



Quality choice and behavior-based price discrimination

Hoe Sang Chung¹

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Abstract

This study examines the impacts of behavior-based price discrimination (BBPD) on profits, consumer surplus, and welfare when firms choose their product qualities. To this end, we consider a differentiated duopoly model in which firms first make quality decisions, and in the two subsequent periods, compete in prices according to the pricing scheme, namely, uniform pricing or BBPD. We show that when consumers are more than moderately forward-looking, firms choose lower quality levels under BBPD than under uniform pricing. The profit and consumer surplus effects of BBPD relative to uniform pricing depend on the level of consumers' myopia and/or quality improvement costs. When consumers are sufficiently myopic or quality costs are high, BBPD reduces industry profits and raises consumer surplus. However, the reverse happens when consumers are sufficiently forward-looking and quality costs are low. Interestingly, BBPD is detrimental to both firms and consumers when consumers are sufficiently forward-looking and quality costs are moderate, or when consumers are moderately forward-looking and quality costs are low. Social welfare is always lower under BBPD than under uniform pricing.

Keywords Behavior-based price discrimination · Consumer myopia · Quality costs

JEL classification: D43 · L13

1 Introduction

Owing to the development of more sophisticated techniques for acquiring, storing, and analyzing information on the customers' past shopping behavior, firms can offer different prices to their own customers and those who purchased from rivals before.

✉ Hoe Sang Chung
hschung@kangwon.ac.kr

¹ Department of Economics, Kangwon National University, Chuncheon-si, Republic of Korea

This form of price discrimination, termed behavior-based price discrimination (BBPD), is now widely used in many industries such as web retailing, supermarkets, air travel, telecommunication, restaurants, electricity, gas, banking, and insurance.

There are two approaches to the analysis of BBPD. In the switching cost approach, the consumers' past purchases reveal information about their switching costs (e.g., Chen 1997). In the brand preference approach, the consumers' past purchases reveal information about their brand preferences (e.g., Fudenberg and Tirole 2000).¹ Studies employing this latter approach investigate BBPD within various frameworks. For example, Chen and Percy (2010) investigate BBPD with the dependence of consumers' intertemporal preferences, Esteves (2014) studies BBPD when firms use retention strategies to avoid consumer switching, and Esteves and Reggiani (2014) explore the pricing scheme by relaxing the perfectly inelastic demand assumption. Chung (2016) studies BBPD with experience goods, Carroni (2016) studies BBPD with asymmetric firms, and Carroni (2018) studies BBPD with cross-group externalities. Moreover, Colombo (2016a, 2016b, 2018), examine BBPD when firms have incomplete information about the consumers' purchase histories, when firms differentiate their products, and when firms retain additional information about the price sensitivity of their own consumers, respectively.

This study extends the investigation of BBPD to a situation where firms choose their product qualities. To this end, we consider a differentiated duopoly model in which firms first make quality decisions, and in the two subsequent periods, compete in prices according to the pricing scheme, namely, uniform pricing or BBPD. We assume that quality investment is a longer-run decision than price choice, since it usually involves technological decisions. The papers closest to ours are De Nijs (2013) and Esteves and Cerqueira (2017), which analyze BBPD with informative advertising. The former is based on a homogeneous product duopoly model with an initial stage of advertising investment followed by two periods of price competition, and the latter builds on a horizontally differentiated market where firms make their advertising and first-period price decisions simultaneously. In addition, Ikeda and Toshimitsu (2010) examine the welfare effects of monopolistic third-degree price discrimination with quality choice. Thus, our study not only contributes to the BBPD literature by developing a differentiated duopoly model with sequential quality and price decisions, but also enriches the understanding of how price discrimination affects quality by considering a competitive environment.

Our analysis offers policy implications for markets where BBPD raises antitrust concerns, and quality competition prevails. For example, in South Korea, according to the Mobile Device Distribution Improvement Act, telecommunication companies actively investing in R&D are not permitted to price discriminate between their own and rivals' customers.²

We show that when consumers are more than moderately forward-looking, the firms choose lower quality levels under BBPD than under uniform pricing. This is because if consumers somewhat take into account discounted second-period prices

¹ BBPD is also analyzed in static settings where information used to segment consumers is exogenously given (e.g., Gehrig et al. 2012).

