Product Personalization and Price Competition: An Analytic Approach

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Abstract

Advances in information technologies and the Internet enable firms to tailor their products to individual consumers. It has been widely argued that by offering personalized products, a firm can improve its value to consumers, enhance their loyalty to the firm, and increase the profitability. However, this perspective largely ignores the strategic interaction when competing firms offer personalization in the market, to which little research attention has been maid.

Besides the effects of competition, another important consideration includes the privacy concern of consumers. Collection and use of private information have caused a widespread perception by consumers that their privacy is invaded. Therefore, privacy-concerned consumers choose to remain anonymous rather than to enjoy the value of personalization.

In this paper, we analyze product personalization and price competition based on customer information, incorporating the privacy concern of consumers. We find two different outcomes emerge depending on the relative size of both firms' customer information bases. When the firms have similar size of customer information, a win-win situation occurs where both firms are better off with personalization. On the other hand, when the firms are significantly asymmetric in terms of the size of their customer information bases, the competition is intensified, resulting in a prisoner's dilemma situation. We also find different effects of the proportion of the privacy-concerned consumers in the two cases.

Keywords: Personalization; Customer Information; Privacy; Competitive Analysis

Introduction

Advances in information technologies and the Internet enable firms to understand individual consumers more accurately with less cost than ever before, which, in turn, allows firms to address individual consumers. In particular, personalization technologies enable firms to treat each customer as a unique person and serve that customer's unique needs [8]. It has been widely argued that by offering personalized products, a firm can improve its value proposition to consumers, enhance their loyalty to the firm, and increase the profitability [e.g. 5, 6]. However, this perspective mainly focuses on the relationship between a single firm and its customers, ignoring the strategic interaction when competing firms offer personalization in the market, to which little research attention has been maid. In addition to the effects of competition, another important consideration includes the privacy concern of consumers. The possibility of implementing personalization depends on the availability of customer information. To take advantage of key benefits of personalization, consumers need to provide valuable information about themselves. Collection and use of private information have caused a widespread perception by consumers that their privacy is violated [4, 10]. Therefore, some consumers choose to remain anonymous by deleting cookies and logs in their computers or using temporary credit cards rather than to enjoy the value of personalization through allowing firms to use their information.

In this study, we explore the competitive effect of personalization in a market which consists of two types of consumers depending on their desired level of privacy; the privacy-unconcerned consumers who do not care about their privacy and the privacy-concerned consumers who care much for the privacy. Specifically, two competing firms offer personalized products to the privacy-unconcerned consumers in their customer information bases and standard products to the other consumers. We find two different outcomes emerge depending on the relative size of both firms' customer information bases and the size of the privacy-unconcerned segment. When the firms have similar size of customer information bases or the proportion of the privacy-unconcerned consumers is low, both firms' equilibrium strategies are to exploit their customer information bases, leading to a win-win situation. On the other hand, when the firms are significantly asymmetric in terms of the size of their customer information bases, the smaller firm tries to undercut the larger one's customer base, resulting in a prisoner's dilemma situation.

Our research draws on existing literature in spatial product differentiation and price discrimination. Thisse and Vives [12] treat personalization as redesigning a basic product to satisfy buyers' diverse tastes, with the marginal cost of redesign increasing in the distance between the basic product and a buyer's ideal taste. Dewan et al. [2, 3] develop a circular city model of product customization and flexible pricing, and find that adoption of customization lead to a prisoner's dilemma situation. This result is based on the assumption that competing firms are symmetric ex ante. In contrast, our model allows asymmetry between firms, which turns out to play a key role in formulating equilibrium strategies.

There is extensive literature on price discrimination although most of the literature has focused on the case of monopoly. A taxonomy commonly used for price discrimination considers three types [7]. When a firm is able to charge different prices to different customers, it is termed first-degree price discrimination. A firm engages in second-degree price discrimination when it makes available a set of related offerings with fixed prices associated with each, and customers choose the product that best fits their needs. Applications of second-degree price discrimination include product-line pricing and versioning [13]. In third-degree price discrimination, firms charge different prices to different segments. Our model is based on second-degree price discrimination, where consumers choose standard or personalized product based on their preference (transportation cost) and the prices of the products.

