Behavior-Based Quality Discrimination

Krista J. Li

Assistant Professor of Marketing
Kelley School of Business
Indiana University
1309 East Tenth Street
Hodge Hall 2115
Bloomington, IN 47405
(812) 856-0823
kjli@indiana.edu

Abstract

New technology enables firms to recognize customers from their purchase histories and then provide different quality levels of product features or services for repeat and new customers. Extant research has examined behavior-based price discrimination (BBP), that is, how firms set different prices for repeat and new customers. This research extends the literature by investigating behavior-based quality discrimination to reveal the unique effects of quality discrimination beyond the effects of BBP. Using a two-period game-theoretic model, we find that firms reward repeat customers on the quality dimension by offering them higher-quality product features or services than what new customers receive. Such quality discrimination dissuades competitive poaching, softens second-period price competition, and increases second-period profits. Meanwhile, firms reward new customers on the price dimension by offering them a lower price than what repeat customers pay. Therefore, firms should reward different types of customers with the right attribute (i.e., product features or services versus price). In addition, quality discrimination increases customer retention in the second period. Anticipating this outcome, forward-looking firms reduce first-period prices to compete aggressively for initial customers. This effect intensifies first-period competition and reduces first-period profits. Overall, behavior-based quality discrimination decreases firms' total profits but increases consumer surplus and social welfare.

Keywords: behavior-based pricing, customer recognition, game theory, OM-marketing interface

1 Introduction

Information technology such as customer-relationship management systems, Internet cookies, or online logins have given firms an unprecedented ability to track customers' purchase histories. From purchase history data, firms can recognize repeat customers who purchased from them before and new customers. This information enables firms to undertake behavior-based targeting by offering different product features, services, and prices to repeat and new customers based on their purchase histories.

Extant research on behavior-based targeting has examined firms' behavior-based pricing (BBP) decisions, that is, how firms offer different prices for repeat and new customers. Research shows that firms reward new customers with lower prices than what repeat customers pay. For example, the phone service provider Verizon offers up to $650 for customers to switch from another carrier (Welch 2015). The television service provider Dish guarantees $250 savings to customers who switch (Dish 2015). These switching discounts essentially lower the prices that new customers pay, while repeat customers do not receive these price rewards.

Other than setting prices, firms invest heavily in R&D to develop various innovative product features (Comcast 2014). For example, Verizon has invested approximately $17 billion in the 5G network to improve the speed and connectivity of its broadband Internet coverage and to create new applications and experiences for customers (Verizon 2019, Rossolillo 2019). AT&T (2016) invested nearly $10 billion in 2016 to enhance its innovative platform and features such as Network on Demand, Internet of Things (IoT), and AT&T NetBond. The cost of R&D can be considered a fixed cost that does not vary with the number of users of these features. Even when firms incur a variable cost to provide these product features to customers, they incur a fixed cost for R&D in product innovation and infrastructure construction.

With a selection of product features or services, firms can target repeat and new customers with not only different prices but also different sets of product features or services that offer different quality levels or values. For example, television service providers offer new product features such as Voice Remote, steam APP, high-dimensional channels, and advanced search with personalized recommendations for customers. These features provide additional value and higher-quality experiences to customers. It is feasible that television service providers carry out behavior-based quality discrimination by offering bundles of product features that have different quality levels to repeat and new customers. Similarly, phone service providers such as Verizon can also use behavior-based quality discrimination by rewarding either repeat or new customers with enhanced product features or services such as unlimited shared data plans and mobile protection plans.

Despite the feasibility of behavior-based quality discrimination, it is unclear how firms should provide product features or services with different quality levels for repeat and new customers. In this paper, we fill this research gap and extend the BBP literature by examining behavior-based quality discrimination, that is, how firms offer not only different prices but also product features or services with different quality levels to repeat and new customers. In doing so, we aim to understand the unique effects of behavior-based quality discrimination beyond the effects of BBP and the fundamental difference between these two types of behavior-based targeting. Specifically, we address the following research questions: (1) How do firms offer product features or services with different quality levels for repeat and new customers? Should firms reward repeat or new customers on the quality dimension by offering them higher-quality product features or services than what the other type of customers receive? (2) How do firms offer different prices to repeat and new customers when they use behavior-based quality discrimination? Should firms reward repeat or new customers on the price dimension by offering them a price discount? (3) What is the fundamental difference between quality discrimination and price discrimination? Should firms reward the same type of customers with both higher quality and lower prices, or should they reward different types of customers with different attributes? (4) How does quality discrimination affect firms' competition in the later period when firms differentiate quality and prices and in the earlier period when they acquire initial customers and collect their purchase history data? and (5) How does quality discrimination affect firm profits, consumer surplus, and social welfare?

To address these questions, we build a two-period game-theoretic model with two symmetric and differentiated firms that sell a repeatedly purchased product or service. The firms compete with each other by making quality and pricing decisions. Consumers prefer higher-quality product features or services but also have heterogeneous intrinsic preferences for the two firms. In the first period, consumers' intrinsic preferences are private information, which can be partially revealed by their purchase decisions in this period. Firms set prices to compete for customers in the first period. At the beginning of the second period, firms observe customers' purchase histories to determine whether they purchased from them or the competitor previously. With this information, firms can provide different second-period quality and prices for their repeat and new customers.

