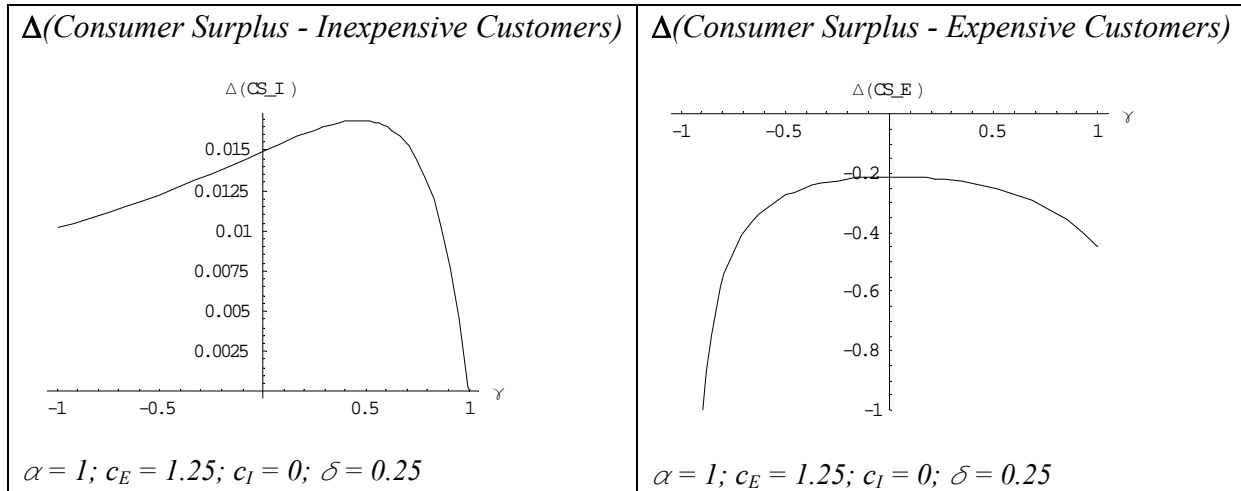
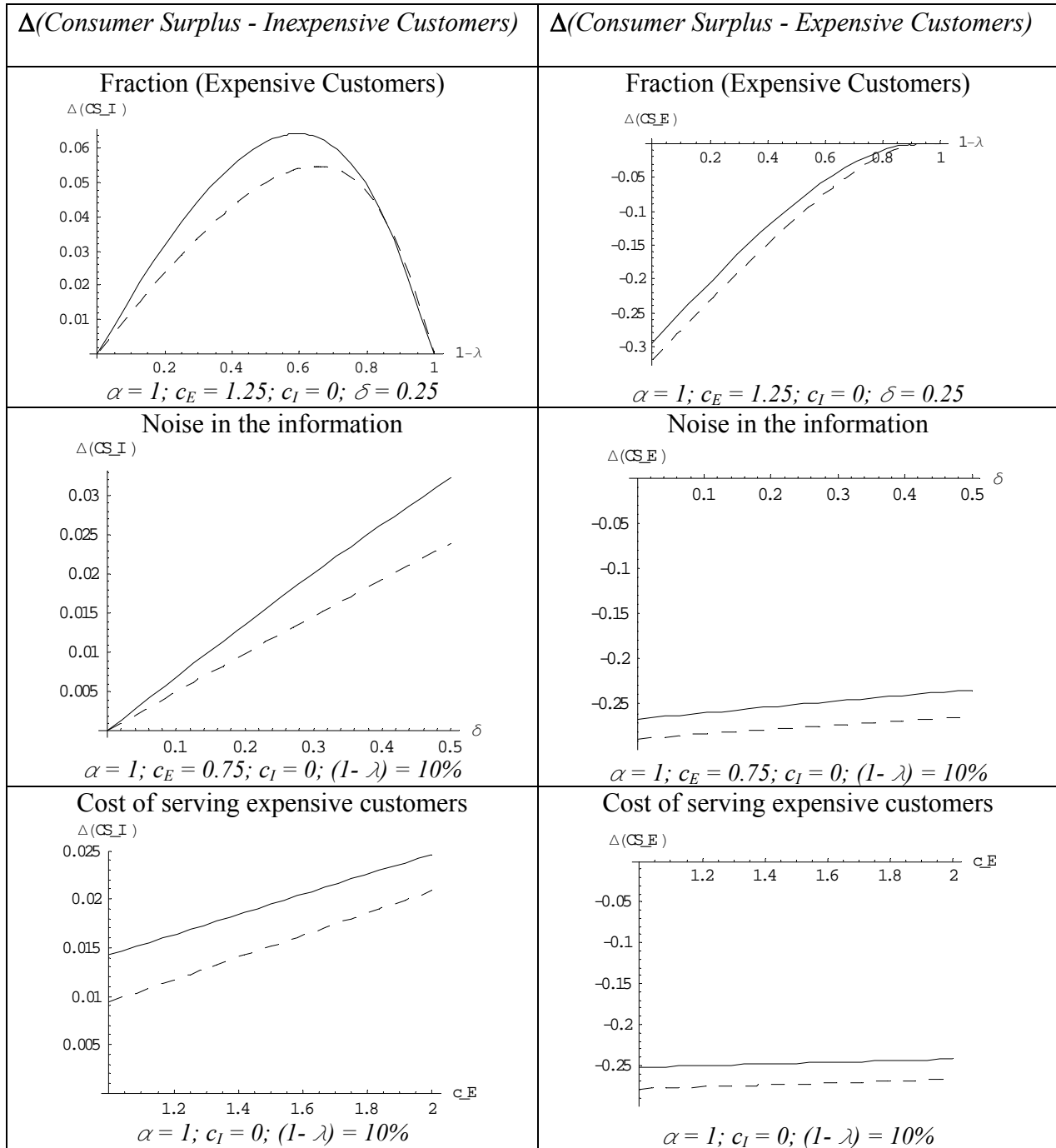


