Customer Privacy and Competition*

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Abstract

We analyze how different degrees of privacy protection affect industry profits, consumer welfare and total welfare. Firms earn higher profits under complete privacy protection compared with limited or no privacy protection. However, with limited privacy protection, the relationship between the degree of privacy protection and equilibrium profits is not monotonic. Consumers benefit from a gradual increase in privacy protection as long as this protection is not complete. However, complete privacy protection generates the lowest consumer surplus among the regimes we study. Finally, total welfare monotonically increases with the degree of privacy protection.

Keywords: customer privacy, privacy protection, customer recognition, price discrimination, behavior-based pricing

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1. Introduction

Technological progress, and, in particular, the Internet, have made it possible for firms to implement increasingly sophisticated methods of customer recognition that can serve as a basis for designing discriminatory pricing schemes. In particular, online retail stores, payment card networks, and search engines collect information that can reveal customer preferences, willingness to pay, and willingness to try out new brands of a wide variety of products and services. Overall, the advances in technology have enabled firms to acquire, store, sell, and share customer-specific information that can be used for implementing targeted advertising and differential pricing tactics.[1]

The exploitation of customer-specific information for advertising and pricing purposes raises important privacy concerns.[2] The Federal Trade Commission has recently issued a report that establishes best practices for firms to protect consumer privacy. This report also recommends that Congress consider reforms of the legislation dealing with consumer protection, see FTC (2012). Furthermore, Brill (2011) addresses the important question of how the FTC might balance consumer protection concerns arising in the context of privacy with competition issues. In particular, should governments regulate how firms can collect and exchange customer-specific information such as surfing habits on the Internet, or should firms be trusted to engage in self-regulating as far as privacy issues are concerned? Consumer protection law as well as competition law play important complementary roles for privacy protection. Hammock and Rubin (2011) emphasize that high priority should be given to systematic economic analysis of the effects of consumer privacy protection. On p. 42 they write: "We have not been able to find any privacy advocates making sensible economic arguments for increased privacy. As far as we can tell, arguments for increased online privacy are based on rights (rather than efficiency) and anecdotes

[1] This can be illustrated with a number of examples. An article in the June 30, 2012 issue of *The Economist* entitled "How Deep Are Your Pockets" describes software designed to detect the willingness of consumers to pay. A December 7, 2012 *Wall Street Journal* article entitled "They Know What You're Shopping For" describes companies that track and sell information about real identities of online shoppers. The world's largest company of this type, Acxiom, and privacy concerns are discussed in a June 16, 2012 *New York Times* article entitled "Mapping, and Sharing, the Consumer Genome."

[2] Goldfarb and Tucker (2012) present empirical documentation of how privacy concerns have changed over time and across age groups.

(rather than data)."

In this study we evaluate the effects of mandating firms to adhere to different degrees of privacy protection on industry profits, consumer surplus and total welfare. More precisely, we compute, evaluate, and compare market performance associated with the following four increasing levels of privacy protection:

- *No privacy protection* (N): Each firm collects information about its customers' specific preferences and shares it with other firms in the industry. Sharing can be facilitated through, for example, a system of information exchange between the firms regarding the recognized preferences of their customers.
- *Weak privacy protection* (W): Each firm collects information about its own customers' preferences, but is not allowed to share this information with other firms.
- *Strong privacy protection* (S): Firms are not allowed to collect information about their customers' preferences. However, firms can identify their customers and differentiate the prices charged to consumers switching from competing brands from those charged to their own customers.
- *Complete privacy protection* (C): Firms are not allowed to collect, maintain, and exchange any information about their customers, and are therefore forced to set a uniform price to all consumers.

The present study solves for the price equilibria associated with each of these four degrees of privacy protection. In particular, we focus on the following questions: How does profit depend on the type of privacy protection? What is the relationship between profits associated with complete privacy protection (uniform prices) and profits generated from limited or no privacy protection? Do firms have a collective incentive to engage in information exchange in the absence of any privacy protection? What are the effects on consumer welfare of different degrees of privacy protection compared with no privacy protection at all?

We show analytically that complete privacy protection softens competition between firms and therefore firms earn higher profit under complete privacy protection compared with limited or no privacy protection. However, with limited privacy protection, the relationship between the degree of privacy protection and equilibrium profits is not monotonic. The reason is that the different degrees of limited privacy protection generate similar average prices, but different dispersion levels of these prices. We establish that consumers benefit from a gradual increase in privacy protection as long as this protection is incomplete. However, complete privacy protection, which implies uniform pricing, generates the lowest consumer surplus among the four regimes we study, because complete privacy protection relaxes price competition and thereby increases average prices. Finally, we demonstrate that total welfare gradually increases as a function of the degree of privacy protection.

Our study is primarily related to the literature focusing on the economics of privacy. Seminal contributions to this literature include Posner (1978, 1981) and Stigler (1980), who argue that privacy protection creates inefficiencies and they see no welfare-enhancing role for government policies to protect consumer privacy. Some subsequent studies have criticized this "Chicago School" view. For example, Hermalin and Katz (2006) argue that data protection may support some valuable insurance schemes, which would not survive in the absence of privacy protection. Taylor (2004) compares two regimes: A confidential regime, in which firms are not allowed to sell customer-specific information, and a disclosure regime, in which such customer-specific information can be traded. Within such a framework he shows that the welfare implications of privacy requirements depend on whether customers anticipate future sales of customer-specific information. Conitzer, Taylor, and Wagman (2012) study a monopolist who is able to keep track of consumers' purchases within a context where the consumers are able to avoid being identified as past customers. Acquisti and Varian (2005) explore the profitability of history-based pricing by focusing on a two-period model, where firms have access to "tracking" technologies and consumers have access to "hiding" technologies. Within such a framework they demonstrate that history-based pricing will promote profits only if the tracking enables additional personalized services. Degryse and Bouckaert (Forthcoming) emphasize that the prevailing default option open to consumers significantly influence the ability of firms to collect and use customer information and they explore the effects of privacy regulation on firm entry and welfare for two reasonable types of default options. Goldfarb and Tucker (2011) make use of a large-scale database of field studies to provide empirical evidence that privacy regulation may diminish the effectiveness of advertising. Tucker (2012) summarizes a set of recent empirical studies focusing on how privacy concerns affect advertising markets with a tension between the desire of a firm to supply information targeted to selected consumers and the disutility imposed on consumers when a firm exploits consumer-specific data to improve the informativeness of advertising. In contrast to all these approaches, our study focuses on strategically competing firms and analyzes the welfare implications of different degrees of privacy protection that restrict firms' ability to target prices based on customer-specific information

