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Abstract

In this paper, we analyze the profitability of behavior-based price discrimination in a duopoly model with switching costs. We find that when firms price discriminate based on consumers' preferences, and remain unaware of their switching costs, price discrimination boosts the equilibrium profits compared to uniform pricing, when the heterogeneity in the consumers' preferences is not too large compared to that in the switching costs.

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1 Introduction

Increasing use of sophisticated technology has made it possible for the competing firms to obtain detailed information about consumers' preferences. Firms can obtain this information on their own or from a third party (called data broker). The data broker collects information about consumers' past activities and aggregate their preferences which they can sell to the firms (Bounie et al., 2021). Firms may use this information to price discriminate among consumers based on their preferences. Such form of price discrimination is called behavior-based price discrimination (henceforth BBPD) in the literature.[1]

Starting from the seminal works (Villas-Boas, 1999; Fudenberg and Tirole, 2000; Shaffer and Zhang, 2000), there is a vast and growing literature on behavior-based price discrimination. There is a general consensus in the literature that, in a symmetric duopoly, BBPD intensifies competition and, thus, results into lower profits for the firms (Esteves et al., 2009; Pazgal and Soberman, 2008; Villas-Boas, 1999). Personalized pricing has two effects, first, since the firms know the characteristics of the consumers, they have more surplus to extract from - surplus extraction effect, second, for each consumer, firms compete more aggressively - competition effect. In general, competition effect outweighs the surplus extraction effect, and this leads to the typical prisoner's dilemma case when both the firms engage in personalized pricing. Yet, there is evidence that personalized pricing is observed in the reality. For example, Hannak et al. (2014) compare prices of identical products on different e-commerce websites, and find the evidence of price discrimination in general retail and on travel websites.[2]. Mahmood (2014), in an experimental set-up consisting of two periods, finds that experimental sellers are likely to choose to price discriminate based on the past behavior of the consumers.

Most of the existing studies on BBPD consider single characteristic of consumers' past behavior, either switching or brand preferences, and focus on analyzing the profit and welfare effects of personalized pricing. However, as it seems to be realistic, it is impor-

[1]See Esteves et al. (2009) and Fudenberg and Villas-Boas (2006) for detailed surveys on BBPD.

[2]See more evidence on price discrimination in Mikians et al. (2012) and Iordanou et al. (2017)

tant to analyze the effect of personalized pricing when consumers have multi-dimensional heterogeneity. In this paper, we investigate the profitability of behavior-based price discrimination when consumers are heterogeneous in two dimensions.

We consider a duopoly model with an inherited purchase history of the consumers. Consumers have continuous brand preferences, and they face idiosyncratic switching costs. Therefore, consumers are heterogenous in their preferences as well as their switching costs. Firms may be able to price discriminate based on consumers' brand preferences. We assume that the firms are not aware of the identity (purchase history) of the consumers, i.e., which consumers have bought from which firm previously. Moreover, firms do not know the idiosyncratic switching costs of the consumers.[3]

We find that price discrimination results into higher equilibrium profits than under uniform pricing when the heterogeneity in consumers' preferences is not too large compared to that in consumers' switching costs. The reason is as follows. On each firm's turf (i.e., set of consumers who have previously bought from the firm), consumers' preferences are uniformly distributed over a unit line. At each location of the preferences, there is a set of consumers distributed uniformly according to their switching costs. Under uniform pricing, firms set prices according to the standard Bertrand logic, i.e., equal to the transportation cost in the more differentiated dimension (preferences or switching costs).[4] That is, when the heterogeneity in switching cost is higher compared to that in preferences, firms set prices according to the switching cost parameter, and vice versa. Under price discrimination, firms compete aggressively at each location in terms of preferences. However, the intensity of price competition is relaxed due to the presence of switching cost. That is, firms set personalized prices according to consumers' preferences augmented by switching cost parameter. Now, the consumers who are initially correctly matched to a firm, i.e.,

[3]We rationalize our assumption about consumer recognition by assuming that firms acquire the information about consumers' brand preferences from a data broker. The data broker sells information only about the consumers' preferences and not their purchase history.

[4]We use 'transportation cost' and 'heterogeneity' interchangeably. We define these terms more precisely in the model description in Section 2.

have bought from their more preferred firm, do not switch in the equilibrium, regardless of their switching costs, both under uniform pricing and under price discrimination. When the heterogeneity in consumers' preferences is smaller than that in switching costs, firms' prices under price discrimination are greater than that under uniform pricing for this segment of consumers. Therefore, firms gain from those consumers who are already correctly matched to them. In the segment of initially mismatched consumers, firms charge lower prices than uniform pricing, but there is less switching of the consumers in the equilibrium. That is, firms serve more consumers from their previous market share. The overall effect is positive, and firms gain by price discriminating. On the other hand, when the heterogeneity in consumers' preferences is greater than that in switching costs, under uniform pricing, the prices are now according to the transportation cost in consumers' preferences. The competition softening effect of switching cost under price discrimination is outweighed by the gain in uniform pricing due to pricing according to the transportation cost in the consumers' preferences, when the heterogeneity in the consumers' preferences is too large compared to that in the switching costs. Therefore, price discrimination is profitable when consumers' heterogeneity in their preferences is not too large compared to that in the switching costs.