² See Gehrig et al. (2011) for European antitrust cases concerned with BBPD.

under BBPD, they are less responsive to quality changes in the first period. The profit and consumer surplus effects of BBPD relative to uniform pricing depend on the level of consumers' myopia and/or quality improvement costs. When consumers are sufficiently myopic or quality costs are high, BBPD reduces industry profits and raises consumer surplus, which is consistent with the common finding in the BBPD literature. Conversely, when consumers care enough about the future and quality costs are low, BBPD benefits the firms and harms consumers, since the positive (negative) effect of BBPD on profits (consumer surplus) due to lower quality levels dominates its negative (positive) effect due to fiercer second-period price competition. Furthermore, both the firms and consumers are worse off under BBPD when consumers are sufficiently forward-looking and quality costs are moderate, or when consumers are moderately forward-looking and quality costs are low. This result has not been noted in the literature. The impact of BBPD on social welfare is negative regardless of the level of consumers' myopia and quality costs. For competition policy, our analysis suggests that it is important to consider the discount factor of consumers and the quality improvement technology of firms when evaluating the profit and consumer surplus effects of BBPD.

The remainder of this paper is as follows. Section 2 constructs the model, and Sect. 3 examines the effects of BBPD on the firms' quality levels and profits. In Sect. 4, we discuss consumer surplus and welfare implications of BBPD. Section 5 summarizes the conclusions.

2 The model

Two firms, A and B , produce a (nondurable) differentiated product at zero marginal cost. The brands produced by A and B are located at $l_A = 0$ and $l_B = 1$, respectively, of an interval $[0, 1]$ representing the product characteristic space. There are three periods: 0, 1, and 2. In period 0, each firm $i \in \{A, B\}$ chooses a quality level $q_i \geq 0$. We assume that the cost of achieving a quality level q_i is $F(q_i) = \frac{\xi}{2}q_i^2$. The cost of quality improvement is treated as a fixed cost that has no influence on the variable cost of production.³ R&D and advertising expenditures are examples of such quality feature. In the subsequent periods 1 and 2, the firms compete in prices according to the pricing scheme, namely, uniform pricing or BBPD.

On the demand side, a continuum of consumers is uniformly distributed on the interval with a unit mass. The location of a consumer on the interval represents his/her most preferred brand. In each of periods 1 and 2, each consumer buys at most one unit of the product from either firm A or B and is willing to pay v . We assume that v is sufficiently large so that all consumers purchase in equilibrium. Each consumer's brand preference remains constant over the two periods of consumption. The per-period utility of a consumer located at $x \in [0, 1]$ buying firm i 's product of

³ Unlike Ikeda and Toshimitsu (2010), which considers the fixed costs of quality, Nguyen (2014) considers the variable costs of quality and obtains results opposite to those of Ikeda and Toshimitsu (2010). In this regard, it would be interesting to see how introducing variable costs of quality affects results that we will present below.

quality q_i at price p_i is $v + q_i - t|x - l_i| - p_i$, where $t > 0$ measures the disutility (per unit of distance) from buying a less preferred brand.⁴

Consumers discount their future utility at a rate $\delta \in [0, 1]$, whereas the firms do not discount the future.⁵ We say consumers are sufficiently forward-looking, moderately forward-looking, and sufficiently myopic when δ is high, intermediate, and low, respectively. We also make the following assumption on the cost parameter to ensure that the second-order and stability conditions are satisfied.

Assumption 1 $c > \underline{c} \equiv \frac{2(2+\delta)(11+6\delta+3\delta^2)}{t(7+9\delta)^2} \in [\frac{15}{32t}, \frac{44}{49t}]$.

To summarize, the timing of the game is as follows. In period 0, firms A and B simultaneously choose the quality levels q_A and q_B , respectively. In period 1, there are no purchase histories of consumers; thus, each firm $i \in \{A, B\}$ charges the same price, p_{1i} , to all consumers. In period 2, each firm i can engage in BBPD by offering \hat{p}_{2i} to its own past consumers and \tilde{p}_{2i} to those who purchased from the rival in period 1. If BBPD is not used (e.g., if it is not permitted), each firm i again charges a single price to all consumers.⁶

3 Analysis

To derive the subgame perfect equilibrium, the game is solved by backward induction as usual. Let the superscript U (D) identify the uniform pricing (BBPD) case.