Legislation that addresses consumer privacy protection limits firms' ability to design price mechanisms contingent on detected customer characteristics. In this analysis we assume that firms learn about their customer-specific characteristics within the framework of a customer relationship[3]. Our study of the effects of competition under varying degrees of customer protection on industry profits and consumer welfare has analytical features similar to an analysis of the effects of price competition associated with different types of customer recognition. In this respect, our analysis is related to the literature on behavior-based price discrimination. Over the past 15 years the literature on behavior-based or history-based price discrimination has developed a spectrum of models to analyze different types of price discrimination based on particular levels of customer recognition. Fudenberg and Tirole (2000) is a seminal contribution for a general analysis of behavior-based pricing within the framework of a two-period Hotelling duopoly model. The Fudenberg and Tirole (2000) model has the feature that the firm can distinguish its own inherited customers from those of the rival and design a discriminatory pricing scheme that exploits the fact that a customer's past decisions reveal information about this customer's brand-specific preferences. This type of behavior-based pricing model could largely be characterized as being consistent with strong privacy protection according to the terminology we introduced above. Chen (1997), Villas-Boas (1999), Shaffer and Zhang (2000),Taylor (2003), Chen (2008), Gehrig, Shy, and Stenbacka (2011), Chen and Zhang (2009), Esteves (2010), and Gehrig and

[3]There could be other mechanisms or institutions, like specialized intermediaries, that acquire information about consumer characteristics, which are not explored in our study.

Stenbacka (2004, 2007) are examples of studies analyzing important theoretical aspects as well as significant implications and applications of behavior-based pricing. Fudenberg and Villas-Boas (2007) and Esteves (2009) present updated literature surveys of this literature.

Our comparison of weak privacy protection with no privacy protection essentially captures the effects of information exchange of customer-specific preferences on industry profits and consumer welfare. In this respect, our analysis is linked to an important branch of studies evaluating the effects of information exchange in oligopolies. Prominent examples of this literature include Shapiro (1986) and Gal-Or (1985, 1986). This literature generally finds that the direction of the ex-ante incentives for information exchange depends on the nature of market competition (Bertrand or Cournot) and on the type of uncertainty (uncertainty concerning common demand conditions or firm-specific costs). This literature tends to reach the conclusion that information exchange often increases total welfare even though it hurts consumers, see for example Shapiro (1986). Our result on privacy protection, which shows that total welfare may rise despite a fall in consumer surplus when firms face restrictions on information exchange, does not support this conclusion. Furthermore, our study adds an important dimension to this literature insofar as information exchange intensifies competition by stimulating poaching activities, a feature that is typically not addressed in the research approach evaluating the effects of information exchange in oligopolies.

Our study proceeds as follows. Section 2 computes equilibrium profits, market shares, number of switching consumers, number of consumers who stay loyal, profits, and consumer welfare when there are no privacy protection, so firms collect and exchange information about their customers' preferences. Section 3 computes the same for weak privacy protection, Section 4 for strong privacy protection, and Section 5 for maximum protection which consequently prevents any degree of price discrimination. Section 6 compares profits, consumer surplus, and total welfare among the four degrees of privacy protection. Section 7 concludes.

2. No Privacy Protection (N)

Consider an industry with two firms producing differentiated brands of products or services labeled as A and B. There are $4n$ consumers. $2n$ consumers are A-oriented, which means that they all prefer A over B if prices are equal. Similarly, $2n$ consumers are B-oriented who prefer B over A under equal prices.

The history of this industry is as follows. Initially, consumers are equally distributed between the two firms with half of the consumers buying their ideal brand and half are mismatched with their less-preferred brand. More precisely, n A-oriented consumers initially buy brand A, and n A-oriented consumers buy brand B (mismatched). Similarly, n B-oriented consumers initially buy brand B, and n B-oriented consumers buy brand A (mismatched).[4] Starting from this configuration, all buyers regardless of their type can remain loyal to their initial supplier, or switch to the competing brand. Switching is costly to buyers. For each consumer type $i = A, B$, switching costs s are uniformly distributed on the unit interval $[0, 1]$.

Each consumer buys exactly one unit (either A or B). Let p_A^v denote the price firm A sets for consumers who have purchased brand A before, and q_A^v the price for consumers who have earlier purchased brand B (the competing brand). Firm B's prices, p_B^v and q_B^v, are defined analogously. We interpret p_A^v and p_B^v as the prices directed to consumers with whom the firms have an established customer relationship. We refer to these these prices as *loyalty* prices. The prices q_A^v and q_B^v are targeted to consumers who have an established customer relationship with the rival firm. We refer to these prices as *poaching* prices. The superscript v indicates whether the consumer is initially matched with the ideal brand, $v = H$, or with the less-preferred brand, $v = L$. Throughout our analysis we assume that the firms face constant marginal costs and that these are normalized to zero.

With no privacy protection, each firm acquires information on the exact preferences of each

[4] For reasons of tractability, consumers' purchase history is treated exogenously in this paper. One possible scenario which may generate the assumed configuration is that consumers' initial purchase, and hence firms' relationship with their customers, is formed before consumers fully learned their exact preferences. Subsequently, consumers (and firms, if there is no strong privacy protection) learn their exact preference prior to the price competition stage.

of its customers at no cost. In addition, firms are assumed to learn about the preferences of consumers who bought from the rival firm. Information exchange between the firms is one mechanism to support such a configuration. With no restriction on acquiring, maintaining, and exchanging customer-specific information, all firms know the exact type of each consumer (A- as well as B-oriented consumers), regardless of the consumer's purchase history. However, it is assumed that firms are unable to identify the idiosyncratic switching cost of each consumer.

With this information, firms can price discriminate among all consumers according their type and purchase history. In particular, firms can also set poaching prices according to the preference orientation of its rival firm's customers. Thus, q_i^H and q_i^L denote the price firm i charges type H (i-oriented) and type L (j-oriented) customers of the competing firm j, where $i, j = A, B$ and $i \neq j$. For example, q_A^H (q_A^L) denotes the poaching price firm A sets for B's customers who are oriented towards brand A (brand B) and gain a benefit v_H (v_L) *after* (and if) they switch from B to A. Similarly, p_i^H and p_i^L denote the prices firm i charges its own type H (i-oriented) and type L (j-oriented) customers.