Our paper is conceptually close to Shy and Stenbacka (2011, 2013, 2016) and Esteves (2009). Shy and Stenbacka (2011, 2013, 2016) consider discrete consumer preferences and switching costs. Their analysis suggests that in their framework, price discrimination is never profitable compared to uniform pricing. Esteves (2009) considers two-dimensional heterogeneity, brand loyalty and brand preference, of consumers without any prior purchase history. The author shows that price discrimination may be profitable when firms price discriminate based on the less heterogenous dimension. However, the mechanism driving this result is quite different from our analysis. In Esteves (2009), even the most loyal consumer to a firm can buy from the rival firm, depending on her brand preference, and vice versa. In our paper, due to previous purchase history, consumers who are initially correctly matched to their more preferred firm do not switch in the equilibrium, regardless of their switching cost. Hence, the result is driven by potential switching of initially mismatched consumers.

The remainder of the analysis is as follows. Section 2 describes the model. Section 3 deals with the equilibrium analysis under uniform pricing and price discrimination, and presents the main results. Section 4 concludes. The Appendix is relegated to the end.

2 Model

Suppose that there are two firms, A and B, producing differentiated goods at zero marginal costs. Without any loss of generality, total mass of consumers is assumed to be 2. Mass 1 of consumers have previously purchased from A, and the others from B. On each firm's turf (i.e., the set of consumers who have previously purchased from the firm), consumers' relative brand preference θ is uniformly distributed over unit interval.[5] We assume that firms A and B are located at extreme ends 0 and 1 respectively on the unit interval $[0, 1]$ characterizing brand preferences, and θ denotes the relative brand preference for firm B over firm A. That is, a higher value of θ indicates a higher preference of the consumer for firm B. The set up implies that half of the consumers are initially mismatched. For example, on firm A's turf, the consumers with preference $\theta > \frac{1}{2}$ have higher relative preference for firm B's product.

Now, all consumers make another purchase. They can either remain loyal to a firm i from which they have previously purchased or they can switch to the rival firm. Switching is costly. In particular, switching costs of consumers s are uniformly distributed over unit interval $[0, 1]$. Suppose that firm i, $i = A,\ B$, sets price p_i.

Utility of a consumer with brand preference θ, switching cost s, and previous purchase

[5]We stress here that this can be rationalized assuming that consumers learn their relative brand preferences after they have patronized one firm previously. See Shy and Stenbacka (2013).

history with firm A is

$$U_A(\theta,\ s) = \begin{cases} v - t\theta - p_A & \text{continues from firm } A \\ v - t(1-\theta) - p_B - \sigma s & \text{switches to firm } B \end{cases} \tag{1}$$

Utility of a consumer with brand preference θ, switching cost s, and previous purchase history with firm B is

$$U_B(\theta,\ s) = \begin{cases} v - t(1-\theta) - p_B & \text{continues from firm } B \\ v - t\theta - p_A - \sigma s & \text{switches to firm } A \end{cases} \tag{2}$$

$v(> 0)$ is the gross utility derived from consuming either product, which is assumed to be large enough such that each consumer buys in equilibrium. $t(> 0)$ is the heterogeneity or transportation cost of brand preferences. A higher value of t indicates higher differentiation in brand preferences across consumers $\theta \in [0, 1]$. Similarly, σ is the heterogeneity or transportation cost of switching costs; a higher value of σ indicates higher switching costs differentiation across consumers $s \in [0, 1]$.[6]

Firms, with the help of technology available to them at zero costs, are able to recognize the brand preferences of all consumers.[7] They can either use this information to set personalized pricing or set uniform prices for all consumers.

3 Analysis

3.1 Uniform Pricing

Suppose that firms can not recognize the brand preferences of the consumers. In this case, both firms set a single price, $p_i,\ i = A,\ B$.

[6]It is also termed as the intensity of switching cost, denoting the same - higher σ means higher differentiation among consumers' switching costs (Shy and Stenbacka, 2013).

[7]We assume that firms have symmetric and perfect consumer recognition technology. This assumption makes the analysis tractable without compromising on the main idea of the paper.

From utility function (1), a consumer with preference θ and switching cost s, who has previously purchased from A, is indifferent between staying loyal to A and switching to B (denoted by $s_A(\theta)$) if condition (3) is satisfied.

$$v - t\theta - p_A = v - t(1-\theta) - p_B - \sigma s_A(\theta) \tag{3}$$

The condition (3) gives the critical value of switching cost, $s_A(\theta)$, which is defined as follows.

$$s_A(\theta) = \min\{\max\{0, \frac{p_A - p_B + t(2\theta - 1)}{\sigma}\}, 1\}$$

For each θ, (a) the consumers for whom switching cost $s \geq s_A(\theta)$, will stay loyal to firm A (i.e., continue to buy from A), and (b) the consumers for whom switching cost $s < s_A(\theta)$ will switch to firm B.