3.1 Uniform pricing

Before proceeding to the BBPD analysis, we consider the benchmark case where there is no BBPD in period 2, either because it is not permitted or because the firms cannot identify whether consumers bought their products in period 1. In this case, there is no link between periods 1 and 2 so that the two-period price competition model reduces to two replications of the static model. We use this benchmark case to evaluate the effects of BBPD.

Consider first the firms' price competition, taking their quality levels as given. When the firms employ uniform pricing, firm $i \in \{A, B\}$ charges the same price, p_i , to all consumers in each of periods 1 and 2. Let \hat{x} denote a consumer who is indifferent between buying from firm A and from firm B . This consumer is determined from $v + q_A - t\hat{x} - p_A = v + q_B - t(1 - \hat{x}) - p_B$. That is,

$$\hat{x} = \frac{p_B - p_A + t + \Delta q}{2t},$$

⁴ The marginal utility of quality is normalized to 1.

⁵ This assumption is based on two arguments (Carroni 2018). First, consumers generally discount future consumption utility at greater rates than are earned on capital. Second, it allows to isolate the effects of consumers' discount factor on quality and first-period price competition under BBPD.

⁶ Our model can be seen as an extension of Fudenberg and Tirole (2000) with the firms' quality choice considered in Economides (1989).

where $\Delta q \equiv q_A - q_B$.

For given quality levels, firm A chooses p_A to maximize $\pi_A = p_A \hat{x}$, and firm B chooses p_B to maximize $\pi_B = p_B(1 - \hat{x})$. The first-order conditions yield the following equilibrium prices

$$p_A^U = \frac{3t + \Delta q}{3} \text{ and } p_B^U = \frac{3t - \Delta q}{3}.$$

Plugging the equilibrium prices into π_A and π_B , we get the per-period profits of the firms as

$$\pi_A^U = \frac{1}{2t} \left(\frac{3t + \Delta q}{3} \right)^2 \text{ and } \pi_B^U = \frac{1}{2t} \left(\frac{3t - \Delta q}{3} \right)^2.$$

Next, consider the firms' quality choice. The profit maximization problems of firms A and B in period 0 are respectively

$$\max_{q_A} \Pi_A = \pi_A^U + \pi_A^U - F(q_A), \tag{1}$$

$$\max_{q_B} \Pi_B = \pi_B^U + \pi_B^U - F(q_B). \tag{2}$$

Solving for the equilibrium yields the following result.⁷

Lemma 1 *Suppose that both firms employ uniform pricing. In a symmetric subgame perfect equilibrium,*

- (i) *each firm chooses a quality level of*

$$q_A^U = q_B^U = \frac{2}{3c}; \tag{3}$$

- (ii) *each firm's price for the two periods of consumption is*

$$p_A^U = p_B^U = t. \tag{4}$$

- (iii) *Each firm earns an overall profit equal to*

$$\Pi_A^U = \Pi_B^U = t - \frac{2}{9c}. \tag{5}$$

Proof See the Appendix. □

3.2 BBPD with quality choice

Now assume that BBPD is feasible. We first investigate the firms' second-period price competition, taking their quality levels and first-period prices as given. Suppose that after period 1, the market is divided at $x_1 \in [0, 1]$ such that all consumers with $x \in [0, x_1]$ ($x \in (x_1, 1]$) bought from firm A (firm B) in period 1.

⁷ When the firms compete in prices only once, this result reduces to Theorem 2 of Economides (1989).

When the firms engage in price discrimination based on purchase history, firm $i \in \{A, B\}$ charges \hat{p}_{2i} and \tilde{p}_{2i} to its own consumers and to the rival's previous consumers in period 2, respectively. Let x_{2A} (x_{2B}) denote a consumer who bought from firm A (firm B) in period 1 and is now indifferent between buying again from firm A (firm B) and switching to firm B (firm A). This consumer is determined from $v + q_A - tx_{2A} - \hat{p}_{2A} = v + q_B - t(1 - x_{2A}) - \tilde{p}_{2B}$ ($v + q_A - tx_{2B} - \tilde{p}_{2A} = v + q_B - t(1 - x_{2B}) - \hat{p}_{2B}$). That is,

$$x_{2A} = \frac{\tilde{p}_{2B} - \hat{p}_{2A} + t + \Delta q}{2t} \text{ and } x_{2B} = \frac{\hat{p}_{2B} - \tilde{p}_{2A} + t + \Delta q}{2t}.$$