The utility function of a consumer who has a customer relationship with firm i and switching cost s is defined by

$$U_i(s) = \begin{cases} v_H - p_i^H & i\text{-oriented and continues to buy } i \\ v_L - p_i^L & j\text{-oriented and continues to buy } i \\ v_L - q_j^L - \sigma s & i\text{-oriented and switches to } j \\ v_H - q_j^H - \sigma s & j\text{-oriented and switches to } j. \end{cases} \tag{1}$$

$v_H > v_L > 0$ are the benefits to buyers. More precisely, $\Delta \stackrel{\text{def}}{=} v_H - v_L > 0$ measures the utility loss associated with a mismatch (or the utility gain from a proper match). The parameter $\sigma > 0$ measures the intensity of the switching costs, in the sense that high values of σ generate higher switching cost differentiation across all buyers indexed on $s \in [0, 1]$. Subsequently, we will assume lower bounds for σ relative to the loss from a mismatch, Δ to obtain interior equilibria.

In view of the utility function (1), an A-oriented consumer who has purchased A before and is now indifferent between being loyal to brand A and switching to brand B, denoted by s_A^H, is determined from $v_H - p_A^H = v_L - q_B^L - \sigma s_A^H$. Similarly, a B-oriented consumer who has purchased B before and is now indifferent between being loyal to brand B and switching to brand A, denoted by s_B^H, is determined from $v_H - p_B^H = v_L - q_A^L - \sigma s_B^H$.

A B-oriented consumer who has purchased A before and is now indifferent between being loyal to brand A and switching to brand B, denoted by s_A^L, is determined from $v_L - p_A^L = v_H - q_B^H - \sigma s_A^L$. Similarly, an A-oriented consumer who has purchased B before and is now indifferent between being loyal to brand B and switching to brand A, denoted by s_B^L, is determined from $v_L - p_B^L = v_H - q_A^H - \sigma s_B^L$.

Figure 1 illustrates that consumers with high switching costs (high values of s) stay loyal to brand i, whereas consumers indexed with low s switch to the competing brand. It also illustrates that the switching cost threshold, above which consumers stay loyal, is higher for consumers who are initially mismatched than for consumers who are initially correctly matched with their preferred brand, that is, $s_i^L > s_i^H$.

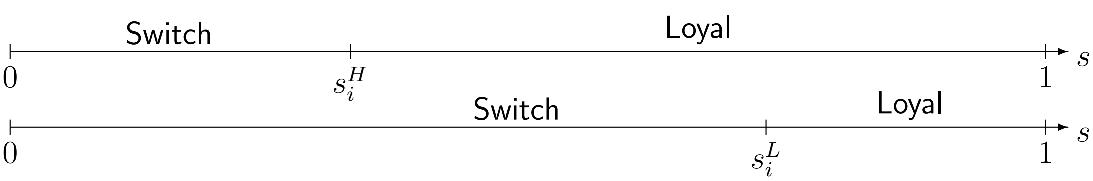

Figure 1: Allocation of brand i's loyal and switching consumers, $i = A, B$. The top figure illustrates initially correctly matched consumers, whereas the bottom figure illustrates initially mismatched consumers.

Recall that $\Delta \stackrel{\text{def}}{=} v_H - v_L > 0$. Therefore, the utility function (1) implies that the switching cost thresholds are given by

$$s_A^H = \frac{p_A^H - q_B^L - \Delta}{\sigma} \quad \text{and} \quad s_A^L = \frac{p_A^L - q_B^H + \Delta}{\sigma}, \tag{2}$$

$$s_B^H = \frac{p_B^H - q_A^L - \Delta}{\sigma} \quad \text{and} \quad s_B^L = \frac{p_B^L - q_A^H + \Delta}{\sigma}. \tag{3}$$

Firm A selects its loyalty prices, p_A^H and p_A^L, and its poaching prices, q_A^H and q_A^L, to solve

$$\max_{p_A^H, p_A^L, q_A^H, q_A^L} \pi_A = p_A^H(1 - s_A^H)n + p_A^L(1 - s_A^L)n + q_A^H s_B^L n + q_A^L s_B^H n. \tag{4}$$

The first two terms in (4) are profits from consumers who initially buy brand A and remain loyal to brand A because of high switching costs. The proportion $(1 - s_A^H)$ of A's inherited A-oriented customers (correctly matched) remain loyal, whereas the proportion $(1 - s_A^L)$ of A's inherited B-oriented customers (mismatched) stay loyal to A. The last two terms are the profit from consumers poached from firm B. The proportion s_B^H of consumers belonging to B's inherited segment are B-oriented, but switch to A in response to an attractive poaching price and because of low switching costs. The remaining proportion s_B^L of B's inherited A-oriented consumers are initially mismatched with brand B and accept A's poaching offer.

Analogously, firm B selects its loyalty prices, p_B^H and p_B^L, and its poaching prices, q_B^H and q_B^L, to solve

$$\max_{p_B^H, p_B^L, q_B^H, q_B^L} \pi_B = p_B^H(1 - s_B^H)n + p_B^L(1 - s_B^L)n + q_B^H s_A^L n + q_B^L s_A^H n. \tag{5}$$

Substituting (2) and (3) into (4) and (5), the equilibrium prices are

$$p_A^{N,H} = p_B^{N,H} = \frac{2\sigma + \Delta}{3}, \quad p_A^{N,L} = p_B^{N,L} = \frac{2\sigma - \Delta}{3},$$
$$q_A^{N,H} = q_B^{N,H} = \frac{\sigma + \Delta}{3}, \quad \text{and} \quad q_A^{N,L} = q_B^{N,L} = \frac{\sigma - \Delta}{3}, \tag{6}$$

where superscript N denotes equilibrium values under no privacy protection. Substituting (6) into (2) and (3) yields the switching cost thresholds

$$s_A^{N,H} = s_B^{N,H} = \frac{1}{3} - \frac{\Delta}{3\sigma} \quad \text{and} \quad s_A^{N,L} = s_B^{N,L} = \frac{1}{3} + \frac{\Delta}{3\sigma}. \tag{7}$$

An interior equilibrium $(0 < s_i^{N,H} < s_i^{N,L} < 1)$ exists as long as $\Delta < \sigma$.