Note that $s_A(\theta)$ denotes a continuum of indifferent consumers, which can be interpreted as follows. At each location θ, there is a mass 1 of consumers with heterogeneous switching cost s uniformly distributed over $[0, 1]$.[8] In Fig. 1, the dotted line represents the indifferent consumers $s_A(\theta)$. Consider the consumers located at $\hat{\theta}$. Then, mass $s_A(\hat{\theta})$ of consumers stay loyal to the firm A, and mass $(1 - s_A(\hat{\theta}))$ of consumers switch to firm B.

Likewise, from utility function (2), a consumer with preference θ and switching cost s, who has previously purchased from firm B, is indifferent between staying loyal to B and switching to A (denoted by $s_B(\theta)$) if the condition (4) is satisfied.

$$v - t(1-\theta) - p_B = v - t\theta - p_A - \sigma s_B(\theta) \tag{4}$$

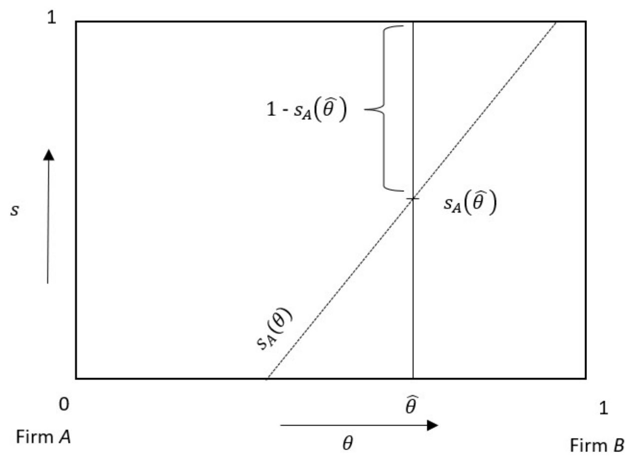
The condition (4) gives the critical value of the switching cost, $s_B(\theta)$, which is defined as follows.

$$s_B(\theta) = \min\{\max\{0, \frac{p_B - p_A + t(1 - 2\theta)}{\sigma}\}, 1\}$$

Similar to $s_A(\theta)$, $s_B(\theta)$ denotes a continuum of indifferent consumers.

[8] This can also be interpreted as two-dimensional spatial competition. See, for instance, Esteves (2009), Tabuchi (1994).

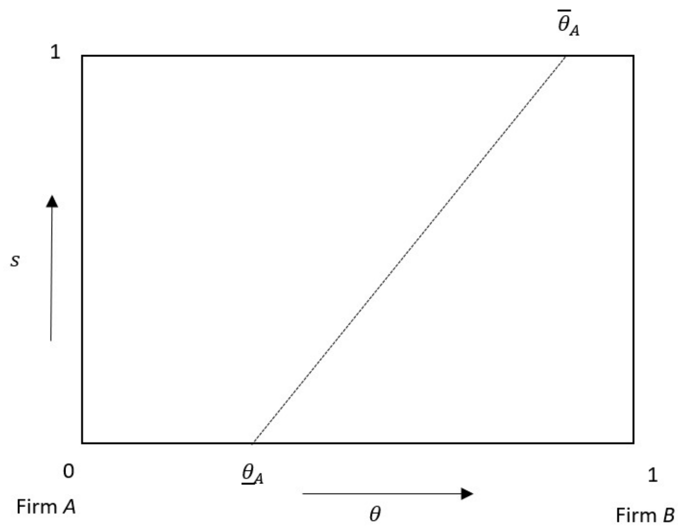
Figure 1: Firm A's Previous Consumers



Demand of firms from firm A's previous consumers:

Suppose that there exist marginal consumers, $\underline{\theta}_A$ and $\overline{\theta}_A$, such that consumers with preferences $\theta < \underline{\theta}_A$ continue to buy from the firm A, and consumers with $\theta > \overline{\theta}_A$ switch to the firm B, regardless of the value of their switching costs. For illustration, see Fig 2. We must show that, in equilibrium, $\underline{\theta}_A$, $\overline{\theta}_A \in [0, 1]$.

Figure 2: Demand from Firm A's Previous Consumers



In this case, $s_A(\underline{\theta}_A) = 0$ and $s_A(\overline{\theta}_A) = 1$. This implies

$$\underline{\theta}_A = \frac{1}{2} - \frac{p_A - p_B}{2t}, \quad \overline{\theta}_A = \frac{1}{2} + \frac{\sigma}{2t} - \frac{p_A - p_B}{2t} \tag{5}$$

Therefore, demand of firm A from firm A's previous consumers is

$$\underline{\theta}_A + \int_{\underline{\theta}_A}^{\overline{\theta}_A} (1 - s_A(\theta))\, d\theta$$

and demand of firm B from firm A's previous consumers is

$$\int_{\underline{\theta}_A}^{\overline{\theta}_A} s_A(\theta)\, d\theta + (1 - \overline{\theta}_A)$$

Demand of firms from firm B's previous consumers:

Suppose that there exist marginal consumers, $\underline{\theta}_B$ and $\overline{\theta}_B$, such that consumers with preferences $\theta < \underline{\theta}_A$ switch to firm A, and consumers with $\theta > \overline{\theta}_A$ continue to buy from the firm B, regardless of the value of their switching costs. We must show that, in equilibrium, $\underline{\theta}_B,\ \overline{\theta}_B \in [0, 1]$.