The literature has established three effects of BBP (Fudenberg and Villas-Boas 2006). First, firms reward new customers with lower prices than what repeat customers pay. This is because a purchase from a firm in the last period reveals that the customer has a higher preference for the firm's product than the competitor's product. Thus, the firm can exploit the revealed preference by charging this customer a higher price than what it charges new customers who purchased from the competitor last time. To attract new customers, firms need to offer them a discount to lure them to switch firms. Second, the BBP literature indicates that the practice of BBP intensifies the second-period price competition. This is because although it is profitable for one firm to poach its competitor's customers, when firms poach each other's customers, competition intensifies and their profit declines. Third, the BBP literature has also established that when consumers are forward looking, they understand that if they purchase from a firm at a higher price in the first period, the purchase history data reveal that they have a stronger preference for the firm's product, which leads the competing firm to poach them with a higher discount in the second period. Anticipating a better deal, consumers become less price sensitive in the first period. This strategic consumer behavior allows firms to raise prices in the first period when they collect consumers' purchase history data.

Our analysis reveals several important findings about quality discrimination over and above these effects of BBP. First, our results show that firms provide higher-quality product features or services for repeat customers than for new customers. In other words, firms reward repeat customers on the quality dimension to encourage them to stay. Our results also indicate that when firms differentiate quality, they still reward new customers on the price dimension by offering them lower prices than what repeat customers pay. This finding implies that managers should reward different types of customers with the right attribute (i.e., quality or price).

The reason firms reward repeat customers on the quality dimension is that *such quality discrimination makes it more difficult for the competitor to poach these customers, thus dissuading competitive poaching and softening second-period price competition.* Note that firms make quality decisions before making pricing decisions. This sequence of decisions also reflects that prices are short-term decisions that are easier to adjust than investment in quality. By offering higher-quality product features or services to repeat customers than to new customers, firms force their competitor to reduce prices when poaching their customers. As a result, poaching each other's customers becomes more costly and less profitable for firms. As competitive poaching decreases, price competition becomes softer. Firms can better retain their existing customers and extract higher surplus from them. As a result, profits in the second period increase. Thus, quality discrimination is a *coordination device* that firms use to mitigate competitive poaching and soften price competition. This finding also underscores the difference and connection between behavior-based quality discrimination and price discrimination: *firms use behavior-based price discrimination to poach each other's customers, which intensifies competition, whereas firms use behavior-based quality discrimination to soften price competition associated with price discrimination and competitive poaching.* As a result, firms' profits in the second period increase with quality discrimination.

Second, we also find that quality discrimination intensifies price competition in the first period, when firms acquire initial customers and collect purchase history data. This is because with quality discrimination, by offering repeat customers higher-quality product features or services than what new customers receive, firms can better retain repeat customers in the second period. Anticipating this effect, firms cut prices in the first period to compete aggressively for initial customers, because customers are more likely to stay with them to enjoy the higher-quality product features or services in the second period. Thus, firms' profits in the first period decrease with quality discrimination.

Third, although quality discrimination increases second-period profits, the increase is offset by the decrease in the first-period profits. Firms' total profits over two periods decline with quality discrimination. Our analysis shows that firms have incentives to unilaterally differentiate quality. When both firms differentiate quality, they make lower profits than when they do not differentiate quality. Therefore, quality discrimination is a prisoner's dilemma. In addition, quality discrimination improves consumer surplus by allowing consumers to buy first-period products at lower prices. Quality discrimination also increases social welfare by leading more customers to stay with their preferred firms.

This research makes several theoretical contributions. First, it contributes to the BBP literature by revealing the unique effects of quality discrimination beyond the effects of BBP. Our results on how firms set discriminatory quality levels for repeat and new customers and how quality discrimination affects second- and first-period prices and profits are new insights to the BBP literature. Second, this research illustrates the different mechanisms of behavior-based quality discrimination and price discrimination. The mechanisms that firms use quality discrimination to soften second-period price competition by dissuading competitive poaching and that they reduce prices in the first period to compete for initial customers in anticipation of increased repeat purchase due to quality discrimination are new to the BBP literature. Third, this research provides a theoretical framework that shows how firms customize multiple attributes (i.e, quality and price) on the basis of consumers' purchase history data. We show that firms penalize repeat purchase on the price dimension and reward repeat purchase on the quality dimension. From managers' perspectives, the results highlight the importance of rewarding different types of customers with the right attribute (quality or price). Specifically, firms should reward repeat customers with higher-quality product features or services and reward new customers with lower prices. Managers should also understand that customer retention will increase with quality discrimination. Therefore, they need to reduce first-period prices to acquire customers and build up their customer base.