To compute the equilibrium profits we substitute (6) and (7) into (4) and (5) to obtain

$$\pi_A^N = \pi_B^N = \frac{2n(5\sigma^2 + 2\Delta^2)}{9\sigma}. \tag{8}$$

Consumer surplus for those who initially bought from firm i (some remain loyal and some switch to the competing brand) is given by

$$CS_i^N = n \int_{s_i^{N,H}}^{1} (v_H - p_i^{N,H}) ds + n \int_{0}^{s_i^{N,H}} (v_L - q_j^{N,L} - \sigma s) ds$$
$$+ n \int_{s_i^{N,L}}^{1} (v_L - p_i^{N,L}) ds + n \int_{0}^{s_i^{N,L}} (v_H - q_j^{N,H} - \sigma s) ds. \tag{9}$$

The first term in (9) measures the surplus of i-oriented consumers with high switching costs who are correctly matched with firm i and stay loyal to i. The second term is the surplus of i-oriented consumers with low switching costs who are correctly matched with i, but decide to accept the poaching price offer from j (hence, become mismatched and gain a utility of v_L). The third term in (9) measures the surplus of j-oriented consumers who are initially mismatched with firm i. Because these consumers have high switching costs, they remain loyal and continue to purchase their less-preferred brand i. The fourth term is the surplus of j-oriented consumers with low switching costs who are initially mismatched with i and switch to j (their preferred brand).

Substituting the equilibrium prices (6) and the corresponding switching cost thresholds (7) into (9) obtains the level of consumer surplus with no privacy protection

$$CS^N = CS_A^N + CS_B^N = \frac{2n}{9\sigma}\left[\Delta^2 + 9\sigma(v_H + v_L) - 11\sigma^2\right]. \tag{10}$$

Finally, adding (8) and (10) yields total welfare

$$W^N = CS^N + \pi_A^N + \pi_B^N = \frac{2n}{9\sigma}\left[5\Delta^2 + 9\sigma(v_H + v_L) - \sigma^2\right]. \tag{11}$$

3. Weak Privacy Protection (W)

Suppose now that firms are permitted to acquire customer-specific information in order to learn the exact preferences of their own customers, but that the firms are not allowed to share this information with other firms. We refer to such a configuration as a regime with weak privacy protection. Hence, with weak privacy protection firms do not know the preferences of consumers who buy from the competing firm. More precisely, firm i identifies which of its $2n$ initial customers are A-oriented and which customers are B-oriented. This information enables each firm to price discriminate among its own customers according to their type. Therefore, let p_i^H and p_i^L denote the price firm i charges its own type-H and type-L customers. Since firm i cannot identify the type of a consumer who purchased from the rival firm, firm i is restricted to setting a single poaching price, q_i, to attract its rival's customers.

The utility function of a consumer who has a customer relationship with firm i and a switching cost s defined in (1) is now modified (restricted) to

$$U_i(s) = \begin{cases} v_H - p_i^H & i\text{-oriented and continues to buy } i \\ v_L - p_i^L & j\text{-oriented and continues to buy } i \\ v_L - q_j - \sigma s & i\text{-oriented and switches to } j \\ v_H - q_j - \sigma s & j\text{-oriented and switches to } j. \end{cases} \tag{12}$$

The utility function (12) corresponds to a uniform poaching price. Applying completely analogous calculations as in the previous section we can characterize the switching cost thresholds associated with the utility function (12). The switching cost thresholds (2) and (3) are now modified to

$$s_A^H = \frac{p_A^H - q_B - \Delta}{\sigma} \quad \text{and} \quad s_A^L = \frac{p_A^L - q_B + \Delta}{\sigma}, \tag{13}$$

$$s_B^H = \frac{p_B^H - q_A - \Delta}{\sigma} \quad \text{and} \quad s_B^L = \frac{p_B^L - q_A + \Delta}{\sigma}. \tag{14}$$

Firm A selects its type-specific loyalty prices, p_A^H and p_A^L, and its poaching price, q_A, to solve

$$\max_{p_A^H, p_A^L, q_A} \pi_A = p_A^H(1 - s_A^H)n + p_A^L(1 - s_A^L)n + q_A(s_B^H + s_B^L)n. \tag{15}$$

Firm B selects its type-specific loyalty prices, p_B^H and p_B^L, and its poaching price, q_B, to solve

$$\max_{p_B^H, p_B^L, q_B} \pi_B = p_B^H(1 - s_B^H)n + p_B^L(1 - s_B^L)n + q_B(s_A^H + s_A^L)n. \tag{16}$$

Substituting (13) and (14) into (15) and (16), the equilibrium prices are

$$p_A^{W,H} = p_B^{W,H} = \frac{4\sigma + 3\Delta}{6}, \quad p_A^{W,L} = p_B^{W,L} = \frac{4\sigma - 3\Delta}{6}, \quad \text{and} \quad q_A^W = q_B^W = \frac{\sigma}{3}, \tag{17}$$

where superscript W denotes equilibrium values under weak privacy protection. Substituting (17) into (13) and (14) yields

$$s_A^{W,H} = s_B^{W,H} = \frac{1}{3} - \frac{\Delta}{2\sigma} \quad \text{and} \quad s_A^{W,L} = s_B^{W,L} = \frac{1}{3} + \frac{\Delta}{2\sigma}. \tag{18}$$

An interior equilibrium $(0 < s_i^{W,H} < s_i^{W,L} < 1)$ exists as long as $\Delta < 2\sigma/3$.

To compute the equilibrium profits we substitute (17) and (18) into (15) and (16) to obtain

$$\pi_A^W = \pi_B^W = \frac{n(20\sigma^2 + 9\Delta^2)}{18\sigma}. \tag{19}$$

Consumer surplus for those who initially bought from firm i (some remain loyal and some switch to the competing brand) is given by

$$CS_i^W = n \int_{s_i^{W,H}}^{1} (v_H - p_i^{W,H}) ds + n \int_{0}^{s_i^{W,H}} (v_L - q_j^W - \sigma s) ds$$
$$+ n \int_{s_i^{W,L}}^{1} (v_L - p_i^{W,L}) ds + n \int_{0}^{s_i^{W,L}} (v_H - q_j^W - \sigma s) ds. \quad (20)$$

Substituting the equilibrium prices (17) and the corresponding switching cost thresholds (18) into (20),

$$CS^W = CS_A^W + CS_B^W = \frac{n}{18\sigma}\left[9\Delta^2 + 36\sigma(v_H + v_L) - 44\sigma^2\right]. \quad (21)$$

Finally, (19) and (21) yield total welfare

$$W^W = CS^W + \pi_A^W + \pi_B^W = \frac{n}{18\sigma}\left[27\Delta^2 + 36\sigma(v_H + v_L) - 4\sigma^2\right]. \quad (22)$$

4. Strong Privacy Protection (S)

Suppose now that each firm is permitted to store information about the identity of its previous customers, but that the firms are not allowed to collect or store any information regarding customer-specific preferences. This means that the firm can implement history-based pricing, contingent only on whether the consumer belongs to the inherited market segment of itself or of its rival. We refer to such a configuration as a regime with strong privacy protection. With no knowledge about customer-specific preferences, each firm i is formally restricted to set only two prices: A single price for its own previous customers, p_i; and a poaching price, q_i, directed to consumers belonging to the rival's inherited market segment.