In that case, $s_B(\underline{\theta}_B) = 1$ and $s_B(\overline{\theta}_B) = 0$. This implies

$$\underline{\theta}_B = \frac{1}{2} - \frac{\sigma}{2t} + \frac{p_B - p_A}{2t}, \quad \overline{\theta}_B = \frac{1}{2} + \frac{p_B - p_A}{2t} \tag{6}$$

Therefore, demand of firm A from firm B's previous consumers is

$$\underline{\theta}_B + \int_{\underline{\theta}_B}^{\overline{\theta}_B} s_B(\theta)\, d\theta$$

and demand of firm B from firm B's previous consumers is

$$\int_{\underline{\theta}_B}^{\overline{\theta}_B} (1 - s_B(\theta))\, d\theta + (1 - \overline{\theta}_B)$$

After substituting the values of switching cost thresholds, we get the total demand of the firms as follows.

$$D_A(p_A, p_B) = 1 + \frac{p_B - p_A}{t}, \quad D_B(p_A, p_B) = 1 + \frac{p_A - p_B}{t} \tag{7}$$

We focus on the symmetric uniform pricing Nash equilibrium. Firm i's maximization problem is $\max_{p_i} \pi_i^U = p_i \ D_i(p_i, p_j); \ i, j = A, B; \ i \neq j$. Superscript 'U' denotes uniform pricing.

From the profit maximization problems of both firms, we get the following equilibrium prices and profits.

$$p_A^U = p_B^U = t, \quad \pi_A^U = \pi_B^U = t \tag{8}$$

Substituting the equilibrium prices in equations (5) and (6), we get $\underline{\theta}_A = \frac{1}{2}$, $\overline{\theta}_A = \frac{1}{2} + \frac{\sigma}{2t}$ and $\underline{\theta}_B = \frac{1}{2} - \frac{\sigma}{2t}$, $\overline{\theta}_B = \frac{1}{2}$. It is easy to check that $\underline{\theta}_A = \overline{\theta}_B = \frac{1}{2} \in [0, 1]$. Further, $\overline{\theta}_A$, $\underline{\theta}_B \in [0, 1]$, when $\sigma \leq t$.

Therefore, we must consider the case $\sigma > t$ separately. The total demand of firm A in this case is

$$\underline{\theta}_A + \int_{\underline{\theta}_A}^{1} (1 - s_A(\theta)) \ d\theta + \int_0^{\overline{\theta}_B} s_B(\theta) \ d\theta$$

and the total demand of firm B is

$$\int_{\underline{\theta}_A}^{1} s_A(\theta) \ d\theta + \int_0^{\overline{\theta}_B} (1 - s_B(\theta)) \ d\theta + (1 - \overline{\theta}_B)$$

To illustrate this, see Fig 3 for the demand from firm A's previous consumers.

Substituting the values of $\underline{\theta}_A$ and $\overline{\theta}_B$, we get the following demand functions.

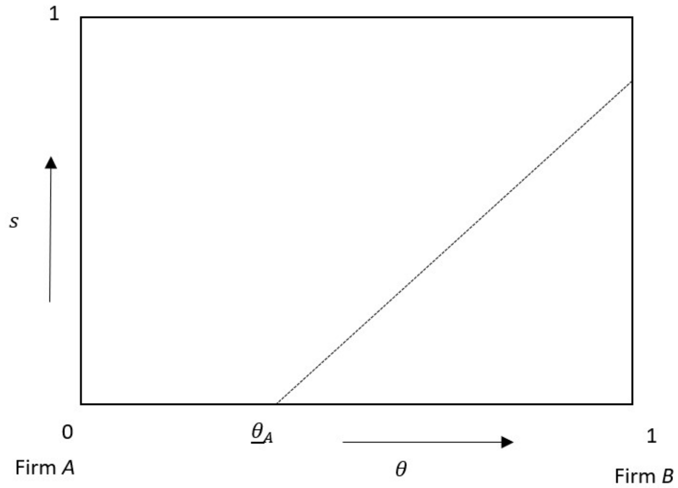
$$D_A(p_A, p_B) = 1 + \frac{p_B - p_A}{\sigma}, \quad D_B(p_A, p_B) = 1 + \frac{p_A - p_B}{\sigma} \tag{9}$$

Firm i's maximization problem is $\max_{p_i} \pi_i^U = p_i \ D_i(p_i, p_j); \ i, j = A, B; \ i \neq j$. From the profit maximization problems of both firms, we get the following equilibrium prices and profits.

$$p_A^U = p_B^U = \sigma, \quad \pi_A^U = \pi_B^U = \sigma \tag{10}$$

From equations (8) and (10), we have Lemma (1).

Figure 3: Demand from Firm A's Previous Consumers ($\sigma > t$)



Lemma 1: *When both firms set uniform prices, the equilibrium prices are given by*

$$p_i^U = \begin{cases} t & if \quad t \geq \sigma \\ \sigma & if \quad t < \sigma \end{cases}$$

and the equilibrium profits are

$$\pi_i^U = \begin{cases} t & if \quad t \geq \sigma \\ \sigma & if \quad t < \sigma \end{cases}$$

The equilibrium obtained is consistent with Nash-Bertrand equilibrium in a Hotelling model with transportation costs. Note that, in equilibrium, $\underline{\theta}_A = \overline{\theta}_B = \frac{1}{2}$, regardless of the relative magnitude of σ and t. This implies that the consumers who are initially correctly matched with their preferred firm ($\theta < \frac{1}{2}$ in case of firm A's previous consumers and $\theta > \frac{1}{2}$ in case of firm B's previous consumers) do not switch in the equilibrium. That is, firms compete only for the consumers who are initially mismatched.