1.1 Related Literature

This article is closely related to the economics and marketing literature on BBP (see Fudenberg and Villas-Boas 2006 for a comprehensive review). Research has investigated how firms set discriminatory prices for repeat and new customers. In a typical BBP framework, firms reward new customers by offering them a switching discount. In other words, firms pay customers to switch (Chen 1997). Researchers have extended the BBP model to show conditions under which firms may reward repeat customers by offering them a lower price than what new customers pay. Firms may reward repeat customers (on the price dimension) if their customers face lower switching costs (Shaffer and Zhang 2000), customers have heterogeneous demand and changing preferences (Shin and Sudhir 2010), or customers sufficiently discount the future and firms are vertically differentiated (Rhee and Thomadsen 2016). The current study extends this research stream by investigating whether and how firms reward new and repeat customers when they can differentiate both quality and prices.

Other research has examined firms' dynamic price discrimination on the basis of other types of customer information. Chen and Iyer (2002) find that firms invest in customer addressability, in which they know the locations of some customers in the database and offer individualized prices accordingly. They also show that firms may choose not to include all customers in their database to soften price competition. In Shin et al.'s (2012) study, firms differentiate prices on the basis of the cost to serve customers. In a monopoly setting, they show that firms may sometimes fire some profitable customers and that cost-based pricing can be profitable. In a competitive setting, Subramanian et al. (2014) show that firms may retain unprofitable customers who are costly to serve to deter poaching by the competitor.

These studies all focus on firms' pricing decisions when firms can access customers' information. Although new technology enables firms to tailor the quality of product features or services according to consumers' purchase histories, scant research has examined how firms make behavior-based quality discrimination decisions. One important work in this area is the study by Zhang (2011), who examines how symmetric and horizontally differentiated firms differentiate products' horizontal attributes on the basis of consumers' purchase histories. That study reveals that behavior-based personalization reduces design differentiation and intensifies price competition between firms. Our research supplements this study by investigating how firms differentiate vertical attributes (i.e., quality) on the basis of consumers' purchase histories. In contrast with that work, which shows the perils of behavior-based personalization in both periods, our results suggest that behavior-based quality discrimination allows firms to reduce competitive poaching and soften price competition in the second period.

Other researchers have extended the BBP framework by allowing firms to provide enhanced benefits to repeat customers. For example, Acquisti and Varian (2005) assess firms that provide higher benefits to repeat customers and show that a monopolist should not price-discriminate between high-value and low-value customers even when it is feasible to do so. Pazgal and Soberman (2008) allow differentiated firms to choose whether to use BBP when they can add benefits to repeat customers. They show that, in general, BBP leads to lower profits for firms with identical ability to add benefits to repeat customers. However, the firm with an advantage in adding benefits can attain higher profits than it can without BBP. Our research is different from Pazgal and Soberman (2008) in two important aspects: First, Pazgal and Soberman (2008) assume that firms provide enhanced quality to repeat customers. When firms also use BBP, they charge a lower price to new customers. This research assumes away the possibility that firms provide higher quality to new customers than to repeat customers and that firms charge new customers a higher price than what repeat customers pay. By contrast, we allow for these possibilities by endogenizing firms' quality and pricing decisions and allowing firms to reward either repeat or new customers on quality and pricing dimensions. Second, Pazgal and Soberman (2008) focus on whether firms adopt BBP or not when they reward repeat customers with enhanced quality. However, it is unclear why firms reward repeat customers instead of new customers with enhanced quality and why firms charge repeat customers a higher price than what new customers pay. We seek to understand how and why firms reward repeat customers with enhanced quality but at the same time penalize them with higher prices. Our analysis and mechanism provide new insights into the fundamental difference between quality discrimination and price discrimination.

Lastly, our research relates to the steam of literature on loyalty programs. Loyalty programs are structured marketing efforts which reward repeat purchase and loyal behavior (Sharp and Sharp 1997). Research has examined various forms of loyalty programs and their impact on competition, profits, and repeat purchase. For example, Kim et al. (2001) show that cash rewards are inefficient as they have higher unit cost than offering a free product. Zhang et al. (2000) assess the profitability of front-loaded and rear-loaded incentives. They find that front-loaded incentives are generally more profitable than rear-loaded incentives. However, consumers' variety-seeking behavior can make rear-loaded incentives more profitable. Roehm et al. (2002) find that cue-compatible incentives can increase favorable brand association and postprogram loyalty. By contrast, tangible or concrete incentives undermine postprogram loyalty. Singh et al. (2008) use a game-theoretical model to examine the type of loyalty programs that provide benefit to loyal customers in the form of discount over market prices. They find conditions under which both symmetric and asymmetric equilibrium can be sustained. Wang et al. (2016) used a field experiment to assess the impact of goal achievement loyalty program on guests' purchase at a hotel chain. They found that guests who reached the goal significantly increased post-promotion purchase than those who failed to reach the goal. The behavior-based quality discrimination that we study in this paper relates to the loyalty program in that firms reward repeat customers with a higher quality level than new customers. We show that this format of reward in quality instead of price is an endogenous firm decision. Firms choose to reward repeat purchase with a higher quality to soften competitive poaching and price competition.

2 Model

We consider a duopoly setting in which firms A and B sell a repeatedly purchased product or service with base value v to consumers over two periods. We assume that the value of v is sufficiently high so that all consumers make a purchase and the market is fully covered in each period.