The utility function of a consumer with switching cost s and a customer relationship with firm i, given in (12), is now further simplified to

$$U_i(s) = \begin{cases} v_H - p_i & i\text{-oriented and continues to buy } i \\ v_L - p_i & j\text{-oriented and continues to buy } i \\ v_L - q_j - \sigma s & i\text{-oriented and switches to } j \\ v_H - q_j - \sigma s & j\text{-oriented and switches to } j. \end{cases} \quad (23)$$

The utility function (23) corresponds to two prices, a loyalty price and a poaching price, but note that these prices do not depend on customer-specific types. From the utility function (23), the switching cost thresholds (2) and (3) are now simplified to

$$s_A^H = \frac{p_A - q_B - \Delta}{\sigma} \quad \text{and} \quad s_A^L = \frac{p_A - q_B + \Delta}{\sigma}, \tag{24}$$

$$s_B^H = \frac{p_B - q_A - \Delta}{\sigma} \quad \text{and} \quad s_B^L = \frac{p_B - q_A + \Delta}{\sigma}. \tag{25}$$

Firm A selects its loyalty price, p_A, and its poaching price, q_A, to solve

$$\max_{p_A, q_A} \pi_A = p_A(1 - s_A^H + 1 - s_A^L)n + q_A(s_B^H + s_B^L)n. \tag{26}$$

Similarly, firm B selects its loyalty price, p_B, and its poaching price, q_B, to solve

$$\max_{p_B, q_B} \pi_B = p_B(1 - s_B^H + 1 - s_B^L)n + q_B(s_A^H + s_A^L)n. \tag{27}$$

Substituting (24) and (25) into (26) and (27), the equilibrium prices are

$$p_A^S = p_B^S = \frac{2\sigma}{3} \quad \text{and} \quad q_A^S = q_B^S = \frac{\sigma}{3}, \tag{28}$$

where the superscript S denotes equilibrium values under strong privacy protection. Intuitively, firms set their poaching prices to be lower than the loyalty prices in order to induce consumers to switch brands. Substituting (28) into (24) and (25) yields

$$s_A^{S,H} = s_B^{S,H} = \frac{1}{3} - \frac{\Delta}{\sigma} \quad \text{and} \quad s_A^{S,L} = s_B^{S,L} = \frac{1}{3} + \frac{\Delta}{\sigma}. \tag{29}$$

Equation (29) characterizes the equilibrium proportion of consumers who switch or stay loyal for each brand i, as illustrated in Figure 1. An interior equilibrium ($0 < s_i^{S,H} < s_i^{S,L} < 1$) exists as long as $\Delta < \sigma/3$.

To compute the equilibrium profits, we substitute (28) and (29) into (26) and (27) to obtain

$$\pi_A^S = \pi_B^S = \frac{10}{9} n\sigma. \tag{30}$$

Consumer surplus for those who intially bought from firm i (some remain loyal and some switch to the competing brand) is given by

$$CS_i^S = n \int_{s_i^{S,H}}^{1} (v_H - p_i^S) ds + n \int_{0}^{s_i^{S,H}} (v_L - q_j^S - \sigma s) ds$$
$$+ n \int_{s_i^{S,L}}^{1} (v_L - p_i^S) ds + n \int_{0}^{s_i^{S,L}} (v_H - q_j^S - \sigma s) ds. \quad (31)$$

Substituting the equilibrium prices (28) and the corresponding switching cost thresholds (29) into (31) yields aggregate consumer surplus

$$CS^S = CS_A^S + CS_B^S = \frac{2n}{9\sigma}\left[9\Delta^2 + 9\sigma(v_H + v_L) - 11\sigma^2\right]. \quad (32)$$

Finally, (30) and (32) yield total welfare

$$W^S = CS^S + \pi_A^S + \pi_B^S = \frac{2n}{9\sigma}\left[9\Delta^2 + 9\sigma(v_H + v_L) - \sigma^2\right]. \quad (33)$$

5. Complete Privacy Protection (C)

The last privacy rule that we analyze is complete privacy protection. Such a configuration could be an outcome of a regulatory ban on firms to collect, store and exchange any information about the types and purchase history their customers. Formally, with complete privacy protection each firm is forced to set a *uniform* price to all consumers. Note also that a uniform pricing policy could also be an outcome of a regulatory ban on all forms of price discrimination, thereby forcing firms to apply one price to all consumers.

Despite the simplicity associated with the maximization of profit with respect to a single uniform price, the equilibrium price involves a corner solution with the feature that customers who are properly matched with their ideal brand do not switch to the competing brand.

We first demonstrate the nonexistence of a fully interior equilibrium. Suppose that such an equilibrium exists. When firm A is restricted to set p_A only and firm B to p_B only, (24) and (25) become

$$s_A^H = \frac{p_A - p_B - \Delta}{\sigma} \quad \text{and} \quad s_A^L = \frac{p_A - p_B + \Delta}{\sigma}, \tag{34}$$

$$s_B^H = \frac{p_B - p_A - \Delta}{\sigma} \quad \text{and} \quad s_B^L = \frac{p_B - p_A + \Delta}{\sigma}. \tag{35}$$

Even without going into the precise derivation of the equilibrium prices, a close look at (34) and (35) reveals that $s_A^H < 0$ and $s_B^H < 0$ when $p_A \approx p_B$. In fact, allowing for negative values of switching cost thresholds would yield the "false equilibrium" prices $p_A = p_B = \sigma/2$.