There are several articles on price discrimination that are closely related with our work. Shaffer and Zhang [11] explore the competitive effects of one-to-one promotions when competing firms differ in size and consumers have heterogeneous loyalty. Chen et al. [1] show, with a focus on the level of targetability of a firm, that the improvement in targetability can lessen price competition in the market, and results in win-win competition. Although these studies provide important insights on the competition in the information era, firms in their model offer only standard products. Therefore, they do not incorporate the possibility of product personalization in the analysis.

Model

Consider a market with two competing firms, A and B. Each consumer buys at most one unit of product A, or one unit of product B, or neither. To capture the heterogeneity of consumers' preferences, which is a prerequisite for personalization, we use a horizontal differentiation model. Consumers' preferences are uniformly distributed on [0, 1] with mass normalized to one. Firms A and B are located at 0 and 1, respectively.

There are two segments of consumers depending on their willingness to share information about their preferences with firms: privacy-unconcerned consumers and privacy-concerned consumers. Consumers in the privacy-unconcerned segment do not incur any cost in providing or allowing the use of their private information. On the other hand, privacy-concerned consumers do not share their private information with firms because they are deeply concerned about privacy. The proportion of the privacy-unconcerned consumers is λ, and the proportion of the privacy-concerned consumers is, therefore, $1-\lambda$. Consumers in each segment are uniformly distributed in the interval [0, 1]. We can reasonably expect that λ would be higher for a market with less amount of information requirement for personalization; this interpretation would enable us to understand the effect of personalization depending on the industry characteristics in terms of the information requirement for personalization.

Initially, consumers in the interval $[0, s_A]$ make up firm A's customer base while those in $(s_A, 1]$ belongs to firm B's customer base. Through previous transactions, firms have accumulated information about individual consumer in the privacy-unconcerned segment of their own customer bases. The information can be used for the firm to provide a personalized product for each consumer. In this paper, we refer to each firm's customer base as each firm's customer information base. Thus, the size of the customer information bases of firms A and B are s_A and s_B $(= 1 - s_A)$, respectively. Without loss of generality, we assume that $s_A \geq 1/2$. If $s_A = 1/2$, the firms are symmetric in terms of the size of their customer information bases. As s_A increases, so does the degree of asymmetry, $s_A - s_B$.

We exclude the possibility that both firms have information about a specific consumer at the same time. Although a consumer in one firm's territory may have transacted with the other firm revealing the information about her preference, value of the information diminishes greatly in a market where tastes change fast [14]. Moreover, in some cases, personalization is based on real-time information about consumers. For example, location-based services for wireless users, which are regarded as one of the most prominent applications of personalization, require information about the consumer's present location. The information can be accessed only by the firm that the consumer is subscribing to, and used under the consumer's consent. Additionally, other firms do not have a channel to interact with the consumer to provide location-based services.

Each firm produces its standard product corresponding to its location at a constant marginal cost, which is assumed to be zero without loss of generality. Each consumer has a maximum demand of one unit and has a reservation value of v for a product which is at her ideal location. A consumer has disutility from consuming a product which is not at her ideal location. The total disutility incurred by a consumer from consuming a firm's standard product is tx, where x represent the distance between the consumer and the firm. Then, t measures the consumer's heterogeneity of preference.

Based on the available customer information, each firm can offer personalized products to the consumers in its customer information base with a constant marginal cost of c. We assume that this cost is sufficiently low, specifically, $c < \min(s_A t, s_B t) = s_B t$. It is assumed that the information about a consumer' preference is accurate enough for the firm to provide a product that fits with the consumer's preference. Then, when both firms offer standard and personalized products, a consumer in firm i's customer information base, where i = A or B, has three product choices: the standard product and the personalized product by firm i, and the standard product by firm j $(\neq i)$. On the other hand, only standard products are available for consumers in the privacy-concerned segment.

We consider a second-degree price discrimination, in which firm i charges p_i^S and p_i^P for its standard and personalized products, respectively. This pricing scheme is frequently observed in practice. For example, Levi's Personal Pair jeans are priced 20% higher than a premanufactured jeans, and Land's End, a catalog clothing company sells tailor-made pants for $54 vs. $35 for a standard pair. Vodafone, the world's largest mobile telecommunications company, offers Find and Seek service, a location-based personalization service, which provides travel information or location guide about places of users' interests based on their location information at monthly subscription fee of 2.5 Euro [15].