Figure 5: Change in consumer surplus of inexpensive and expensive customers, when firms share information, when the products are substitutes ($\gamma = 0.5$) or complements ($\gamma = -0.5$).



Legend: ——— Substitutes ($\gamma = 0.5$) - - - - - Complements ($\gamma = -0.5$)

Figure 6: Change in aggregate consumer surplus when firms share information, as a function of product differentiation, $(-1 < \gamma < 1)$, when %Expensive Customers $(1 - \lambda) = 10\%$

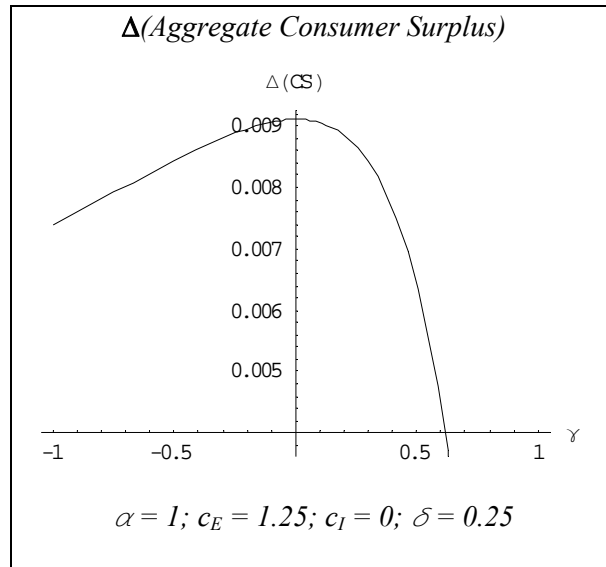
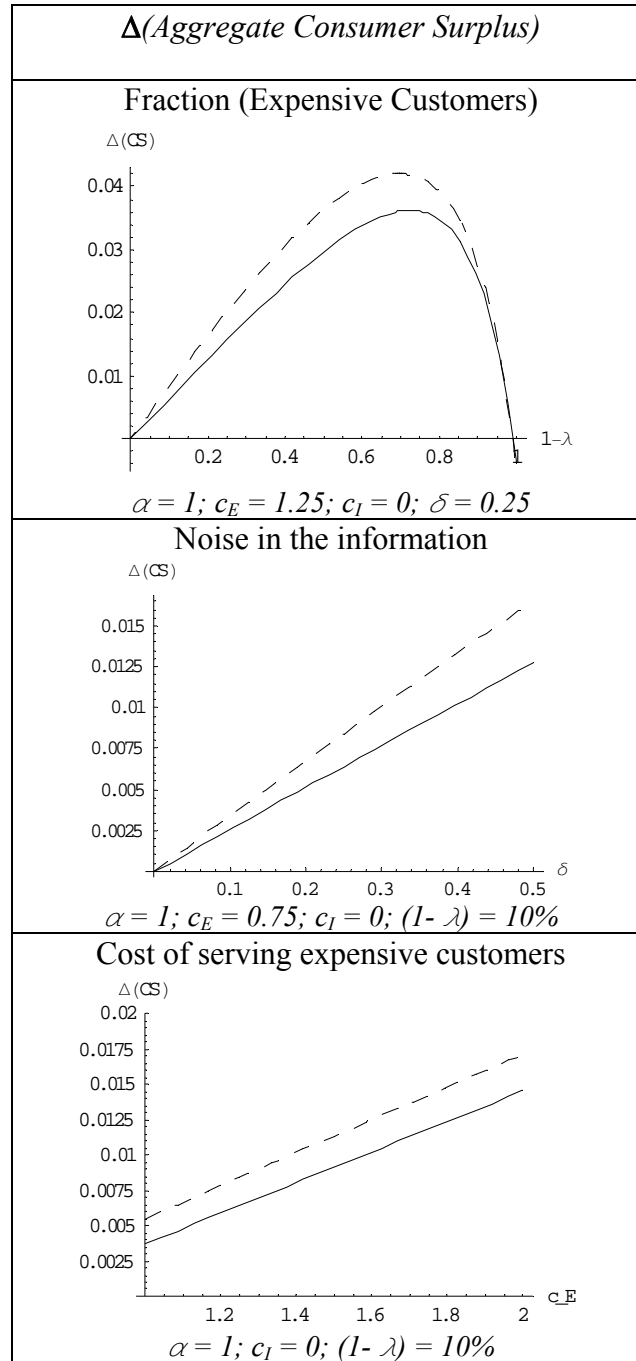


Figure 7: Change in aggregate consumer surplus when firms share information, when the products are substitutes ($\gamma = 0.5$) or complements ($\gamma = -0.5$).



Legend: ——— Substitutes ($\gamma = 0.5$) - - - - - Complements ($\gamma = -0.5$)

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Appendix A

Proof of Lemma 1

Given Condition A, we have $\alpha < c_E$, the firm will not make any profits serving H signal customers who are identified as expensive customers. To prove that the firm will earn positive profits serving L customers. We must have strictly positive equilibrium sales or $q_{pr} > 0$.