Setting $s_A^H = s_B^H = 0$ implies that customers who are correctly matched with their ideal brands do not switch under uniform pricing. In this case, the profit maximization problems (26) and (27) become

$$\max_{p_A} \pi_A = p_A(1 - 0 + 1 - s_A^L + 0 + s_B^L)n \tag{36}$$
$$\max_{p_B} \pi_B = p_B(1 - 0 + 1 - s_B^L + 0 + s_A^L)n,$$

where s_A^L and s_B^L are characterized in (34) and (35). The equilibrium prices and profit levels are

$$p_A^C = p_B^C = \sigma, \quad s_A^{C,L} = s_B^{C,L} = \frac{\Delta}{\sigma}, \quad \text{and} \quad \pi_A^C = \pi_B^C = 2n\sigma, \tag{37}$$

where superscript C indicates equilibrium values under complete privacy protection. To prove that the prices (37) indeed constitute a Nash-Bertrand equilibrium, we must establish that no firm, say firm A for the sake of demonstration, would find it profitable to undercut this price and grab some of the customers oriented towards the competing brand. Formally, if firm A undercuts, it chooses p_A to maximize $p_A(1 - 0 + 1 - s_A^L + s_B^H + s_B^L)n$, yielding $\tilde{p}_A^U = (5\sigma - \Delta)/6$ and $\tilde{\pi}_A^U = n(5\sigma - \Delta)^2/(12\sigma)$. Now, firm A will not deviate from the equilibrium price (37) if the profit from deviation satisfies $n(5\sigma - \Delta)^2/(12\sigma) < 2n\sigma$. This inequality is satisfied if $\Delta < (2\sqrt{6} + 5)\sigma$, which is assumed throughout, as indicated in Table 1.

Next, the consumer surplus of buyers initially matched with firm i is

$$CS_i^C = n\int_0^1 (v_H - p_i^C)ds + n\int_{s_i^{C,L}}^1 (v_L - p_i^C)ds + n\int_0^{s_i^{C,L}} (v_H - p_j^C - \sigma s)ds. \tag{38}$$

The first term captures the surplus of the n correctly matched i-oriented consumers. We have already shown that none of these consumers switches under uniform pricing. The second term applies to the n incorrectly matched j-oriented consumers who, because of high switching costs, do not switch. The last term applies to consumers who switch from i to j (their preferred brand). Substituting the equilibrium prices (37) into (34) and (35) for s_A^L and s_B^L, and then into (38) we obtain

$$CS^C = CS_A^C + CS_B^C = \frac{n}{\sigma}\left[\Delta^2 + 2\sigma(v_H + v_L) - 4\sigma^2\right]. \tag{39}$$

Finally, (37) and (39) yield total welfare

$$W^C = CS^C + \pi_A^C + \pi_B^C = \frac{n}{\sigma}\left[\Delta^2 + 2\sigma(v_H + v_L)\right]. \tag{40}$$

6. Privacy Protection: Effects on Profits and Welfare

Sections 2, 3, 4, and 5 characterized equilibria under configurations corresponding to four exogenously-imposed degrees of privacy protection. In this section we explore the consequences for profits and welfare of the different degrees of privacy protection. For that purpose we compare industry profit, consumer surplus, and total welfare across the four configurations of privacy protection.

The comparisons in this section will be shown to depend on the relative magnitudes of the value consumers attach to be matched with their most-preferred brand, $\Delta = v_H - v_L$, and the switching cost parameter, σ. Table 1 provides the parameter range under which interior equilibria exist in the four market configurations with less than complete privacy protection.[5] Table 1 shows

Parameter restriction	$0 < \Delta < \frac{\sigma}{3}$	$0 < \Delta < \frac{2\sigma}{3}$	$0 < \Delta < \sigma$
Interior equilibria	0, 1, 2, 3	1, 2, 3	2, 3

Table 1: Parameter restrictions needed for the existence of interior equilibria under different degrees of privacy protection.

[5] For the configuration with complete privacy protection, characterized in Section 5, the interior equilibrium exists only for consumers who are initially mismatched with their less-preferred brand. Consumers who are initially correctly matched do not switch, hence, the model implies a corner solution for correctly-matched consumers.

that $0 < \Delta < \sigma/3$ is a sufficient condition for interior equilibria to exist in all four levels of privacy protection. But less restrictive conditions are needed for interior equilibria with weak, strong, and complete privacy protection.

6.1 Profit comparisons

Comparing (8), (19), (30), and (37) we can formulate the following result.

Result 1. *Firms always benefit from complete privacy protection compared with limited or no privacy protection. However, with limited privacy protection, the relationship between the degree of privacy protection and equilibrium profits is not monotonic. Formally,* $\pi_i^C > \pi_i^W > \pi_i^N > \pi_i^S$ *for every firm* $i = A, B$.

The profit comparisons incorporated in Result 1 can be explained by close observations of the average prices and the price dispersions implied by the different regimes of privacy protection. We initially observe that the equilibrium price associated with complete privacy protection (37) exceeds the average prices associated with any of the regimes characterized by limited privacy protection, compare with (6), (17) and (28). This captures the idea that complete privacy protection serves as a device to soften price competition to the benefit of firms. It should be emphasized that this conclusion relies strongly on our interpretation of complete privacy protection as a policy imposing firms to apply uniform pricing[6].

Competition becomes more intense when firms compete under limited or no privacy protection. This is because with limited or no privacy protection, firms are able to strategically use discriminatory pricing schemes based on customer recognition which vary with the degree of privacy protection and therefore the degree of customer recognition. Thisse and Vives (1988) demonstrated a qualitatively similar feature under circumstances where firms compete with completely individualized prices (perfect price discrimination). Discriminatory pricing essentially enlarges the

[6]Admittedly, from a practical policy perspective this could be viewed as a fairly extreme interpretation, because firms may be able to achieve market segmentation by application of strategic instruments which are not privacy-invasive. However, the analysis of such strategic instruments are formally outside the scope of our model. Furthermore, as our goal is to investigate the implications for firms and consumers of different degrees of privacy protection we want the spectrum of available policies to be as wide as possible.

set of strategic pricing options available to competing firms. Discriminatory pricing schemes make it possible for firms to fine-tune their prices with respect to buyers' specific characteristics. When competitors are restricted to uniform prices under complete privacy protection, deviating to discriminatory pricing rules typically generates a strategic advantage to the deviating firm. However, when all competitors realize the strategic potential of price discrimination and apply discriminatory pricing, competition is intensified and profits fall. Consequently, under price discrimination all firms in the industry earn lower margins, whereas the consumers benefit from more intense competition. Thus, with oligopolistic competition, the availability of discriminatory pricing schemes, facilitated by limited or no privacy protection, catches firms in a classical "prisoner's dilemma" trap. A regime with complete privacy protection would benefit all the firms collectively by eliminating the strategic incentive of firms to introduce discriminatory pricing schemes based on all available information on consumer characteristics. Chen (1997) established an analogous result in his analysis of behavior-based pricing in which consumers are differentiated according to their switching costs.