A firm can improve customers' utility by incurring a fixed cost for R&D and product innovation to provide higher-quality product features or services. We assume that the cost of providing quality is a quadratic function of the quality improvement to ensure that profits are a concave function of quality. Specifically, in the first period, the cost for firm i to provide product features or services with quality level q_{i1} is $C(q_{i1}) = q_{i1}^2$. In the second period, if the firm provides standardized quality to all customers, the cost of further improving the quality to level q_{i2} is $C(q_{i2}) = (q_{i2} - q_{i1})^2$, where $q_{i2} - q_{i1}$ is the magnitude of quality improvement. This assumption reflects that product or service quality does not reinitialize to zero at the beginning of the first period. In Section 4.1, we show that our main results continue to hold even if the second-period quality reinitializes to zero or the first-period quality level is standardized to zero. If firms differentiate quality in the second period, q_{io} and q_{in} denote firm i's quality for repeat and new customers, respectively. The cost of providing quality to the segment of repeat customers is $\gamma(q_{io} - q_{i1})^2$ and the cost of providing quality to the segment of new customers is $\gamma(q_{in} - q_{i1})^2$, where $\gamma > 0$ indicates the cost efficiency of quality discrimination to serve a segment of customers. A higher value of γ indicates that quality discrimination is more costly. Thus, the total cost of quality discrimination in the second period is $\gamma\,[(q_{io} - q_{i1})^2 + (q_{in} - q_{i1})^2]$.[1] We assume that firms incur the same marginal cost to serve customers, and we standardize the marginal cost to zero. In Section 4.1, we allow the firms to incur a marginal cost of quality provision and show that our main results are robust to this specification.

All consumers enter the market at the beginning of the first period and stay for two periods. Each consumer has single-unit demand in each period, prefers higher quality, and has different intrinsic preferences for the two firms. We capture the intrinsic preferences by assuming that consumers are uniformly distributed on a Hotelling line that ranges from 0 to 1. Firm A is located at 0, and firm B is located at 1. The location of a consumer on the line represents his or her taste. A consumer incurs a mismatch disutility when he or she consumes a product that is not ideal. The mismatch disutility is captured by the distance from the customer's location to the firm's location. Let q_{ij} denote the quality of product features or services that firm $i \in \{a, b\}$ provides in period j and p_{ij} denote firm i's price in period j. For a consumer located at θ, the utility from consuming firm A's product is $v - \theta + q_{aj} - p_{aj}$, and the utility from consuming firm B's product is $v - (1 - \theta) + q_{bj} - p_{bj}$.

The game unfolds as follows: There are two periods, and each period comprises three stages. In the first period, because no prior information is available for firms to discriminate among customers, each firm provides the same level of quality at the same price to all customers. Firms first simultaneously set the quality level (denoted by q_{a1} and q_{b1}) of their first-period quality and then simultaneously set the first-period prices (denoted by p_{a1} and p_{b1}). The sequence of firms' quality and pricing decisions indicates that prices are easier to adjust than quality levels. Customers observe the quality levels and prices and decide which product to buy.

A customer's purchase decision in the first period partially reveals his or her intrinsic preference. If firms store customers' purchase history data, they can use these data to differentiate quality and prices in the second period. In this case, firms first simultaneously set quality levels, where q_{ao} and q_{bo} denote the levels of firm A's and firm B's quality for

[1] Our model allows for the corner solution that $q^*_{an} = q^*_{a1}$, that is, firms only improve quality for repeat customers in the second period. Our analysis shows that it is optimal for firms to improve quality for both repeat and new customers in the second period.

own repeat customers and q_{an} and q_{bn} denote the quality levels for new customers. Then, firms simultaneously set prices, where p_{ao} and p_{bo} denote the prices firm A and firm B charge their own repeat customers and p_{an} and p_{bn} denote the prices they charge new customers. Customers observe the quality levels and prices that firms offer to them from their first-period purchase record and decide whether to stay with the original firm or switch to the competing firm. For analytical simplicity, we standardize firms' and consumers' discounting factors to 1. We will relax this assumption to examine the impact of firm and consumer patience in Section 4.2.

3 Analysis

Before analyzing the main model with BBP and quality discrimination, we first analyze the benchmark model in which firms use BBP but do not differentiate quality based on purchase histories. The difference between these two models is whether firms differentiate quality. Comparison of the equilibrium outcomes of these models reveals the unique effects of quality discrimination.[2]

3.1 Benchmark Model: Without Quality Discrimination

The Second Period. When firms use BBP, they charge repeat and new customers different prices in the second period although they provide them the same quality. Figure 1 depicts the consumption pattern. Let θ_a indicate the location of the marginal customer who is indifferent between staying with firm A and switching to firm B. Then, we have

$$v - \theta_a + q_{a2} - p_{ao} = v - (1 - \theta_a) + q_{b2} - p_{bn}, \tag{1}$$

$$\theta_a = \frac{1}{2} + \frac{q_{a2} - q_{b2}}{2} - \frac{p_{ao} - p_{bn}}{2}. \tag{2}$$

The left-hand side of Equation (1) is the utility of staying with firm A to receive quality q_{a2} at the repeat-customer price p_{ao}. The right-hand side is the utility of switching to firm B to receive quality q_{b2} at the new-customer price p_{bn}. Similarly, the marginal customer at θ_b is