Note that $q_{pr} = \left(\frac{\lambda}{(1+\gamma)} + \delta(1-\lambda)\right)(\alpha - p_{pr})$. Since we always have $\frac{\lambda}{(1+\gamma)} + \delta(1-\lambda) > 0$, this implies that $\alpha > p_{pr}$. Substituting for p_{pr} and simplifying yields the following inequality

$$\lambda(\alpha - c_I) + \delta(1-\lambda)(1-\gamma^2)(\alpha - c_E) > 0,$$

which further simplifies to

$$(\alpha - c_I)(M + \lambda) - M(c_E - c_I) > 0, \text{ or}$$

$$1. M(\alpha - c_I) \left[\frac{(M + \lambda)}{M} - (c_E - c_I) \right] > 0$$

Next, we need to prove that the price charged to the customers is higher than the average cost, that is

$$\frac{\lambda(p_{pr} - c_I)}{1 + \gamma} + \delta(1 - \lambda)(p_{pr} - c_E) > 0$$

which reduces to $(\alpha - c_I)(M + \lambda(1 - \gamma))^2 - M(M + \lambda)(c_E - c_I) > 0$, or

$$2. M(M + \lambda)(\alpha - c_I) \left[\frac{(M + \lambda(1 - \gamma))^2}{M(M + \lambda)} - (c_E - c_I) \right] > 0$$

We now analyze which of the two inequalities 1. or 2. dominates.