Consumers maximize their surplus given each firm's products and their prices. For example, a consumer located at x and in, say, firm A's customer information base gets a surplus of $v - p_A^S - tx$ from firm A's standard product, $v - p_A^P$ from firm A's personalized product, and $v - p_B^S - t(1 - x)$ from firm B's standard product. The consumer chooses the product that gives the largest surplus. A privacy-concerned consumer located at x compares $v - p_A^S - tx$ and $v - p_B^S - t(1 - x)$, and chooses the larger one. It is assumed that v is high enough to ensure that all consumers buy one unit in the equilibrium. Then, note that a consumer's choice to maximize the surplus is equivalent to that to minimize the total cost, the price plus the transportation cost.

A privacy-unconcerned consumer located in the interval $[0, (p_A^P - p_A^S) / t]$ would prefer firm A's standard product to its personalized product as long as $p_A^P > p_A^S$. Therefore, as the firm tries to charge a more price premium for the personalized products, more consumers would choose the standard product instead of the personalized product intended for her. This potential of cannibalization links the firm's decisions of the two prices, and therefore, relates the privacy-unconcerned and -concerned segments.

In this way, our model captures essential features of information-intensive markets: Firms can build up information bases for the consumers who have different desired level of their privacy, and compete using personalized products based on the information and price discrimination.

Analysis

Customer Information Base, Privacy, and Competitive Equilibrium

We now analyze the competitive outcomes in a duopoly setting when firms can offer personalized products using their customer information. Firm i's strategy is given by (p_i^S, p_i^P). Various cases are possible depending on the relative magnitude of the prices. Intuitively, we expect that the consumer indifferent between purchasing the standard products by firms A and B be located in $(0, s_A)$ since firm A with the larger customer information base is likely to set higher prices. This intuition can be verified as stated in the following lemma.

Lemma 1: In any pure strategy Nash equilibrium to the game, the equilibrium prices for standard products satisfy the following inequalities, $-(2s_A - 1)t < p_A^S - p_B^S < t$.

Given the price conditions in lemma 1, there are three possible cases with different profit functions as shown in Figure 1. By lemma 1, no consumer in firm B's information base chooses firm A's standard product because it costs more than firm B's standard product. Then, it is not optimal for firm B to price its personalized products lower than p_B^S since it is inferior to $p_B^P = p_B^S$, or higher than $p_B^S + s_Bt$ since no consumer would choose it. Similarly, the price of firm A's personalized products should be between min $(p_A^S, p_B^S + s_Bt)$ and $(p_A^S + p_B^S + t)/2$ (see figure 1). Then, first possible case is min $(p_A^S, p_B^S + s_Bt) < p_A^P <$ max $(p_A^S, p_B^S + s_Bt)$ and $p_A^S < p_B^S + s_Bt$, that is, $p_A^S < p_A^P < p_B^S + s_Bt$ (Case 1). Second possible case is min $(p_A^S, p_B^S + s_Bt) < p_A^P <$ max $(p_A^S, p_B^S + s_Bt)$ and $p_A^S > p_B^S + s_Bt$, that is, $p_B^S + s_Bt < p_A^P < p_A^S$ (Case 2). Finally, Case 3 involves max $(p_A^S, p_B^S + s_Bt) < p_A^P < (p_A^S + p_B^S + t)/2$. Among the three cases, we find that Cases 1 and 3 are equilibria. The next proposition summarizes the results.

Proposition 1: There exist two pure strategy Nash equilibria to the game depending on the values of s_A and λ.

(i) In the first equilibrium, which corresponds to Case 1, the equilibrium prices are given by

$$p_A^S = \frac{3 + (s_A - s_B)\lambda}{3(1-\lambda)}t,\ p_A^P = p_A^S + \frac{c + s_At}{2},$$

$$p_B^S = \frac{3 + (s_B - s_A)\lambda}{3(1-\lambda)}t, \text{ and } p_B^P = p_B^S + \frac{c + s_Bt}{2}.$$

The necessary condition for this equilibrium is $s_A < \frac{2(3-\lambda)t - 3(1-\lambda)c}{(9-\lambda)t}$.

(ii) In the second equilibrium, which corresponds to Case 3, the equilibrium prices are given by

$$p_A^S = \frac{(3+\lambda)t + \lambda c}{3(1+\lambda)},\ p_A^P = p_A^S + \frac{c}{2},\ p_B^S = \frac{(3-\lambda)t + 2\lambda c}{3(1+\lambda)},$$

and $p_B^P = p_B^S + \frac{c + s_Bt}{2}$.