For given quality levels and first-period prices, firm A chooses \hat{p}_{2A} and \tilde{p}_{2A} to maximize $\pi_{2A} = \hat{p}_{2A}x_{2A} + \tilde{p}_{2A}(x_{2B} - x_1)$, and firm B chooses \hat{p}_{2B} and \tilde{p}_{2B} to maximize $\pi_{2B} = \hat{p}_{2B}(1 - x_{2B}) + \tilde{p}_{2B}(x_1 - x_{2A})$. The first-order conditions yield the second-period equilibrium prices as follows.

$$\hat{p}_{2A}^D = \frac{t + 2tx_1 + \Delta q}{3} \text{ and } \tilde{p}_{2A}^D = \frac{3t - 4tx_1 + \Delta q}{3}, \tag{6}$$

$$\hat{p}_{2B}^D = \frac{3t - 2tx_1 - \Delta q}{3} \text{ and } \tilde{p}_{2B}^D = \frac{-t + 4tx_1 - \Delta q}{3}. \tag{7}$$

Plugging (6) and (7) into π_{2A} and π_{2B} , we get the firms' second-period profits as

$$\begin{aligned} \pi_{2A}^D &= \frac{1}{2t} \left(\frac{t + 2tx_1 + \Delta q}{3} \right)^2 + \frac{1}{2t} \left(\frac{3t - 4tx_1 + \Delta q}{3} \right)^2, \\ \pi_{2B}^D &= \frac{1}{2t} \left(\frac{3t - 2tx_1 - \Delta q}{3} \right)^2 + \frac{1}{2t} \left(\frac{-t + 4tx_1 - \Delta q}{3} \right)^2. \end{aligned}$$

Next, we consider the first-period pricing and consumption decisions. In the case of poaching in period 2, the consumer located at x_1 must be indifferent between buying from firm A in period 1 and then buying from firm B in period 2, or buying from firm B in period 1 and then buying from firm A in period 2. This consumer is defined by $v + q_A - tx_1 - p_{1A} + \delta[v + q_B - t(1 - x_1) - \tilde{p}_{2B}^D] = v + q_B - t(1 - x_1) - p_{1B} + \delta[v + q_A - tx_1 - \hat{p}_{2A}^D]$. Solving with respect to x_1 , we get

$$x_1 = \frac{1}{2} + \frac{3(p_{1B} - p_{1A}) + (3 - \delta)\Delta q}{2t(3 + \delta)}. \tag{8}$$

For given quality levels, firm A chooses p_{1A} to maximize $\pi_A = p_{1A}x_1 + \pi_{2A}^D$, and firm B chooses p_{1B} to maximize $\pi_B = p_{1B}(1 - x_1) + \pi_{2B}^D$. From the first-order conditions, we get the first-period equilibrium prices as⁸

$$p_{1A}^D = \frac{t(3 + \delta)}{3} + \frac{(1 + 4\delta - \delta^2)\Delta q}{7 + 9\delta}, \tag{9}$$

⁸ It is straightforward to see that the second-order conditions are also satisfied.

$$p_{1B}^D = \frac{t(3 + \delta)}{3} - \frac{(1 + 4\delta - \delta^2)\Delta q}{7 + 9\delta}. \tag{10}$$

Finally, we turn to the firms' quality choice. The profit maximization problems of firms *A* and *B* in period 0 can be expressed as

$$\max_{q_A} \Pi_A = p_{1A}^D x_1^* + \pi_{2A}^D - F(q_A), \tag{11}$$

$$\max_{q_B} \Pi_B = p_{1B}^D (1 - x_1^*) + \pi_{2B}^D - F(q_B), \tag{12}$$

where $x_1^* = \frac{1}{2} + \frac{(5-3\delta)\Delta q}{2t(7+9\delta)}$, which is obtained by plugging (9) and (10) into (8). Solving for the equilibrium yields the following result.