Inequality 2. dominates inequality 1. whenever $(M + \lambda(1 - \gamma))^2 / [M(M + \lambda)] < (M + \lambda) / M$, or

$$(M + \lambda - \lambda\gamma)^2 < (M + \lambda)^2$$

Squaring both sides and simplifying, this is equivalent to

$$\gamma(2M + (2 - \gamma)\lambda) > 0$$

Note that $(2M + (2 - \gamma)\lambda) > 0$ is always true.

This implies that inequality 2. dominates inequality 1. when the products are substitutes or $\gamma > 0$, while inequality 1. dominates inequality 2. when the products are complements or $\gamma < 0$.

Thus, we get

$$c_E < c_I + \frac{(\alpha - c_I)(M + \lambda(1 - \gamma))^2}{M(M + \lambda)} \text{ when the products are substitutes or } \gamma > 0.$$

And we get

$$c_E < c_I + \frac{(\alpha - c_I)(M + \lambda)}{M} \text{ when the products are complements or } \gamma < 0.$$

Combining the above analysis, we get Condition A as follows:

Condition A:

$$c_I < \alpha < c_E < c_I + \frac{(\alpha - c_I)(M + \lambda(1 - \gamma))^2}{M(M + \lambda)} \text{ when } \gamma > 0.$$

$$c_I < \alpha < c_E < c_I + \frac{(\alpha - c_I)(M + \lambda)}{M}, \text{ when } \gamma < 0.$$

QED

Proof of Lemma 2

Lemma 2 follows immediately from the assumption that $c_I < \alpha$ in condition A.

Proof of Lemma 3

We need to prove that the equilibrium price when the firms share information is lower than the equilibrium price when they keep information private, or $p_{pr} > p_{sh}$.

$$\text{Recall } p_{pr} = \frac{\lambda(\alpha(1-\gamma)+c_I)+\delta(1-\lambda)(1-\gamma^2)(\alpha+c_E)}{\lambda(2-\gamma)+2\delta(1-\lambda)(1-\gamma^2)}, p_{sh} = \frac{\alpha(1-\gamma)+c_I}{(2-\gamma)}$$

Note that for any general positive variables, $a, b, x, y > 0$, we have $\frac{a+x}{b+y} > \frac{a}{b} \Leftrightarrow \frac{a}{b} < \frac{x}{y}$

$$\text{Let } a = \alpha(1-\gamma) + c_I; b = (2-\gamma); x = \frac{\delta(1-\lambda)(1-\gamma^2)(\alpha+c_E)}{\lambda}; y = \frac{2\delta(1-\lambda)(1-\gamma^2)}{\lambda}$$

$$\text{Thus, } p_{pr} = \frac{a+x}{b+y}; p_{sh} = \frac{a}{b}$$

$$p_{pr} > p_{sh} \Leftrightarrow \frac{\alpha(1-\gamma)+c_I}{(2-\gamma)} < \frac{\delta(1-\lambda)(1-\gamma^2)(\alpha+c_E)}{2\delta(1-\lambda)(1-\gamma^2)} \Leftrightarrow \frac{\alpha(1-\gamma)+c_I}{(2-\gamma)} < \frac{(\alpha+c_E)}{2} \Leftrightarrow \gamma\alpha + (2-\gamma)c_E > 2c_I$$

$$\text{Thus, } p_{pr} > p_{sh} \Leftrightarrow \gamma\alpha + (2-\gamma)c_E > 2c_I$$

From Condition A, $\alpha > c_I$.

$$\text{Thus, } \gamma\alpha + (2-\gamma)c_E > \gamma c_I + (2-\gamma)c_E = (2-\gamma)(c_E - c_I) + 2c_I > c_I,$$

$$\text{or } \gamma\alpha + (2-\gamma)c_E > 2c_I \Leftrightarrow p_{pr} > p_{sh} \text{ QED}$$

Appendix B

Proof of Proposition 1

Prisoner's Dilemma when the firms are substitutes ($0 < \gamma < 1$).