3.2 Price Discrimination

Suppose that firms can observe the preferences (θ) of all consumers but not their purchase history. That is, firms have information about relative preferences of all the consumers, but they are not aware of which firm consumers have previously bought from. We assume that the firms get this information from a third party (data broker) which aggregate consumers' past behavior to predict their preferences. For simplicity, we assume that this information is perfect. Further, firms do not observe the idiosyncratic switching cost (s) of the consumers also.

Now, for each value of θ, both firms set personalized prices, $p_i(\theta),\ i = A,\ B$.

From utility function (1), a consumer with a previous purchase history with firm A, preference θ and switching cost s is indifferent between staying loyal to the firm A and switching to the firm B if the following condition holds.

$$v - t\theta - p_A(\theta) = v - t(1-\theta) - p_B(\theta) - \sigma s_A(\theta)$$

This condition gives the switching cost threshold of the marginal consumer as follows.

$$s_A(\theta) = \frac{p_A(\theta) - p_B(\theta) + t\ (2\theta - 1)}{\sigma} \tag{11}$$

Similarly, from indifference condition using utility function (2), we get the switching cost threshold of the marginal consumer in firm B's previous consumers as follows.

$$s_B(\theta) = \frac{p_B(\theta) - p_A(\theta) - t\ (2\theta - 1)}{\sigma} \tag{12}$$

Note that, from equations (10) and (11), $s_A(\theta) = -s_B(\theta)$. Also, $s_i(\theta) \in [0, 1],\ i = A,\ B$.

Therefore, we consider the following cases.

Case (i): $0 \leq s_A(\theta) \leq 1$.

Now, $s_B(\theta) = -s_A(\theta)$ and since switching cost can not be negative, we set $s_B(\theta) = 0$. A negative switching cost threshold implies that no consumer will switch to the other firm. This is equivalent to setting $s_B(\theta) = 0$.

Note that for each value of θ, there are two sets of consumers distributed uniformly according to their switching costs, one on firm A's turf and the other on firm B's turf. Note that, in this case, no consumer from the previous consumers of firm B will switch to firm A. Therefore, given θ, firm B's demand from its previous consumers is 1.

Now, for the observed value of θ, total demands of the firms A and B are as follows.

$$D_A(p_A(\theta), p_B(\theta); \theta) = 1 - s_A(\theta), \quad D_B(p_A(\theta), p_B(\theta); \theta) = 1 + s_A(\theta)$$

The firm i's objective function is $\max_{p_i(\theta)\geq 0} \pi_i(\theta) = D_i(p_i(\theta), p_j(\theta); \theta)\ p_i(\theta), i \neq j;\ i,\ j = A, B$. Solving this maximization problem of both the firms, we get the following equilibrium prices.

$$p_A(\theta) = \sigma - \frac{t(2\theta - 1)}{3}, \;\; p_B(\theta) = \sigma + \frac{t(2\theta - 1)}{3} \tag{13}$$

Now, $s_A(\theta) = \frac{t(2\theta-1)}{3\sigma}$. The condition $s_A(\theta) \in [0, 1]$ requires that $\frac{1}{2} \leq \theta \leq \frac{1}{2} + \frac{3\sigma}{2t}$. Note that, prices are non-negative in this range of θ. Therefore, the equilibrium prices given by equation (13), are valid for $\frac{1}{2} \leq \theta \leq \frac{1}{2} + \frac{3\sigma}{2t}$.

Case (ii): $0 \leq s_B(\theta) \leq 1$.

Analogous to the case (i), $s_A(\theta) = 0$. Now, for the observed value of θ, firms' demands are as follows.

$$D_A(p_A(\theta), p_B(\theta); \theta) = 1 + s_B(\theta), \quad D_B(p_A(\theta), p_B(\theta); \theta) = 1 - s_B(\theta)$$

Solving the profit maximization problems of both the firms, $\max_{p_i(\theta)\geq 0} \pi_i(\theta) = D_i(p_i(\theta), p_j(\theta); \theta)\ p_i(\theta), i \neq j;\ i,\ j = A, B$, we get the following equilibrium prices.

$$p_A(\theta) = \sigma - \frac{t(2\theta - 1)}{3}, \;\; p_B(\theta) = \sigma + \frac{t(2\theta - 1)}{3} \tag{14}$$

Now, $s_B(\theta) = \frac{t(1-2\theta)}{3\sigma}$. The condition $s_B(\theta) \in [0, 1]$ requires that $\frac{1}{2} - \frac{3\sigma}{2t} \leq \theta \leq \frac{1}{2}$. Prices are non-negative in this range.