[2]For completeness, we also analyze a benchmark model in which firms do not target customers with BBP or quality discrimination. We compare the two benchmark models to replicate the effects of BBP (for detailed analysis, see Section A1 of the Appendix).

indifferent between switching to firm A and staying with firm B. We therefore write

$$v - \theta_b + q_{a2} - p_{an} = v - (1 - \theta_b) + q_{b2} - p_{bo}, \quad (3)$$

$$\theta_b = \frac{1}{2} + \frac{q_{a2} - q_{b2}}{2} - \frac{p_{an} - p_{bo}}{2}. \quad (4)$$

Firms' profit functions in the second period are

$$\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - (q_{a2} - q_{a1})^2, \quad (5)$$

$$\Pi_{b2} = p_{bo}(1 - \theta_b) + p_{bn}(\theta_1 - \theta_a) - (q_{b2} - q_{b1})^2. \quad (6)$$

We obtain second-period prices and quality levels using first-order conditions; second-order conditions are also satisfied. Prices are $p^*_{an} = \frac{3-4\theta_1}{3} + \frac{q_{a2}-q_{b2}}{3}$, $p^*_{ao} = \frac{1+2\theta_1}{3} + \frac{q_{a2}-q_{b2}}{3}$, $p^*_{bn} = \frac{4\theta_1-1}{3} + \frac{q_{b2}-q_{a2}}{3}$, and $p^*_{bo} = \frac{3-2\theta_1}{3} + \frac{q_{b2}-q_{a2}}{3}$. Quality levels are $q^*_{a2} = \frac{5}{21} - \frac{\theta_1}{7} + \frac{8q_{a1}-q_{b1}}{7}$ and $q^*_{b2} = \frac{2}{21} + \frac{\theta_1}{7} + \frac{8q_{b1}-q_{a1}}{7}$.

The First Period. The marginal customer at θ_1 makes a trade-off between buying from firm A and firm B in the first period. Anticipating switching firms in the second period, this customer takes the anticipated second-period utilities into account. We have

$$v - \theta_1 + q_{a1} - p_{a1} + [v - (1 - \theta_1) + q^{e*}_{b2} - p^{e*}_{bn}] = v - (1 - \theta_1) + q_{b1} - p_{b1} + [v - \theta_1 + q^{e*}_{a2} - p^{e*}_{an}], \quad (7)$$

where the superscript $e*$ indicates customers' expectations of the second-period quality and prices. Assuming rational expectations, we insert the second-period equilibrium quality and prices into Equation (7) and obtain

$$\theta_1 = \frac{1}{2} + \frac{2(q_{a1} - q_{b1})}{9} + \frac{7(p_{b1} - p_{a1})}{18}. \quad (8)$$

The total profits that firms maximize in the first period are

$$\Pi_{at} = p_{a1}\theta_1 + \Pi^*_{a2} - q^2_{a1}, \quad (9)$$

$$\Pi_{bt} = p_{b1}(1 - \theta_1) + \Pi^*_{b2} - q^2_{b1}. \quad (10)$$

We solve for the first-period equilibrium prices and obtain $p^*_{a1} = \frac{4}{3} + \frac{8(q_{a1}-q_{b1})}{25}$ and $p^*_{b1} = \frac{4}{3} + \frac{8(q_{b1}-q_{a1})}{25}$. The first-period equilibrium quality levels are $q^*_{a1} = q^*_{b1} = \frac{19}{75}$. We summarize the rest of the equilibrium outcomes in Table 1.

Next, we analyze the main model with quality discrimination. By comparing the main model with the benchmark model, we aim to understand how quality discrimination affects the equilibrium.

3.2 Main Model: With Quality Discrimination

Now, consider the case in which firms use consumers' purchase history data recorded from the first period to differentiate both quality and prices in the second period. Figure 2 depicts the consumption pattern.

The Second Period. The marginal customer at θ_a is indifferent between staying with firm A and switching to firm B. We can write

$$v - \theta_a + q_{ao} - p_{ao} = v - (1 - \theta_a) + q_{bn} - p_{bn}, \tag{11}$$
$$\theta_a = \frac{1}{2} + \frac{q_{ao} - q_{bn}}{2} - \frac{p_{ao} - p_{bn}}{2}. \tag{12}$$

The left-hand side of Equation (11) is the utility of buying from firm A as a repeat customer. In this case, the customer receives firm A's differentiated quality for repeat customers, where the quality is q_{ao} and price is p_{ao}. The right-hand side is the utility of switching to firm B. In this case, the customer receives firm B's differentiated quality for new customers, where the quality is q_{bn} and price is p_{bn}. Similarly, the marginal customer at θ_b is indifferent between switching to firm A and staying with firm B. We can write

$$v - \theta_b + q_{an} - p_{an} = v - (1 - \theta_b) + q_{bo} - p_{bo}, \tag{13}$$
$$\theta_b = \frac{1}{2} + \frac{q_{an} - q_{bo}}{2} - \frac{p_{an} - p_{bo}}{2}. \tag{14}$$