The Prisoner's Dilemma occurs if three conditions are satisfied:

1. A firm earn more profits by sharing information, or $\Pi_{sh} > \Pi_{pr}$.
2. A firm has an incentive to deviate from the scenario where both firms share information. This occurs if $\Pi_{g2} > \Pi_{sh}$.
3. A firm also prefers to keep information private, whenever a competitor is keeping information private, or $\Pi_{pr} > \Pi_{g1}$.

Firms share information when they are complements ($-1 < \gamma < 0$). This occurs if two conditions are satisfied:

1. A firm earn more profits by sharing information, or $\Pi_{sh} > \Pi_{pr}$. (same as above)
2. Neither firm has an incentive to deviate from sharing information, or $\Pi_{sh} > \Pi_{g2}$. (converse of condition 2 above)

3. A firm also prefers to share information private, whenever a competitor is keeping information private, or $\Pi_{pr} < \Pi_{g1}$.

We first prove that $\Pi_{sh} > \Pi_{pr}$, notice first that Π_{pr} is a decreasing function of c_E . Thus we have, for $\gamma < 0$. Notice that $p_{pr} > p_{sh}$, given the equilibrium pricing strategy of firm 2, firm 1 will always make lower profit in the private information strategy:

$$\begin{aligned}\Pi_{pr} &= \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{pr}}{1-\gamma^2} + \delta(1-\lambda)(p_1 - c_E)(\alpha - p_1) \\ &< \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{pr}}{1-\gamma^2} \\ &< \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{sh}}{1-\gamma^2} = \Pi_{sh}\end{aligned}$$

Next, we prove the case for $\gamma \geq 0$, first notice that we have

$$2\gamma^2 - \gamma - 2 < 0,$$

which implies that

$$4 > (1-2\gamma)(2-\gamma),$$

which implies that

$$4M + 4\lambda(2-\gamma) > \lambda(1-2\gamma)(2-\gamma)^2$$

and we have

$$(A1) \quad \frac{M(1-2\gamma)}{4M^2 + 4M\lambda(2-\gamma)} < \frac{(1-\gamma)^2}{\lambda(2-\gamma)^2}$$

$$\begin{aligned}(A2) \quad \Pi_{pr} &= \frac{[M(\alpha - c_E) + \lambda(\alpha - c_I)][(\alpha - c_I)(M + \lambda(1-\gamma))^2 - M(M + \lambda)(c_E - c_I)]}{(1-\gamma^2)(2M + \lambda(2-\gamma))^2} \\ &< \frac{\lambda(\alpha - c_I)^2 [(M + \lambda(1-\gamma))^2 - M(M + \lambda)]}{(1-\gamma^2)(2M + \lambda(2-\gamma))^2} < \frac{\lambda(\alpha - c_I)^2 (1-\gamma)^2}{(1-\gamma^2)(2-\gamma)^2} = \Pi_{sh}\end{aligned}$$

Notice that for the last inequality in (A2), we have used (A1).

Next, we prove that $p_{g1} > p_{sh}$.

Notice that p_{g1} is the weighted average of $(\alpha + c_E)/2$ and p_{sh} , moreover, $(\alpha + c_E)/2 > \alpha > p_{sh}$, thus we must have $p_{g1} > p_{sh}$. For $\gamma > 0$,

$$\begin{aligned}\Pi_{g2} &= \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{g1}}{1-\gamma^2} \\ &> \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{sh}}{1-\gamma^2} \\ &= \Pi_{sh}\end{aligned}$$

For $\gamma < 0$,

$$\begin{aligned}\Pi_{g2} &= \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{g1}}{1-\gamma^2} \\ &< \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{sh}}{1-\gamma^2} \\ &= \Pi_{sh}\end{aligned}$$

Finally, notice that p_{pr} and p_{g2} are both the weighted average of $(\alpha + c_E)/2$ and p_{sh} and $(\alpha + c_E)/2 > p_{sh}$. However in the expression of p_{pr} , there is more weight on $(\alpha + c_E)/2$ because

$$\frac{2M}{\lambda/(2-\gamma)} > \frac{2\gamma M}{(\lambda(2+\gamma) + 2M)/(2-\gamma)}$$

Consequently, we have that $p_{pr} > p_{g2}$.