From equations (13) and (14), the equilibrium prices, contingent upon the values of θ, are given as

$$p_A(\theta) = \sigma - \frac{t(2\theta - 1)}{3}, \;\; p_B(\theta) = \sigma + \frac{t(2\theta - 1)}{3} \;\text{ if }\; \frac{1}{2} - \frac{3\sigma}{2t} \leq \theta \leq \frac{1}{2} + \frac{3\sigma}{2t}$$

Let $\underline{\theta} = \frac{1}{2} - \frac{3\sigma}{2t}$ and $\overline{\theta} = \frac{1}{2} + \frac{3\sigma}{2t}$. It is easy to check that when $3\sigma \geq 2t$, the condition $\underline{\theta} \leq \theta \leq \overline{\theta}$ boils down to the condition $0 \leq \theta \leq 1$, as $\underline{\theta} < 0$ and $\overline{\theta} > 1$.

Consider the case when $3\sigma < 2t$. Then, note that $p_A(\theta)$ is negative for $\theta \in (\overline{\theta}, 1]$ and $p_B(\theta)$ is negative for $\theta \in [0, \underline{\theta})$. Since prices can not be negative, firms will set prices equal to their marginal costs of production (zero in this case), and the best response of the rival firm to a zero price is the difference in the transportation costs. Therefore, when $3\sigma < 2t$, $p_A(\theta) = t(1 - 2\theta) - \sigma$ for $\theta \in [0, \underline{\theta})$, and $p_B(\theta) = t(2\theta - 1) - \sigma$ for $\theta \in (\overline{\theta}, 1]$. See the Appendix for the details.

From the above discussion, we have the following result.

Lemma 2: *When both firms can observe the preferences of all the consumers and price discriminate, then, the equilibrium prices are given as follows.*

(i) When $3\sigma \geq 2t$,

$$p_A(\theta) = \sigma - \frac{t(2\theta - 1)}{3}$$
$$p_B(\theta) = \sigma + \frac{t(2\theta - 1)}{3}$$

(ii) When $3\sigma < 2t$,

$$p_A(\theta) = \begin{cases} t(1-2\theta)-\sigma & \text{if } \; 0 \le \theta < \frac{1}{2} - \frac{3\sigma}{2t} \\ \sigma - \frac{t(2\theta-1)}{3} & \text{if } \; \frac{1}{2} - \frac{3\sigma}{2t} \le \theta \le \frac{1}{2} + \frac{3\sigma}{2t} \\ 0 & \text{if } \; \frac{1}{2} + \frac{3\sigma}{2t} < \theta \le 1 \end{cases}$$

$$p_B(\theta) = \begin{cases} 0 & \text{if } \; 0 \le \theta < \frac{1}{2} - \frac{3\sigma}{2t} \\ \sigma + \frac{t(2\theta-1)}{3} & \text{if } \; \frac{1}{2} - \frac{3\sigma}{2t} \le \theta \le \frac{1}{2} + \frac{3\sigma}{2t} \\ t(2\theta-1)-\sigma & \text{if } \; \frac{1}{2} + \frac{3\sigma}{2t} < \theta \le 1 \end{cases}$$

It can be easily checked that $p_A(\theta)$ decreases in θ and $p_B(\theta)$ increases in θ. The intuition is straightforward. Firms charge higher prices to those consumers who prefer their product, and lower prices to those who prefer their rival's product.

The equilibrium profits of the firms can be calculated as follows.

When $3\sigma \ge 2t$,

$$\pi_A^D = \int_0^{\frac{1}{2}} (1 + s_B(\theta))p_A(\theta)\, d\theta + \int_{\frac{1}{2}}^1 (1 - s_A(\theta))p_A(\theta)\, d\theta$$

$$\pi_B^D = \int_0^{\frac{1}{2}} (1 - s_B(\theta))p_B(\theta)\, d\theta + \int_{\frac{1}{2}}^1 (1 + s_A(\theta))p_B(\theta)\, d\theta$$

where superscript 'D' denotes that firms price discriminate. Substituting the equilibrium values of prices and switching cost thresholds, we get

$$\pi_A^D = \pi_B^D = \sigma + \frac{t^2}{27\sigma} \tag{15}$$

When $3\sigma < 2t$,

$$\pi_A^D = \int_0^{\frac{1}{2}-\frac{3\sigma}{2t}} 2(t(1-2\theta)-\sigma)\, d\theta + \int_{\frac{1}{2}-\frac{3\sigma}{2t}}^{\frac{1}{2}} (1 + s_B(\theta))p_A(\theta)\, d\theta + \int_{\frac{1}{2}}^{\frac{1}{2}+\frac{3\sigma}{2t}} (1 - s_A(\theta))p_A(\theta)\, d\theta$$

$$\pi_B^D = \int_{\frac{1}{2}-\frac{3\sigma}{2t}}^{\frac{1}{2}} (1 - s_B(\theta))p_B(\theta)\, d\theta + \int_{\frac{1}{2}}^{\frac{1}{2}+\frac{3\sigma}{2t}} (1 + s_A(\theta))\, d\theta + \int_{\frac{1}{2}+\frac{3\sigma}{2t}}^1 2(t(2\theta-1)-\sigma)\, d\theta$$

Substituting the equilibrium values, we get the following profits.

$$\pi_A^D = \pi_B^D = \frac{t}{2} - \sigma - \frac{3\sigma^2}{2t} \tag{16}$$

From equations (15) and (16), we have the following equilibrium profits.

$$\pi_i^D = \begin{cases} \sigma + \frac{t^2}{27\sigma} & \text{if} \quad 3\sigma \geq 2t \\ \frac{t}{2} - \sigma - \frac{3\sigma^2}{2t} & \text{if} \quad 3\sigma < 2t \end{cases} \tag{17}$$

We compare the equilibrium profits under uniform pricing and under price discrimination, using Lemma (1) and equation (17), and we have the following result.