The necessary condition for this equilibrium is $s_A > \frac{2(3+\lambda)t - (3+\lambda)c}{6(1+\lambda)t}$.

(iii) The regions satisfying the two necessary conditions do not overlap.

Proof: See the Appendix.

Part (iii) of the proposition implies that given λ, the first equilibrium emerges when both firms are almost symmetric in terms of the size of their customer information bases ($s_A \fallingdotseq s_B$) while the second one does when the firms are sufficiently asymmetric in terms of the size ($s_A \gg s_B$). Sufficient conditions which ensure no incentive for unilateral deviation is derived by examining the possible deviations. In the following, we examine each equilibrium.

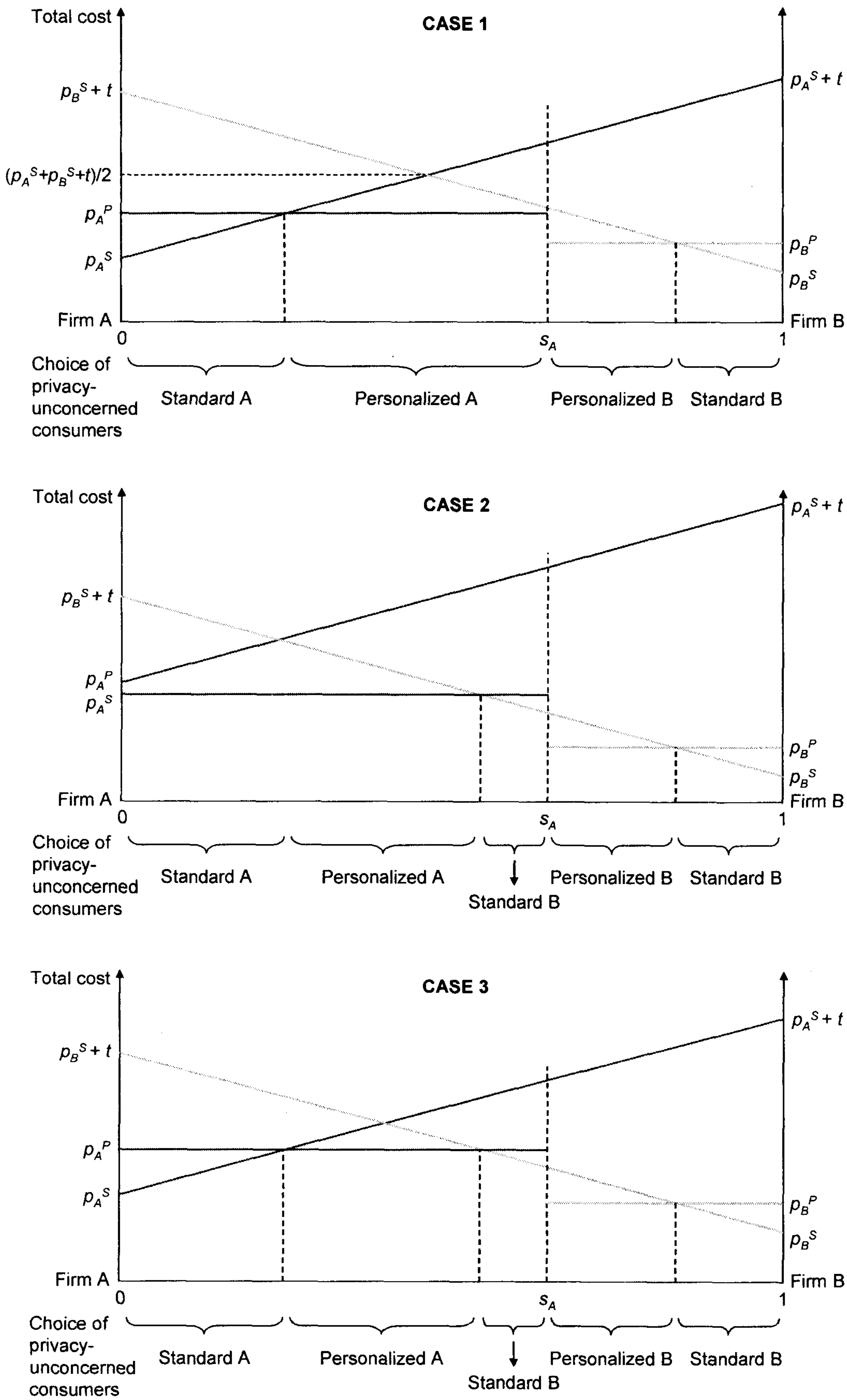

Figure 1 - Three possible cases and choice of the privacy-unconcerned consumers

Competition under Almost Symmetric Customer Information Base

Part (i) of Proposition 1 characterizes the equilibrium prices when the firms are almost symmetric in terms of the size of their customer information bases. In this equilibrium, both firms fully serve the consumers in their own customer information bases (See Case 1 in Figure 1). In the privacy-unconcerned segment, consumers near the firm's location choose the standard products, and consumers far from the firm choose the personalized products. The number of the privacy-unconcerned consumers who choose firm i's standard and personalized products are, from the equilibrium prices, $\lambda(s_i/2+c/2t)$ and $\lambda(s_i/2-c/2t)$, respectively. As the level of differentiation increases (a larger t) or the cost of personalization decreases (a smaller c), consumers who choose the personalized products (standard products) increases (decreases). Then, which firm is better off with the adoption of personalization, both, the larger one, or none? The following proposition summarizes the results.

Proposition 2: When the firms have similar size of customer information bases, both firms price their standard products higher than t, the equilibrium price without personalization, and both firms' equilibrium profits are greater than $t/2$, the profit without personalization.

Proposition 2 states that personalization benefits both firms, leading to a win-win situation when the firms have similar size of customer information bases. A firm may set high prices for the personalized products to exploit its customer information base. Then, given the cannibalization effect, the firm should also increase the price of the standard product for successful exploitation, which reduces the market share in the privacy-concerned segment. Alternatively, the firm can lower the standard price, and therefore the price of the personalized product, to capture its competitor's customer base aggressively.