Lemma 2 *Suppose that both firms engage in BBPD. In a symmetric subgame perfect equilibrium,*

(i) *each firm chooses a quality level of*

$$q_A^D = q_B^D = \frac{(1 + \delta)(16 - 3\delta)}{3c(7 + 9\delta)}; \tag{13}$$

(ii) *each firm's first- and second-period prices are*

$$p_{1A}^D = p_{1B}^D = \frac{t(3 + \delta)}{3}, \tag{14}$$

$$\hat{p}_{2A}^D = \hat{p}_{2B}^D = \frac{2t}{3}, \tag{15}$$

$$\tilde{p}_{2A}^D = \tilde{p}_{2B}^D = \frac{t}{3}. \tag{16}$$

(iii) *Each firm earns an overall profit equal to*

$$\Pi_A^D = \Pi_B^D = \frac{t(14 + 3\delta)}{18} - \frac{(1 + \delta)^2(16 - 3\delta)^2}{18c(7 + 9\delta)^2}. \tag{17}$$

Proof See the Appendix. □

As δ increases, the equilibrium level of quality decreases and the first-period equilibrium price increases. This is because the first-period demand is less sensitive to quality and price changes as consumers take into account discounted second-period prices. Note also that quality improvements increase the utility of consumers in a symmetric way, and the equilibrium prices are not affected by the quality levels.

Thus, the equilibrium profits are lower than the case where there is no quality choice ($c \rightarrow \infty$).⁹ Quality improvements are a mere cost for the firms.¹⁰

Compared to the uniform pricing scheme, the firms set higher prices in period 1 ($p_{1i}^D \geq p_{1i}^U$) and lower prices in period 2 ($\tilde{p}_{2i}^D < \tilde{p}_{2i}^D < p_{2i}^U$). In period 2, each firm poaches its competitor’s former consumers by charging them a lower price ($\tilde{p}_{2i}^D < \tilde{p}_{2i}^D$). Both firms equally share the market in period 1, i.e., $x_1^* = \frac{1}{2}$. The market allocation in period 2 is described by $x_{2A}^* = \frac{1}{3}$ and $x_{2B}^* = \frac{2}{3}$. That is, consumers with $x \in [0, \frac{1}{3})$ ($x \in [\frac{2}{3}, 1]$) remain loyal to firm A (B), whereas those with $x \in [\frac{1}{3}, \frac{1}{2})$ ($x \in [\frac{1}{2}, \frac{2}{3})$) switch to firm B (A).

By comparing (3) and (13), we have that $q_i^U - q_i^D = \frac{(\delta+2)(3\delta-1)}{3c(7+9\delta)} \geq (\leq) 0$ if $\delta \geq (\leq) \frac{1}{3}$. Thus,

Proposition 1 *Compared to uniform pricing, BBPD leads to lower quality levels if consumers are more than moderately forward-looking. Otherwise, it is quality-increasing.*

The intuition is the following. There are two forces at work here: on the one hand, the firms have incentives to invest in quality to increase the first-period demand (demand effect); on the other hand, they have incentives to reduce quality to mitigate price competition in the first period (strategic effect). Under BBPD, if consumers somewhat take into account lowered second-period prices, they are less responsive to quality changes in the first period. Thus, the demand effect is weaker than under uniform pricing, resulting in softened quality competition.¹¹ However, if consumers are sufficiently myopic, the demand effect is stronger, thus making quality competition fiercer than under uniform pricing. The result of Proposition 1 is in line with that of Colombo (2016b) who shows that BBPD induces higher (lower) firms’ differentiation than uniform pricing when consumers are sufficiently forward-looking (myopic). In addition, the quality difference between uniform pricing and BBPD gets smaller (larger) as quality improvements become more (less) costly.

Using (5) and (17), the difference in each firm’s overall profits under BBPD and uniform pricing is computed as

$$\Pi_i^D - \Pi_i^U = \frac{t(3\delta - 4)}{18} - \frac{(\delta + 2)(3\delta - 1)(3\delta^2 - 31\delta - 30)}{18c(9\delta + 7)^2},$$

and we have that when $\delta > 0.732949$, $\Pi_i^D > (<) \Pi_i^U$ if $c < (>) c_1 \equiv \frac{(\delta+2)(3\delta-1)(3\delta^2-31\delta-30)}{t(3\delta-4)(9\delta+7)^2}$, and when $\delta \leq 0.732949$, $\Pi_i^D < \Pi_i^U$. Thus,

⁹ When $c \rightarrow \infty$, we replicate the results of Fudenberg and Tirole (2000).