The left-hand side of Equation (13) is the utility of switching to firm A, and the right-hand side is the utility of staying with firm B. Then, firms' profit functions in the second period are

$$\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - \gamma\left[(q_{ao} - q_{a1})^2 + (q_{an} - q_{a1})^2\right], \tag{15}$$
$$\Pi_{b2} = p_{bo}(1 - \theta_b) + p_{bn}(\theta_1 - \theta_a) - \gamma\left[(q_{bo} - q_{b1})^2 + (q_{bn} - q_{b1})^2\right]. \tag{16}$$

We solve for second-period prices and obtain $p^*_{ao} = \frac{q_{ao}-q_{bn}}{3} + \frac{2\theta_1}{3} + \frac{1}{3}$, $p^*_{an} = \frac{q_{an}-q_{bo}}{3} - \frac{4\theta_1}{3} + 1$, $p^*_{bo} = \frac{q_{bo}-q_{an}}{3} - \frac{2\theta_1}{3} + 1$, and $p^*_{bn} = \frac{q_{bn}-q_{ao}}{3} + \frac{4\theta_1}{3} - \frac{1}{3}$. Then, we solve for the second-period quality and obtain $q^*_{ao} = \frac{54\gamma^2 q_{a1} - 3\gamma(q_{a1}+q_{b1}) + 6\gamma\theta_1 + 3\gamma - \theta_1}{6\gamma(9\gamma-1)}$, $q^*_{an} = \frac{54\gamma^2 q_{a1} - 3\gamma(q_{a1}+q_{b1}) - 12\gamma\theta_1 + 9\gamma + \theta_1 - 1}{6\gamma(9\gamma-1)}$, $q^*_{bo} = \frac{54\gamma^2 q_{b1} - 3\gamma(q_{a1}+q_{b1}) - 6\gamma\theta_1 + 9\gamma + \theta_1 - 1}{6\gamma(9\gamma-1)}$, and $q^*_{bn} = \frac{54\gamma^2 q_{b1} - 3\gamma(q_{a1}+q_{b1}) + 12\gamma\theta_1 - 3\gamma - \theta_1}{6\gamma(9\gamma-1)}$.

The First Period. In the first period, each firm provides the same quality level of product features or services to all customers at the same price. The marginal customer at θ_1 is indifferent between buying from firm A and firm B in the first period after taking second-period utilities into account. Thus, we have

$$v - \theta_1 + q_{a1} - p_{a1} + [v - (1-\theta_1) + q_{bn}^{e*} - p_{bn}^{e*}] = v - (1-\theta_1) + q_{b1} - p_{b1} + [v - \theta_1 + q_{an}^{e*} - p_{an}^{e*}] . \quad (17)$$

The left-hand side of Equation (17) is the total utility of buying from firm A in the first period and switching to firm B in the second period. The right-hand side is the total utility of buying from firm B in the first period and switching to firm A in the second period. Superscript $e*$ indicates consumers' expectations of the second-period quality and prices for new customers. Assuming rational expectations, we plug the second-period equilibrium quality and prices into Equation (17) and obtain

$$\theta_1 = \frac{1}{2} - \frac{3\gamma(9\gamma-1)(p_{a1}-p_{b1})}{(12\gamma-1)(6\gamma-1)} + \frac{3\gamma(q_{a1}-q_{b1})}{12\gamma-1}. \quad (18)$$

Firms set first-period prices to maximize total profits over two periods. The profit functions are

$$\Pi_{at} = p_{a1}\theta_1 + \Pi_{a2}^* - q_{a1}^2, \quad (19)$$

$$\Pi_{bt} = p_{b1}(1-\theta_1) + \Pi_{b2}^* - q_{b1}^2. \quad (20)$$

We solve for first-period prices using first-order conditions and obtain:

$$\begin{aligned} p_{a1}^* &= \frac{(6\gamma-1)\left[31104\gamma^4 - 17928\gamma^3 + 3330\gamma^2 - 255\gamma + 7 + (5832\gamma^4 - 2268\gamma^3 + 288\gamma^2 - 12\gamma)(q_{a1}-q_{b1})\right]}{6\gamma(23328\gamma^4 - 14094\gamma^3 + 2817\gamma^2 - 234\gamma + 7)} \\ p_{b1}^* &= \frac{(6\gamma-1)\left[31104\gamma^4 - 17928\gamma^3 + 3330\gamma^2 - 255\gamma + 7 - (5832\gamma^4 - 2268\gamma^3 + 288\gamma^2 - 12\gamma)(q_{a1}-q_{b1})\right]}{6\gamma(23328\gamma^4 - 14094\gamma^3 + 2817\gamma^2 - 234\gamma + 7)} \end{aligned} \quad (21)$$

Using first-order conditions with respect to quality, we obtain:

$$q_{a1}^* = q_{b1}^* = \frac{4212\gamma^3 - 2124\gamma^2 + 279\gamma - 11}{6(2592\gamma^3 - 1278\gamma^2 + 171\gamma - 7)} \quad (22)$$

The second-order conditions are satisfied for $\gamma > \frac{1}{3}$, i.e., providing quality to a segment of customers is not too cost efficient than providing quality to all customers. We focus our analysis on this region of parameter. We illustrate the equilibrium outcomes in Table 1. Let us understand how firms differentiate quality levels and prices for repeat and new customers and the resulting implications on profits in the second period.