The proposition shows that the exploitation of customer information bases is both firms' equilibrium choices when both firms' customer information bases are balanced. To understand the reason in the simplest way, suppose that λ = 1, and compare firm A's strategy given in case 1 in figure 1 and its reducing prices to capture firm B's customer base. Firm A should reduce its standard price at least by $p_A^S + s_A t - p_B^P$ to capture any consumer in firm B's base, which sacrifices its profit margin a great deal. Therefore, exploitation becomes its equilibrium strategy. By the same reason, firm B also choose exploitation. In this case, the firms interact with each other only through the competition in the privacy-concerned segment. Note that as λ approaches 1, that is, the interaction becomes weaker and weaker, prices skyrocket to the reservation price.

Next, we examine the effects of customer information base on pricing strategy and resulting profitability of the firms. From part (i) of proposition 1, it is easy to see that the prices of both standard and personalized products are increasing in the firm's customer information base size. Profit is also found to be an increasing function of the information base size. This observation indicates the importance of building customer information base and implies that customer information base works as a source of competitive advantage in the information-intensive competitive environment.

In addition to the relative size of each firm's customer information base (s_A vs. s_B), what are the effects of the total size of both firms' bases, λ? We can examine the effects by differentiating p_i^S, p_i^P, and π_i with respect to λ, and the results are stated in the following proposition.

Proposition 3: As more consumers share information about their preferences, or alternatively, as the total size of firms' customer information bases increases, the equilibrium prices increase and both firms earn higher profits.

Proposition 3 is quite straightforwardly expected from the argument given for Proposition 2. Because both firms' equilibrium strategies are to exploit its customer base while limiting competition to the privacy-concerned segment, they become less competitive as the size of the privacy-concerned segment decreases. Thus, the equilibrium prices and profits increase.

Proposition 3 implies that firms in an industry are better off by increasing customer information base of the industry as a whole. Therefore, attenuating consumers' privacy concern and thereby boosting information sharing plays a key role in making the most of personalization. Proposition 3 provides some support to the widespread efforts to induce consumers to share their information. It also implies that personalization is most profitable in the market where the amount of information needed for personalization is not significant, and therefore, many consumers are willing to provide the information or allow the firm to use it.

Given the importance of customer information base, is it always beneficial for the firm to increase its customer information base? The answer is "Not necessarily" as will be examined in the following.