¹⁰ The firms are caught in a prisoners’ dilemma type of situation where at equilibrium, they invest equally in quality, which leaves market shares and gross profits unchanged but reduces net profits by quality costs. Note then that the firms choose a quality level lower than the socially optimal level.

¹¹ In the same vein, Esteves and Cerqueira (2017) show that adopting BBPD leads firms to strategically reduce their advertising efforts.

Proposition 2 *Compared to uniform pricing, BBPD boosts the firms' overall profits if consumers are sufficiently forward-looking and the cost of quality improvement is low enough. Otherwise, it is detrimental to the firms.*

Unless consumers are sufficiently forward-looking ($\delta \leq 0.732949$), BBPD intensifies quality and first-period price competition, and thus reduces profits with respect to uniform pricing. When consumers care enough about the future ($\delta > 0.732949$), the profit effects of BBPD also depend on quality costs. The quality difference between uniform pricing and BBPD depends negatively on quality costs. Thus, if quality costs are low (high), i.e., $c < (>) c_1$, the positive effect of BBPD on profits due to lower quality levels dominates (is dominated by) its negative effect due to intensified price competition, making BBPD more (less) profitable than uniform pricing.

4 Welfare

This section provides the welfare consequences of BBPD with quality choice. Social welfare is defined as the sum of industry profits and consumer surplus. Under each pricing scheme, consumer surplus and social welfare are calculated in the following two lemmas.

Lemma 3 *Under uniform pricing, overall consumer surplus and welfare are respectively given by*

$$CS^U = v(1 + \delta) - \frac{5t(1 + \delta)}{4} + \frac{2(1 + \delta)}{3c}, \quad (18)$$

$$W^U = v(1 + \delta) + \frac{t(3 - 5\delta)}{4} + \frac{2(1 + 3\delta)}{9c}. \quad (19)$$

Proof See the Appendix. \square

Lemma 4 *Under BBPD, overall consumer surplus and welfare are respectively given by*

$$CS^D = v(1 + \delta) - \frac{t(45 + 43\delta)}{36} + \frac{(1 + \delta)^2(16 - 3\delta)}{3c(7 + 9\delta)}, \quad (20)$$

$$W^D = v(1 + \delta) + \frac{t(11 - 31\delta)}{36} + \frac{5(1 + \delta)^2(1 + 6\delta)(16 - 3\delta)}{9c(7 + 9\delta)^2}. \quad (21)$$

Proof See the Appendix. \square

Subtracting (18) from (20) yields

$$CS^D - CS^U = \frac{t\delta}{18} + \frac{6(1+\delta)(2+\delta)(1-3\delta)}{18c(7+9\delta)},$$

and we have that when $\delta > 0.373141$, $CS^D < (>) CS^U$ if $c < (>) c_2 \equiv \frac{6(\delta+1)(\delta+2)(3\delta-1)}{t\delta(7+9\delta)}$, and when $\delta \leq 0.373141$, $CS^D > CS^U$. Hence,

Proposition 3 *BBPD reduces consumer surplus compared to uniform pricing if consumers are more than moderately forward-looking and the cost of quality improvement is low enough. Otherwise, it is beneficial to consumers.*

When consumers are more than moderately forward-looking ($\delta > 0.373141$), BBPD has two opposing effects on consumer surplus. On the one hand, it hurts consumers by lowering the quality levels (as shown in Proposition 1); on the other hand, it benefits them by lowering the second-period prices compared to uniform pricing. When quality costs are low ($c < c_2$), the negative impact of BBPD on consumer surplus outweighs its positive impact, since the quality difference between the two pricing schemes is large. However, the opposite occurs when quality costs are high ($c > c_2$), making consumer surplus higher than under uniform pricing. When consumers are sufficiently myopic ($\delta \leq 0.373141$), they are better off under BBPD as the pricing scheme intensifies quality and first-period price competition.

From Propositions 2 and 3, we can establish the effects of BBPD on profits and consumer surplus as follows.