Proposition 1: *Price discrimination based on consumers' preferences results into higher profits than uniform pricing if the heterogeneity in consumers' preferences is not too large compared to the heterogeneity in their switching costs.*

Proof: See the Appendix.

The intuition behind Proposition (1) is as follows. When $t < \sigma$, firms set prices equal to σ under uniform pricing. Under price discrimination, firms target consumers aggressively based on their preferences. However, the competition is softened by the presence of switching costs of the consumers, which is unobserved by the firms. The larger the value of σ, the more is the competition softening effect. In the case of $t < \sigma$, the net effect of switching cost and increased competition due to price discrimination is positive, over the uniform pricing profits. Hence, the price discrimination boosts profits relative to uniform pricing. When $\sigma \leq t \leq 3\sigma/2$, firms set prices equal to t now under uniform pricing. The net effect of switching cost and competition is outweighed by the gain of the firms under uniform pricing when t becomes sufficiently larger than σ, i.e., $t > 1.04\sigma$, and price discrimination becomes unprofitable. For even higher values of t ($t > 3\sigma/2$), discriminating firms set zero prices to some consumers due to increased competition, which results into even lower profits. Therefore, price discrimination results into higher profits if the consumers are not too heterogeneous in their preferences compared to their switching costs.

That is, unlike one-dimensional heterogeneity, where price discrimination necessarily intensifies competition, the presence of another dimension (switching cost in this case) may be profitable under price discrimination if it is unobserved by the firms.

4 Conclusion

In this paper, we analyze the profitability of behavior-based price discrimination in a simple duopoly model with switching costs. We show that when firms price discriminate based on consumers' preferences, and remain unaware of the switching costs of the consumers, price discrimination may boost profits compared to uniform pricing. This happens when the heterogeneity in consumers' preferences is not too large compared to that in switching costs. The presence of switching cost softens the competition intensifying effect of price discrimination.

This result has important managerial implications. In industries which are characterized by idiosyncratic consumer relationship, such as service industries, or if the learning costs of switching are significantly high for some consumers (Shy and Stenbacka, 2016), it is profitable for the firms to engage in price discrimination based on consumers' preferences, regardless of what the rival firms do.

It is important to note here that we have considered a fairly simple model to clearly illustrate the central point of the paper. It seems interesting to extend the analysis when firms' information about consumers' preferences is not perfect a la Colombo (2016) and Shrivastav et al. (2021). Further, it is also worthwhile to analyze asymmetric consumer recognition (Colombo, 2016). We leave these issues for future research.

References

Bounie, D., Dubus, A., and Waelbroeck, P. (2021). Selling strategic information in digital competitive markets. *The RAND Journal of Economics*, 52(2):283–313.

Colombo, S. (2016). Imperfect behavior-based price discrimination. *Journal of Economics & Management Strategy*, 25(3):563–583.

Esteves, R.-B. (2009). Price discrimination with partial information: Does it pay off? *Economics Letters*, 105(1):28–31.

Esteves, R. B. et al. (2009). A survey on the economics of behaviour-based price discrimination. Technical report, NIPE-Universidade do Minho.

Fudenberg, D. and Tirole, J. (2000). Pricing a network good to deter entry. *Journal of Industrial Economics*, 48(4):373–90.

Fudenberg, D. and Villas-Boas, J. M. (2006). Behavior-based price discrimination and customer recognition. *Handbook on economics and information systems*, 1:377–436.

Hannak, A., Soeller, G., Lazer, D., Mislove, A., and Wilson, C. (2014). Measuring price discrimination and steering on e-commerce web sites. In *Proceedings of the 2014 conference on internet measurement conference*, pages 305–318.

Iordanou, C., Soriente, C., Sirivianos, M., and Laoutaris, N. (2017). Who is fiddling with prices? building and deploying a watchdog service for e-commerce. In *Proceedings of the Conference of the ACM Special Interest Group on Data Communication*, pages 376–389.

Mahmood, A. (2014). How do customer characteristics impact behavior-based price discrimination? an experimental investigation. *Journal of Strategic Marketing*, 22(6):530–547.

Mikians, J., Gyarmati, L., Erramilli, V., and Laoutaris, N. (2012). Detecting price and search discrimination on the internet. In *Proceedings of the 11th ACM workshop on hot topics in networks*, pages 79–84.

Pazgal, A. and Soberman, D. (2008). Behavior-based discrimination: Is it a winning play, and if so, when? *Marketing Science*, 27(6):977–994.

Shaffer, G. and Zhang, Z. J. (2000). Pay to switch or pay to stay: preference-based price discrimination in markets with switching costs. *Journal of Economics & Management Strategy*, 9(3):397–424.