Competition under Asymmetric Customer Information Base

Part (ii) of Proposition 1 characterizes the equilibrium prices when the firms are asymmetric in terms of the size of their customer information bases. Different from the previous equilibrium, some consumers in firm A's base choose firm B's standard product instead of the personalized products intended for them by firm A (See Case 3 in Figure 1). The number of these consumers is, from the equilibrium prices, $\lambda(s_A-(3+\lambda)(2t-c)/6(1+\lambda)t)$. By partially differentiating this with respect to s_A and λ, the effects of these parameters on the number of the consumers can be identified. The following proposition summarizes the results.

Proposition 4: When firm A's customer information base is significantly larger than that of firm B, some of the consumers in firm A's information base located near firm B buy from firm B instead of firm A. The size of this switching segment increases with the size of firm A's customer information base (s_A) and with λ. On the other hand, firm B sell to all consumers in its customer information base.

In the asymmetric case, the firm with a smaller customer information base does not get much by exploiting its customer information base. Instead, the firm has a strong incentive to undercut its competitor to aggressively capture its competitor's customers through lowering the price. This in turn, makes firm A to react by reducing its prices, which intensifies the competition. However, because firm A has a large information base to capitalize on, its price reduction is not as aggressive as firm B's. As a result, firm B can successfully capture some of firm A's customers while securing all consumers in its customer base. Intuitively, the firm with a smaller customer information base would have a greater incentive to be aggressive as its customer information base decreases as derived in proposition 4.

Next, given a higher incentive for firm A to exploit with an increase of λ, firm B can also exploit its customer information base. Alternatively, it may try to undercut firm A's base. The latter is more attractive for firm B because the difference of customer information base size, $\lambda(s_A-s_B)$, increases with λ. Therefore, firm B tries to undercut firm A, which leads firm A to reduce their prices. However, because firm A has a stronger incentive to exploit its base as λ increases, firm B can increase its share of consumers in firm A's information base.

Then, what are the effects of this intensified competition on prices and profits? The following proposition summarizes the results.

Proposition 5: The prices for the standard products by both firms are lower than t (the equilibrium price with no customization). Firm A's profit is always higher than firm B's. However, both firms' equilibrium profits are less than $t/2$, the profit with no personalization.

Compared with the previous symmetric case, the firm with a lager customer information base has a greater advantage over its competitor in terms of the relative size of the base. However, the results in proposition 5 state that interestingly, the larger firm earns a smaller profit than in the previous case. Moreover, the profit is even less than that in the absence of personalization, $t/2$. Therefore, adoption of personalization leads to a prisoner's dilemma situation when competing firms have quite different size of customer information bases. The reason underlying this result is the strong incentive of the firm with a smaller customer information base to undercut its competitor as explained in proposition 4.

Next, what are the effects of the total size of both firms' bases, λ in the asymmetric case? Can be the firms better off with larger λ as in the previous equilibrium? By differentiating p_i^S, p_i^P, and π_i with respect to λ, we can obtain the following results.

Proposition 6: As more customers share information about their preferences, or alternatively, as the total size of firms' customer information bases increases, the equilibrium prices decrease and both firms earn lower profits.

Proposition 6 states that the effect of the size of the privacy-unconcerned segment is opposite to what we obtained in the previous equilibrium. As more consumers share information about their preferences, the industry encounters an intensified price competition. Therefore, undermining customers' privacy concern and thereby boosting information sharing is not beneficial for any player in the industry.

Chen *et al.* [1] show that through the analysis of the effect of imperfect targetability of firms providing homogeneous products, win-win competition occurs at a low level of targetability, whereas the prisoner's dilemma occurs at a high level of targetability. Based on the result, they argue that protecting customer privacy and, hence, limiting the availability of customer information to all competing firms through industry-wide self-regulation can ensure the win-win outcomes in the industry. However, our results from the two equilibria suggest that limiting information availability is desirable only when the size of the customer information bases is quite asymmetric across the industry.