Corollary 1 *In comparison to uniform pricing,*

- (i) *when $\delta \in [0, 0.373141]$, BBPD reduces industry profits and raises consumer surplus;*
- (ii) *when $\delta \in (0.373141, 0.732949]$, BBPD reduces industry profits and raises (reduces) consumer surplus if $c > (<) c_2$;*
- (iii) *when $\delta \in (0.732949, 1]$, BBPD raises industry profits and reduces consumer surplus if $c < c_1$; BBPD reduces both industry profits and consumer surplus if $c_1 < c < c_2$; BBPD reduces industry profits and raises consumer surplus if $c > c_2$.*

Corollary 1 shows that consumers' myopia and quality costs play a key role in determining the profit and consumer surplus effects of BBPD relative to uniform pricing. When consumers discount much the future or quality costs are high, our results are consistent with the common finding in the literature that BBPD harms firms and benefits consumers. However, BBPD boosts industry profits at the expense of consumer surplus when consumers care enough about the future and quality costs are low. In the context of advertising choice, De Nijs (2013) and Esteves and Cerqueira (2017) also obtain this opposite result. The differences with our study are that it happens in the former when advertising costs are high, and in the latter regardless of the advertising cost. What is interesting is that BBPD does not cause a distributional conflict between firms and consumers when consumers are sufficiently forward-looking and quality costs are moderate, or when consumers are

moderately forward-looking and quality costs are low. In this case, both the firms and consumers are worse off under BBPD. To our knowledge, this result has not been noticed before and supports a policy of banning BBPD without hurting both firms and consumers. Corollary 1 has an immediate policy implication. If a competition authority takes care of the impacts of BBPD on profits and consumer surplus, it needs to consider the discount factor of consumers and the quality improvement technology of firms.

Finally, we look at the effects of BBPD on social welfare. Subtracting (21) from (19) yields

$$W^U - W^D = \frac{t(8 - 7\delta)}{18} + \frac{(2 + \delta)(9 + 10\delta)(1 - 3\delta)^2}{9c(7 + 9\delta)^2} > 0.$$

Therefore,

Proposition 4 *Regardless of the level of consumers' myopia and quality costs, social welfare is lower under BBPD compared to uniform pricing.*

5 Conclusions

In this study, we investigate the effects of BBPD on profits, consumer surplus, and welfare when the firms choose their product qualities before competing in prices. In comparison to uniform pricing, when consumers are more than moderately forward-looking, BBPD leads the firms to strategically reduce their quality levels to soften price competition in the first period. The profit and consumer surplus effects of BBPD relative to uniform pricing depend on the level of consumers' myopia and/or quality improvement costs. When consumers are sufficiently myopic or quality costs are high, our results are consistent with the usual finding in the literature that BBPD is detrimental to firms and beneficial to consumers. However, the reverse happens when consumers are sufficiently forward-looking and quality costs are low, since the positive (negative) effect of BBPD on profits (consumer surplus) due to lower quality levels dominates its negative (positive) effect due to fiercer second-period price competition. In particular, BBPD reduces both industry profits and consumer surplus when consumers are sufficiently forward-looking and quality costs are moderate, or when consumers are moderately forward-looking and quality costs are low. This result, which has not been shown before, supports a policy of banning BBPD without hurting both firms and consumers. Social welfare is always lower under BBPD than under uniform pricing.

Our study suggests that a competition authority needs to consider the discount factor of consumers and the quality improvement technology of firms when evaluating the effects of (banning) BBPD on profits and consumer surplus.

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Appendix

Proof of Lemma 1 In the problems (1) and (2), the overall profits of firms A and B are respectively

$$\Pi_A = \frac{1}{t} \left(\frac{3t + \Delta q}{3} \right)^2 - \frac{c}{2} q_A^2 \text{ and } \Pi_B = \frac{1}{t} \left(\frac{3t - \Delta q}{3} \right)^2 - \frac{c}{2} q_B^2.$$

From $\frac{\partial \Pi_i}{\partial q_i} = 0$, we have the firms' best-response functions as follows.

$$q_A = \frac{6t - 2q_B}{9tc - 2} \text{ and } q_B = \frac{6t - 2q_A}{9tc - 2}.$$

Solving the system of the best-response functions, we get (3). It immediately leads to (4) and (5). □