Proposition 1 ***(The Second Period)***

a. Firms provide higher-quality product features or services to repeat customers than to new customers.

b. Firms charge new customers a lower price than the price they charge repeat customers.

c. Firms' second-period profits increase with quality discrimination.

The BBP literature shows that in a typical BBP setting, firms reward new customers by offering them lower prices than what repeat customers pay. This is because new customers have lower preferences for the firm's product and buy from the competitor in the first period. At the same time, firms penalize repeat customers by charging them higher prices than what new customers pay, because repeat customers have stronger preferences for the firm's product than the competitor's product. Proposition 1 suggests that when firms differentiate quality, they *reward repeat customers on the quality dimension* by offering them higher-quality product features or services than what new customers receive. We also find that when firms reward repeat customers with higher-quality product features or services, they *reward new customers on the price dimension* by offering them a discounted price (see Table 1).

This result is interesting for two reasons. First, it lends new insights to the BBP literature into whether and how to reward repeat and new customers. Specifically, this result suggests that managers should reward repeat and new customers with different attributes; that is, firms should reward new customers with lower prices and reward repeat customers with a higher quality. Second, this result reveals the (supply-side) difference between quality discrimination and price discrimination. Consumers' utility from consumption can be simplified as quality minus price (i.e., $q - p$). From the demand side, quality and prices are perfect substitutes. An increase in price (p) has the same effect on consumers' utility function as a decrease in quality (q). Discriminating quality and prices could affect consumers' purchase decisions the same way. Consequently, rewarding new customers on the price dimension seems to suggest that firms should also reward new customers on the quality dimension. Because new customers have lower preferences for the firm's product, we may expect the firm to offer higher-quality product features or services to lure the competitor's customers to switch firms. However, our result shows that the opposite is true; firms offer higher-quality product features or services to encourage repeat customers to stay.

Let us understand the difference between quality discrimination and price discrimination. Given that two firms are symmetric, we can understand the intuition from firm A's perspective in terms of the difference between quality and price provision for repeat customers. The same intuition drives the difference between quality and price provision for new customers. For repeat customers, firms can reward them by reducing prices or increasing quality. If firm A reduces prices, the marginal increase in second-period profit is

$$-\frac{\partial \Pi_{a2}^*}{\partial p_{ao}} \quad = \quad -p_{ao}\frac{\partial \theta_a}{\partial p_{ao}} - \theta_a = \frac{p_{ao}}{2} - \theta_a. \tag{23}$$

Note that firms set prices after observing their competitor's quality. If firm A increases quality for repeat customers, it needs to take firm B's equilibrium pricing decisions into account. Using the envelope theorem, we can write the marginal impact of an increase in the quality for repeat customer as

$$\frac{\partial \Pi_{a2}^*}{\partial q_{ao}} \quad = \quad \frac{\partial \Pi_{a2}}{\partial q_{ao}} + \frac{\partial \Pi_{a2}}{\partial p_{bn}}\frac{\partial p_{bn}^*}{\partial q_{ao}} = p_{ao}^*\frac{\partial \theta_a}{\partial p_{ao}} - 2\gamma(q_{ao} - q_{a1}) + \frac{p_{ao}^*}{2} \cdot \left(-\frac{1}{3}\right), \tag{24}$$

$$= \quad \frac{p_{ao}^*}{2} - 2\gamma(q_{ao} - q_{a1}) - \frac{p_{ao}^*}{6} = \frac{p_{ao}^*}{3} - 2\gamma(q_{ao} - q_{a1}). \tag{25}$$

Comparing Equation (23) with Equation (25), we find similarities and differences between discounting prices and improving quality. If prices are held constant, improving quality shifts demand (i.e., θ_a) by $\frac{1}{2}$, the same as the marginal effect of discounting prices. In other words, the partial effect of increasing quality on demand is the same as the effect of decreasing prices. This is because from a consumer's perspective, the consumption utility is $q - p$. An increase in q is equivalent to a decrease in p. Both changes affect the customer's utility by the same degree, leading to the same degree of changes in demand. However, from the supply side, increasing quality differs from decreasing prices in two ways. First, increasing quality is costly; the marginal cost of increasing quality for repeat customers is $(q_{ao} - q_{a1})$ in Equation (25). However, firms incur the same marginal cost for improving quality for new customers (i.e., $q_{an} - q_{a1}$). Therefore, cost consideration does not explain why firms provide higher-quality product features or services for repeat customers than for new customers. The second difference between improving quality and discounting prices is that firms make quality decisions before setting prices, because prices are short-term decisions that are easier to adjust than investment in quality. Increasing quality makes it more costly for the competitor to poach the focal firm's customers. If firm A increases its quality, firm B must cut prices to attract A's customers (i.e., $\frac{\partial p^*_{bn}}{\partial q_{ao}} < 0$).