Discussion and Conclusion

The Internet and information technologies allow firms to better understand each consumer's preference, facilitating provision of personalized goods. At the same time, the consumer would like to obtain personalized products by providing minimal information. In this study, we analyzed the competitive effects of personalization offered to consumers who are heterogeneous in terms of their preferences and their desired level of privacy. We identify two pure strategy equilibrium, depending on the relative size of both firms' customer information bases and the size of the privacy-unconcerned segment. When the firms have similar size of customer information bases or the proportion of the privacy-unconcerned consumers is low, both firms' equilibrium strategies are to exploit their customer information bases, and both firms' profits are greater than that without personalization, leading to a win-win situation. In this case, as more consumers share information about their preferences, both firms earn higher profits.

On the other hand, when the firms are significantly asymmetric in terms of the size of their customer information bases or the proportion of the privacy-unconcerned consumers is high, the smaller firm tries to undercut the larger one's customer base. Because of the intensified price competition, both firms' equilibrium profits are even less than that with no personalization, resulting in a prisoner's dilemma situation. In this case, as more consumers share information about their preferences, both firms' profits decrease.

The results imply that the firm should be careful in building customer information base: It is not always optimal to induce consumers to provide information about their preferences or to increase the size of customer information base. When the firms are almost symmetric in terms of the sizes of their customer information bases, each firm can be better off by increasing its customer information base to some extent. However, building excessive information base leads to a totally different result in which profit is significantly reduced by enhanced competition. On the other hand, it is always beneficial for all firms in the industry to induce more customers to provide their information to the firms. When the firms are asymmetric in terms of the sizes of their customer information bases, firms are worse off by adopting personalization. In this situation, inducing more customers to share information intensifies competition and further reduces the industry profit.

Although our model captures important features of personalization, there are other interesting issues to further investigate. First, our model is a single-period and does not capture intertemporal effects. A dynamic model could endogenize the consumers' decision to provide information, and the firm's strategy to induce customer information provision, for example, through offering a reward for the information to the consumer. Next, a different pricing scheme is possible. For example, a firm may price its personalized products depending on the location. This modification is expected to result in different equilibrium outcomes.

Appendix

Proof of Proposition 1

Case i) In this case the profit functions for firms A (π_A) and B (π_B) are, respectively,

$$\pi_A = \lambda\left[p_A{}^S \frac{p_A{}^P - p_A{}^S}{t} + (p_A{}^P - c)\left(s_A - \frac{p_A{}^P - p_A{}^S}{t} \right) \right] + (1-\lambda) p_A{}^S \left(\frac{p_B{}^S - p_A{}^S + t}{2t} \right), \quad \text{(A1)}$$

and

$$\pi_B = \lambda\left[p_B{}^S \frac{p_B{}^P - p_B{}^S}{t} + (p_B{}^P - c)\left(1 - s_A - \frac{p_B{}^P - p_B{}^S}{t} \right) \right] + (1-\lambda) p_B{}^S \left(1 - \frac{p_B{}^S - p_A{}^S + t}{2t} \right). \quad \text{(A2)}$$

The first order conditions for the prices are $\partial \pi_i / \partial p_i{}^S = 0$ and $\partial \pi_i / \partial p_i{}^P = 0$ for i=A, B. By solving these four equations simultaneously, we obtain the following candidate equilibrium prices.

$p_i{}^S = \frac{3 + (s_i - s_j)\lambda}{3(1-\lambda)} t$, and $p_i{}^P = p_i{}^S + \frac{c + s_i t}{2}$.

The resulting profits are

$$\pi_i = \left[(18 + ((9-\lambda)s_i{}^2 + 2(6-\lambda)(s_i - s_j) - 4\lambda s_i)\lambda)t^2 - 9(1-\lambda)\lambda c(2 s_i t - c) \right] / 36(1-\lambda)t. \quad \text{(A3)}$$

The above prices should satisfy the following four conditions to be a candidate equilibrium for Case 1. First, the consumer who is indifferent between the standard products offered by both firms should be located on the left hand of s_A. That is, $s_A - (p_B{}^S - p_A{}^S + t)/2t = (2s_A - 1)(3-\lambda)/6(1-\lambda)$ should be positive, which is always true. Second, the price for firm i's personalized products should be equal to or larger than that for the firm's standard product. $p_i{}^P - p_i{}^S = (c + s_i t) > 0$. Thus, the condition is satisfied. Third, $p_i{}^P$ should be smaller than $p_i{}^S + s_i t$ to ensure that some consumers choose personalized products, which is satisfied because $p_i{}^S + s_i t - p_i{}^P = s_i t - c > 0$. Fourth, for the consumers at s_A, the personalized products by firm A should provide higher utility than firm B's standard product. That is, $p_B{}^S + s_B t - p_A{}^P$ should be positive. This requires the condition given in Part i) of Proposition 1.