Proof of Lemma 2 In the problems (11) and (12), the overall profits of firms A and B are respectively computed as

$$\begin{aligned} \Pi_A &= \frac{t(14 + 3\delta)}{18} + \frac{(2 + \delta)(11 + 6\delta + 3\delta^2)\Delta q^2}{2t(7 + 9\delta)^2} + \frac{(1 + \delta)(16 - 3\delta)\Delta q}{3(7 + 9\delta)} - \frac{c}{2} q_A^2, \\ \Pi_B &= \frac{t(14 + 3\delta)}{18} + \frac{(2 + \delta)(11 + 6\delta + 3\delta^2)\Delta q^2}{2t(7 + 9\delta)^2} - \frac{(1 + \delta)(16 - 3\delta)\Delta q}{3(7 + 9\delta)} - \frac{c}{2} q_B^2. \end{aligned}$$

From $\frac{\partial \Pi_i}{\partial q_i} = 0$, we have the firms' best-response functions as follows.

$$\begin{aligned} q_A &= \frac{t(1 + \delta)(7 + 9\delta)(16 - 3\delta) - 3(2 + \delta)(11 + 6\delta + 3\delta^2)q_B}{3[49tc - 22 + \delta(126tc - 23) + 3\delta^2(27tc - 4) - 3\delta^3]}, \\ q_B &= \frac{t(1 + \delta)(7 + 9\delta)(16 - 3\delta) - 3(2 + \delta)(11 + 6\delta + 3\delta^2)q_A}{3[49tc - 22 + \delta(126tc - 23) + 3\delta^2(27tc - 4) - 3\delta^3]}. \end{aligned}$$

Note that by Assumption 1, the best-response functions are downward sloping, and firm A's best-response function is steeper than firm B's best-response function. Thus, the firms' qualities are strategic substitutes and the equilibrium is stable. The second-order conditions are also satisfied. Solving the system of the best-response functions, we obtain (13). It immediately leads to (14) and $x_1^* = \frac{1}{2}$. From (13) and $x_1^* = \frac{1}{2}$, it is straightforward to show (15) and (16). (17) follows immediately. □

Proof of Lemma 3 Under uniform pricing, overall consumer surplus is calculated as

$$\begin{aligned} CS^U &= (1 + \delta) \left[\int_0^{x^*} (v + q_A^U - tx - p_A^U) dx + \int_{x^*}^1 (v + q_B^U - t(1 - x) - p_B^U) dx \right] \\ &= v(1 + \delta) - \frac{5t(1 + \delta)}{4} + \frac{2(1 + \delta)}{3c}. \end{aligned}$$

As industry profits are

$$\Pi^U = \Pi_A^U + \Pi_B^U = 2t - \frac{4}{9c},$$

social welfare under uniform pricing is

$$W^U = \Pi^U + CS^U = v(1 + \delta) + \frac{t(3 - 5\delta)}{4} + \frac{2(1 + 3\delta)}{9c}.$$

□

Proof of Lemma 4 Overall consumer surplus under BBPD is calculated as

$$\begin{aligned} CS^D &= \int_0^{x_1^*} (v + q_A^D - tx - p_{1A}^D) dx + \int_{x_1^*}^1 (v + q_B^D - t(1-x) - p_{1B}^D) dx \\ &+ \delta \left[\int_0^{x_{2A}^*} (v + q_A^D - tx - \tilde{p}_{2A}^D) dx + \int_{x_{2A}^*}^{x_1^*} (v + q_B^D - t(1-x) - \tilde{p}_{2B}^D) dx \right] \\ &+ \delta \left[\int_{x_1^*}^{x_{2B}^*} (v + q_A^D - tx - \tilde{p}_{2A}^D) dx + \int_{x_{2B}^*}^1 (v + q_B^D - t(1-x) - \tilde{p}_{2B}^D) dx \right] \\ &= v(1 + \delta) - \frac{t(45 + 43\delta)}{36} + \frac{(1 + \delta)^2(16 - 3\delta)}{3c(7 + 9\delta)}. \end{aligned}$$

As industry profits are

$$\Pi^D = \Pi_A^D + \Pi_B^D = \frac{t(14 + 3\delta)}{9} - \frac{(1 + \delta)^2(16 - 3\delta)^2}{9c(7 + 9\delta)^2},$$

social welfare under BBPD is

$$W^D = \Pi^D + CS^D = v(1 + \delta) + \frac{t(11 - 31\delta)}{36} + \frac{5(1 + \delta)^2(1 + 6\delta)(16 - 3\delta)}{9c(7 + 9\delta)^2}.$$

□

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