For $\gamma > 0$,

$$\begin{aligned}\Pi_{pr} &= \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{pr}}{1-\gamma^2} + \delta(1-\lambda)(p_1 - c_E)(\alpha - p_1) \\ &> \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{g2}}{1-\gamma^2} + \delta(1-\lambda)(p_1 - c_E)(\alpha - p_1) \\ &= \Pi_{g1}\end{aligned}$$

For $\gamma < 0$,

$$\begin{aligned}\Pi_{pr} &= \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{pr}}{1-\gamma^2} + \delta(1-\lambda)(p_1 - c_E)(\alpha - p_1) \\ &< \max_{p_1} \lambda(p_1 - c_I) \frac{\alpha(1-\gamma) - p_1 + \gamma p_{g2}}{1-\gamma^2} + \delta(1-\lambda)(p_1 - c_E)(\alpha - p_1) \\ &= \Pi_{g1}\end{aligned}$$

Finally, for the special case, $\gamma = 0$, we have $\Pi_{sh} = \Pi_{g2} > \Pi_{g1} = \Pi_{pr}$.

Collectively, this proves Proposition 1.

QED.

Proof of Proposition 2

The result follows directly from the fact that $p_{sh} < p_{pr}$ and firms does not serve expensive customers.

QED.

Proof of Proposition 3:

The result follows directly from the expression of the difference of CS_{pr} and CS_{sh} . We note that the aggregate consumer surplus when the firms share information and keep information private are given by

the following expressions: $CS_{sh} = \frac{\lambda(\alpha - c_I)^2}{(1 + \gamma)(2 - \gamma)^2}$ and

$$CS_{pr} = \left(\frac{\lambda}{(1 + \gamma)} + \delta(1 - \lambda) \right) \left(\frac{\lambda(\alpha - c_I) + \delta(1 - \lambda)(1 - \gamma^2)(\alpha - c_E)}{\lambda(2 - \gamma) + 2\delta(1 - \lambda)(1 - \gamma^2)} \right)^2$$

Let $M = \delta(1 - \lambda)(1 - \gamma^2)$. Thus we have $CS_{pr} = \left(\frac{\lambda}{(1 + \gamma)} + \delta(1 - \lambda) \right) \left(\frac{\lambda(\alpha - c_I) + M(\alpha - c_E)}{\lambda(2 - \gamma) + 2M} \right)^2$

We are interested in $(CS_{sh} - CS_{pr}) > 0$. After substitution and simplification, we get

$$M^2 \frac{(\alpha - c_E)^2}{(\alpha - c_I)^2} + M \left[\frac{2\lambda(\alpha - c_E)}{\alpha - c_I} + \lambda(1 - \gamma) \left(\frac{(\alpha - c_E)^2}{(\alpha - c_I)^2} - \frac{4}{(2 - \gamma)^2} \right) \right] + \lambda^2 \left[1 - 2(1 - \gamma) \left(\frac{2}{2 - \gamma} - \frac{\alpha - c_E}{\alpha - c_I} \right) \right] < 0$$

Lastly, we show that this inequality is satisfied for $\gamma < 2/3$. We consider the special case when $c_E = \alpha$, noting that the inequality is stronger for the case when $c_E > \alpha$ meaning that if the inequality is true for $c_E = \alpha$, it will be true for $c_E > \alpha$.

When $c_E = \alpha$, first term is zero, and the second term is negative. The third term reduces to

$$\lambda^2 \left[1 - \left(\frac{4(1 - \gamma)}{2 - \gamma} \right) \right], \text{ which is negative when } \gamma < 2/3. \text{ Thus, we conclude that this inequality is}$$

satisfied when $\gamma < 2/3$.

QED.