For the strategies in this candidate equilibrium to constitute a Nash equilibrium, neither firm should have incentive to deviate unilaterally from its strategy. We omit the analysis for this incentive from this paper.

Case ii) In this case, it can be shown that the prices satisfying the first order conditions cannot constitute Case 2. Thus, Case 2 cannot be an equilibrium.

Case iii) In this case the profit functions for firms A (π_A) and B (π_B) are, respectively,

$$\pi_A = \lambda\left[p_A{}^S \frac{p_A{}^P - p_A{}^S}{t} + (p_A{}^P - c)\left(1 - \frac{p_A{}^P - p_B{}^S}{t} - \frac{p_A{}^P - p_A{}^S}{t} \right) \right] + (1-\lambda) p_A{}^S \left(\frac{p_B{}^S - p_A{}^S + t}{2t} \right), \quad \text{(A4)}$$

and

$$\pi_B = \lambda\left[p_B{}^S \frac{p_B{}^P - p_B{}^S}{t} + (p_B{}^P - c)\left(1 - s_A - \frac{p_B{}^P - p_B{}^S}{t} \right) + p_B{}^S \left(s_A - 1 + \frac{p_A{}^P - p_B{}^S}{t} \right) \right] + (1-\lambda) p_B{}^S \left(1 - \frac{p_B{}^S - p_A{}^S + t}{2t} \right). \quad \text{(A5)}$$

By solving the first order conditions simultaneously, we obtain the following candidate equilibrium prices.

$p_A{}^S = \frac{(3+\lambda)t + \lambda c}{3(1+\lambda)}$, $p_A{}^P = p_A{}^S + \frac{c}{2}$, $p_B{}^S = \frac{(3-\lambda)t + 2\lambda c}{3(1+\lambda)}$,

and $p_B{}^P = p_B{}^S + \frac{c + s_B t}{2}$.

The resulting profits are

$$\pi_A = \frac{((3+\lambda)t - 2\lambda c)^2 + 9\lambda c^2}{18(1+\lambda)t}, \qquad \text{(A6)}$$

and

$$\pi_B = [(18 + (11\lambda - 3 - 9(1+\lambda)(1-s_B^2))\lambda)t^2 + 2(9(1+\lambda)(1-s_B) + 3 - 13\lambda)\lambda ct + (9+17\lambda)\lambda c^2] / 36(1+\lambda)t. \qquad \text{(A7)}$$

The above prices should satisfy the following conditions to be a candidate equilibrium for Case 3. First, $s_A-(p_B^S - p_A^S + t)/2t$ should be positive, which leads to $s_A > [(3+\lambda)t+\lambda c]/6(1+\lambda)t$. The second condition is max $(p_A^S, p_B^S + s_Bt) < p_A^P < (p_A^S + p_B^S + t)/2$. $p_A^P - p_A^S = c/2$ is always positive. Next, $p_A^P - p_B^S - s_Bt > 0$ requires $s_A > [2(3+\lambda)t - (3+\lambda)c]/6(1+\lambda)t$. Finally, $(p_A^S + p_B^S + t)/2 - p_A^P = [(3+\lambda)t - (3+2\lambda)c]/6(1+\lambda)$ is always positive. The third condition is $p_B^S < p_B^P < p_B^S + s_Bt$, which is always satisfied. Therefore, the resulting condition is $s_A > \max\left(\frac{(3+\lambda)t+\lambda c}{6(1+\lambda)t}, \frac{2(3+\lambda)t-(3+\lambda)c}{6(1+\lambda)t}\right)$.
It can be easily shown that $\frac{(3+\lambda)t+\lambda c}{6(1+\lambda)t} < \frac{2(3+\lambda)t-(3+\lambda)c}{6(1+\lambda)t}$. Thus, the necessary condition in Part ii) of Proposition 1 is derived.
Finally, it can be shown that $\frac{2(3+\lambda)t-(3+\lambda)c}{6(1+\lambda)t} > \frac{2(3-\lambda)t-3(1-\lambda)c}{(9-\lambda)t}$, which leads to Part iii) of Proposition 1.

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