The average equilibrium prices are constant when comparing the regime with strong privacy protection with that of weak privacy protection. Based on a comparison of (17) with (28) we can conclude that the poaching prices are identical, but that weak privacy protection increases the dispersion of loyalty prices. Since the equilibrium profit is convex as a function of the equilibrium price[7] it follows from Jensen's inequality that weak privacy protection generates higher profits than strong privacy protection ($\pi_i^W > \pi_i^S$). Similar arguments can be applied to reach the conclusion that the profit with no privacy protection exceeds that with strong privacy protection ($\pi_i^N > \pi_i^S$).

The comparison of equilibrium profits between the regime with no privacy protection (π_i^N) and that with weak privacy protection (π_i^W) is somewhat more complicated. From a detailed comparison of the equilibrium prices (6) and (17) we can draw the conclusion that the regime with no privacy protection increases the dispersion of the poaching prices, whereas it reduces the dispersion of prices targeted to own customers. These features have offsetting effects on the equilibrium profits. According to Result 1, the effect on equilibrium profits from reduced

[7]This can be verified by substituting the equilibrium price into the profit functions.

dispersion of the loyalty prices dominates relative to the effect from increased dispersion of the poaching prices.

The configuration of strong privacy protection in our paper enables firms to apply history-based pricing, which was originally analyzed by Chen (1997). Likewise, our configuration with no privacy protection essentially matches perfect price discrimination analyzed by Thisse and Vives (1988) in the sense that competition takes place subject to having firms process all their knowledge regarding the characteristics of their own as well as their rivals' customers. Contrary to this setting, the configuration with weak privacy protection captures the feature that an established customer relationship gives the firm an option to exploit its informational advantage over its rivals regarding the characteristics of its own customers.

According to Result 1, strong privacy protection generates lower profit than weak or no privacy protection ($\pi_i^S < \pi_i^N < \pi_i^W$). This result captures the idea that firms have a collective incentive to acquire information regarding the individual preferences of their own customers but not to share it. Such customer-specific knowledge of individual preferences makes it possible for each firm to differentiate its price among its own customers which promotes the firm's profits compared with the prices the firm sets under strong privacy protection. Recall that strong privacy protection restricts firms to setting prices based on the consumer's purchase history, but not on customer-specific preferences. A comparison of the equilibrium poaching prices (28) with (17) shows that the competitive threat of being poached by the rival firm remains invariant across the configurations with weak privacy protection and strong privacy protection.

Result 1 also states that weak privacy protection leads to higher profits than no privacy protection ($\pi_i^W > \pi_i^N$). This is essentially a comparison of profits when firms acquire knowledge regarding individual preferences of their customers under two regimes: with and without exchange of customer-specific information. In this respect, Result 1 demonstrates that firms do not have a joint interest in sharing information regarding their customers' specific preferences. The reason for this is that information exchange enables firms to refine their targeted poaching price offers, as characterized in (6). Such targeted poaching offers intensify competition to the detriment of industry profits[8]. It is interesting to contrast this result with the effects of information exchange among banks regarding the creditworthiness of borrowers in loan markets. As Pagano and Jappelli (1993), Padilla and Pagano (1997), and Gehrig and Stenbacka (2007) separately establish, banks typically have an incentive to exchange information regarding borrower types as a mechanism to reduce credit losses, that is, as a mechanism to avoid granting finance to consumers who are not creditworthy. As discussed above, in our model information exchange decreases the dispersion of loyalty prices to such an extent that it outweighs the associated increase in the dispersion of poaching prices. This explains why information exchange (allowed only when there is no privacy protection) generates lower industry profit than with weak privacy protection ($\pi_i^N < \pi_i^W$).

6.2 Comparisons of consumer surplus

We next explore the effects of different levels of privacy protection on consumer welfare. Comparing (10), (21), (32), and (39), we can draw the following conclusions.

Result 2. *Consumers benefit from a gradual increase in privacy protection as long as this protection is not complete. However, complete privacy protection, which implies uniform pricing, generates the lowest consumer surplus. Formally,* $CS^S > CS^W > CS^N > CS^C$.

With complete privacy protection firms are restricted to setting uniform prices. Uniform pricing softens price competition to the detriment of consumers. Formally, as discussed in the previous subsection, the equilibrium price with complete privacy protection exceeds the average equilibrium price associated with each of the regimes characterized by limited or no privacy protection. With limited or no privacy protection, Result 2 states that consumers become worse off from a gradual increase in the information that competing firms can exploit. This result captures the intuition that with more information firms can develop more precise discriminatory schemes with the ability to better extract surplus from the consumers.

Result 2 can be explained by examining the effects of privacy protection on the price dispersion faced by different consumer types, and hence on consumer surplus. More precisely, price discrim-

[8] It should be emphasized that we are not analyzing the incentives of firms to engage in information exchange. Our perspective is that of a policy analysis, where we impose different regimes of consumer recognition and compare the outcomes.

ination based on weak or no privacy protection introduces type-contingent price differences for loyal customers compared with pricing under strong privacy protection. Thus, weak or no privacy protection facilitates price discrimination based on preference-based customer recognition, which makes it possible for the firms to extract more surplus from the consumers. Switching costs restrict the power of the rival firm to compete for this surplus extraction. The ability to extract more surplus by fitting type-contingent prices to different consumers explains why $CS^W < CS^S$.

Comparing (6) with (17) reveals that with no privacy protection, information exchange of consumer preferences enables firms to apply differential poaching prices across consumer types. But, it also lowers the dispersion in the type-contingent price charged to loyal customers. Furthermore, by comparing the switching cost thresholds in these two regimes we find that the *total* number of switching consumers is the same with no privacy protection as with weak privacy protection. However, with no privacy protection the variation in poaching prices is larger than the corresponding reduction in the variation in incumbency prices, leading to a greater ability to extract consumer surplus when evaluated at the aggregate level. For this reason, consumer surplus is lower with no privacy protection than with weak privacy protection ($CS^N < CS^W$).