Shrivastav, S. et al. (2021). Price discrimination with imperfect consumer recognition. Technical report, Indira Gandhi Institute of Development Research, Mumbai, India.

Shy, O. and Stenbacka, R. (2011). Customer recognition and competition. Technical report, Working Papers.

Shy, O. and Stenbacka, R. (2013). Investment in customer recognition and information exchange. *Information Economics and Policy*, 25(2):92–106.

Shy, O. and Stenbacka, R. (2016). Customer privacy and competition. *Journal of Economics & Management Strategy*, 25(3):539–562.

Tabuchi, T. (1994). Two-stage two-dimensional spatial competition between two firms. *Regional Science and Urban Economics*, 24(2):207–227.

Villas-Boas, J. M. (1999). Dynamic competition with customer recognition. *The Rand Journal of Economics*, pages 604–631.

Appendix

Equilibrium Prices under Price Discrimination when $3\sigma < 2t$

For observed value of θ, the demand functions of firms A and B can be written as

$$D_A(p_A(\theta), p_B(\theta); \theta) = \begin{cases} 0 & \text{if} \ \ p_A(\theta) \geq p_B(\theta) + \sigma - t(2\theta - 1) \\ 1 - s_A(\theta) & \text{if} \ \ p_B(\theta) - t(2\theta - 1) \leq p_A(\theta) < p_B(\theta) + \sigma - t(2\theta - 1) \\ 1 + s_B(\theta) & \text{if} \ \ p_B(\theta) - \sigma - t(2\theta - 1) \leq p_A(\theta) < p_B(\theta) - t(2\theta - 1) \\ 2 & \text{if} \ \ p_A(\theta) < p_B(\theta) - \sigma - t(2\theta - 1) \end{cases}$$

$$D_B(p_A(\theta), p_B(\theta); \theta) = \begin{cases} 0 & \text{if} \ \ p_B(\theta) \geq p_A(\theta) + \sigma - t(1 - 2\theta) \\ 1 - s_A(\theta) & \text{if} \ \ p_A(\theta) - t(1 - 2\theta) \leq p_B(\theta) < p_A(\theta) + \sigma - t(1 - 2\theta) \\ 1 + s_B(\theta) & \text{if} \ \ p_A(\theta) - \sigma - t(1 - 2\theta) \leq p_B(\theta) < p_A(\theta) - t(1 - 2\theta) \\ 2 & \text{if} \ \ p_B(\theta) < p_A(\theta) - \sigma - t(1 - 2\theta) \end{cases}$$

For $\underline{\theta} \leq \theta \leq \overline{\theta}$, we have equilibrium prices as in the Sub-section 3.2 as

$$p_A(\theta) = \sigma - \frac{t(2\theta - 1)}{3}, \ \ p_B(\theta) = \sigma + \frac{t(2\theta - 1)}{3}$$

where $\underline{\theta} = \frac{1}{2} - \frac{3\sigma}{2t}$ and $\overline{\theta} = \frac{1}{2} + \frac{3\sigma}{2t}$.

For $\theta \in (\overline{\theta}, 1]$, the demand of firm A for observed value of θ is 0. Therefore, firm A sets $p_A(\theta) = 0$. This implies that the maximum price the firm B can charge, satisfies the condition $p_B(\theta) + \sigma - t(2\theta - 1) = 0$.

Therefore, $p_B(\theta) = t(2\theta - 1) - \sigma$ for $\theta \in (\overline{\theta}, 1]$.

For $\theta \in (\underline{\theta}, 1]$, the demand of firm B for observed value of θ is 0. Therefore, firm B sets $p_B(\theta) = 0$. This implies that the maximum price the firm A can charge, satisfies the condition $p_A(\theta) + \sigma - t(1 - 2\theta) = 0$.

Therefore, $p_A(\theta) = t(1 - 2\theta) - \sigma$ for $\theta \in [0, \underline{\theta})$. Combining all the cases above, we get Lemma (2). [QED]

Proof of Proposition 1

First, consider the case $t < \sigma$. Then the equilibrium profits under uniform pricing and price discrimination, respectively, are as follows.

$$\pi_i^U = \sigma, \quad \pi_i^D = \sigma + \frac{t^2}{27\sigma}$$

It is easily observed that $\pi_i^D > \pi_i^U$, as $t,\ \sigma > 0$.

Next, consider the case $\sigma \leq t \leq \frac{3\sigma}{2}$. In this case, equilibrium profits are

$$\pi_i^U = t, \quad \pi_i^D = \sigma + \frac{t^2}{27\sigma}$$

It can be easily checked that $\pi_i^D > \pi_i^U$, when $\sigma \leq t < \frac{27-3\sqrt{69}}{2}\ \sigma \approx 1.04\ \sigma$

Next, consider the case when $t > \frac{3\sigma}{2}$. Then, the equilibrium profits are

$$\pi_i^U = t, \quad \pi_i^D = \frac{t}{2} - \sigma - \frac{3\sigma^2}{2t}$$

It is easily observed that $\pi_i^U > \pi_i^D$. Therefore, price discrimination results into higher profits than uniform pricing when $t \leq 1.04\ \sigma$. [QED]