Result 2 implies that consumers would benefit from a policy that would require firms to provide some privacy protection that bans firms from exchanging information about their customers' individual preferences. This result is far from self-evident. A priori, one could argue that information exchange could weaken the lock-in effects associated with an inherited mismatch of consumers who initially purchased the "wrong" brand. Such a line of reasoning would be analogous to the arguments made by Padilla and Pagano (1997, 2000) in favor of information exchange as a mechanism to reduce the lock-in effects of asymmetric information in lending markets, where incumbent lenders have an informational advantage compared with their rivals regarding the customers' risk characteristics. However, in our model, information exchange, in addition to inducing more aggressive prices targeted to consumers with a low preference for a certain brand, also generates less aggressive prices targeted to consumers with a high preference for the brand. At a fundamental level, information exchange (no privacy protection) reduces consumer surplus because it increases price dispersion across consumer types, thereby promoting firms' ability to extract consumer surplus.

As far as the implications for competition policy are concerned, Result 2 raises warnings against exchange of information about individual customers when all privacy protection is eliminated (compared with weak privacy protection where firms have asymmetric information about the preferences of individual customers). This recommendation against the exchange of information at a very disaggregate level is in line with competition policy objecting to the dissemination of individualized sales data, illustrated by the famous U.K. Agricultural Tractor Exchange case, see European Commission (1992). These implications for competition policy are discussed extensively by Kühn (2001), who emphasizes information exchange as a mechanism for facilitating tacit collusion. Our model highlights another harmful antitrust effect associated with information exchange, namely its potential to serve as a device to facilitate the extraction of consumer surplus.

6.3 Total welfare comparisons

From Results 1 and 2 we can draw the conclusion that some regimes of privacy protection, such as strong privacy protection or complete privacy protection, introduce a distributional conflict between firms and consumers. In addition, we can also directly conclude that a transition from no privacy protection to weak privacy protection generates an unambiguous change in total welfare, defined as the sum of consumer profits and industry profits because $\pi_i^W > \pi_i^N$ and $CS^W > CS^N$. However, a shift from no privacy protection to strong privacy protection has distributional implications. In this subsection we present a detailed analysis of the effects of different privacy policies on total welfare. Comparing (11), (22), (33), (40) yields

Result 3. *Total welfare increases monotonically with the degree of privacy protection. Formally,* $W^C > W^S > W^W > W^N$.

According to Result 3, total welfare is higher under complete privacy protection than under any of the policies with limited or no privacy protection. In order to understand the intuition behind this result we now compare total welfare under strong privacy protection with total welfare under complete privacy protection. In Hotelling competition with full market coverage, changes in price generate only a redistribution of surplus between consumers and producers. In contrast, changes in aggregate costs associated with switching and brand mismatch constitute *real* deadweight losses to the economy. With strong privacy protection, (29) implies that the number of switching consumers is $2n(1/3 - \Delta/\sigma) + 2n(1/3 + \Delta/\sigma) = 4n/3$, where switching consumers include those who are initially mismatched as well as some consumers who are initially correctly matched with their preferred brand. Under complete privacy protection, the number of switching consumers is significantly lower because only mismatched consumers do switch brands. (34) and (35) imply that the total number of switching consumers with complete privacy protection is $n(s_A^L + s_B^L) = 2n\Delta/\sigma < 4n/3$ because the equilibrium with strong privacy protection was restricted, $\Delta < \sigma/3$. Consequently, strong privacy protection generates higher aggregate switching costs than complete privacy protection. In addition, complete privacy protection reduces the amount of preference mismatch. Overall, our total welfare comparison establishes analytically that complete privacy protection induces lower aggregate costs of switching and mismatch than pricing based on strong privacy protection. For this reason the profit gain to firms from complete privacy protection dominates the associated loss to consumers regardless of which regime of limited privacy protection is used as the basis for comparison.

7. Concluding Comments

We analyze four degrees of privacy protection and explore how varying the degree of privacy protection affects industry profits, consumer welfare and total welfare. We find that complete privacy protection softens competition between firms and therefore firms benefit from complete privacy protection compared with limited or no privacy protection. However, under limited privacy protection, the relationship between the degree of privacy protection and equilibrium profits is not monotonic. Consumers benefit from a gradual increase in privacy protection as long as this protection is incomplete. However, complete privacy protection, which implies uniform pricing, generates the lowest consumer surplus among the regimes we study. Finally, we show that total welfare monotonically increases with the degree of privacy protection.

Privacy protection can be analyzed from many different angles, for example, from the perspective of individual freedom. It seems to be a common view that strict privacy protection benefits consumers at the expense of firms. This study focuses on the competitive effects of firms' potential use of unprotected consumer-specific information to refine their pricing tactics. Focusing on this angle, we have reached the remarkable conclusion that, by and large, firms tend to profit from privacy protection, whereas consumers tend to lose.

Our analysis can be extended in a number of directions. The analysis in this paper was restricted to evaluations of industry performance associated with different degrees of privacy protection, but did not explore the unilateral incentives firms may have to self-regulate acquisition and sharing of information. Thus, our study did not characterize which configuration of privacy protection may emerge as an equilibrium outcome of noncooperative decision making. Instead we presented an evaluation of the consequences for firms and consumers of different exogenously-imposed policies for regulating privacy protection.

In addition, our analysis was restricted to a symmetric model where the inherited proportions of correctly matched and mismatched consumers are equal. It would be interesting within the context of our model to explore the implications of different policies for privacy protection with inherited asymmetries between firms. Focusing on firm asymmetries within the framework of a different model Campbell, Goldfarb, and Tucker (2011) argue that privacy regulation may favor incumbents and large firms at the expense of entrants and small firms. Relatedly, our perspective was confined to a static analysis. It would be of obvious interest to explore potential dynamic implications of competition between firms under different policies for privacy protection. For a dynamic analysis it would be particularly interesting to trace the evolution over time of inherited asymmetries.

Finally, our conclusions regarding the consequences of information exchange are drawn based on the standard assumption that the information is revealed to rivals in a truthful manner. It would be interesting to explore the implications of information exchange under circumstances where firms use their knowledge of their customer base to strategically manipulate the information revealed (or leaked) to their rivals.

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