Similarly, firms can also increase quality for new customers, which makes it more costly for the competitor to retain its repeat customers (i.e., $\frac{\partial p^*_{bo}}{\partial q_{an}} < 0$), thereby encouraging firms to poach each other's customers. Firms offer higher-quality product features or services to repeat customers than to new customers, because by doing so, firms make it more appealing for customers to stay with their original firms and more costly for firms to poach each other's customers. As competitive poaching declines, competition becomes softer, and firms' profits in the second period increase from the level without quality discrimination. Therefore, this result of quality discrimination is driven by supply-side considerations. Firms use quality discrimination as a *coordination device* to attenuate competitive poaching associated with price discrimination. This intuition also reflects the difference between quality discrimination and price discrimination; that is, *firms use price discrimination to poach each other's customers, which intensifies competition, while they use quality discrimination to alleviate competitive poaching and soften price competition.*

Mathematically, this intuition is reflected in the finding that firms obtain a higher marginal return on investment (ROI) by improving quality for repeat customers rather than for new customers. To show this, when we account for equilibrium prices, firm A's ROI in quality for repeat and new customers is

$$\frac{\partial \Pi^*_{a2}}{\partial q_{ao}} = \theta^*_a \frac{\partial p^*_{ao}}{\partial q_{ao}} + p^*_{ao}\left(\frac{\partial \theta_a}{\partial q_{ao}} + \frac{\partial \theta_a}{\partial p_{ao}}\frac{\partial p^*_{ao}}{\partial q_{ao}} + \frac{\partial \theta_a}{\partial p_{bn}}\frac{\partial p^*_{bn}}{\partial q_{ao}}\right) - 2\gamma(q_{ao} - q_{a1}), \tag{26}$$

$$= \frac{\theta^*_a}{3} + \frac{p^*_{ao}}{6} - 2\gamma(q_{ao} - q_{a1}). \tag{27}$$

$$\frac{\partial \Pi^*_{a2}}{\partial q_{an}} = (\theta^*_b - \theta^*_1)\frac{\partial p^*_{an}}{\partial q_{an}} + p^*_{an}\left(\frac{\partial \theta_b}{\partial q_{an}} + \frac{\partial \theta_b}{\partial p_{an}}\frac{\partial p^*_{an}}{\partial q_{an}} + \frac{\partial \theta_b}{\partial p_{bo}}\frac{\partial p^*_{bo}}{\partial q_{an}}\right) - 2\gamma(q_{an} - q_{a1}), \tag{28}$$

$$= \frac{\theta^*_b - \theta^*_1}{3} + \frac{p^*_{an}}{6} - 2\gamma(q_{an} - q_{a1}), \tag{29}$$

where the asterisk indicates the best response in the pricing stage of the second period.[3]

A firm can increase demand and raise prices in a customer segment by improving quality for this segment. The ROI is higher if prices are higher in this segment, such that an unit increase in demand generates higher profits. Purchase histories reveal that repeat customers have stronger preferences for the firm's than the competitor's product. When firms do

[3] Note that Equations (27) and (25) are equivalent as $\frac{\theta^*_a}{3} + \frac{p^*_{ao}}{6} - 2\gamma(q_{ao} - q_{a1}) = \frac{p^*_{ao}}{3} - 2\gamma(q_{ao} - q_{a1})$.

not use quality discrimination, they charge higher prices to repeat customers than to new customers (i.e., $p^*_{ao} > p^*_{an}$ when $q_{ao} = q_{an}$ and $q_{bo} = q_{bn}$). Given the price difference, when firms use quality discrimination, it is more profitable to invest in quality improvement to attract repeat customers than new customers. Second, the ROI in quality improvement for a customer segment is higher if there are more customers in this segment, such that an increase in price associated with quality improvement generates higher profits. When firms do not use quality discrimination, they acquire more repeat customers than new customers (i.e., $\theta^*_a > \theta^*_b - \theta^*_1$).[4] Therefore, when firms use quality discrimination, it is more profitable to raise prices for repeat customers by improving quality for them. For both these reasons, firms have stronger incentives to provide higher-quality product features or services to repeat than new customers.

In general, BBP reduces second-period profits, as competitive poaching intensifies price competition from the level in the static game (Fudenberg and Tirole 2000). Our results show that quality discrimination mitigates the traditional BBP's negative impact on firm profits in the second period. Note that second-period profits are still lower than those in the static game without BBP, because quality discrimination does not completely eliminate competitive poaching associated with BBP. Second-period competition is still more intense than that in the static game. Therefore, quality discrimination alleviates BBP's negative impact on second-period profits. Also note that firms increase repeat-customer prices and reduce new-customer prices from the levels without quality discrimination. The price difference between repeat and new customers increases, because firms offer higher-quality product features or services to repeat customers than to new customers and the quality difference enlarges the price difference that arises from BBP. Next, let us examine how second-period quality discrimination affects first-period competition when firms acquire initial customers and generate purchase history data.

Proposition 2 ***(The First Period):*** *Quality discrimination leads to lower prices and profits in the first period.*

Proposition 1 shows that quality discrimination benefits firms in the second period. By contrast, Proposition 2 shows that quality discrimination hurts firms in the first period. The

[4] $\theta^*_a - (\theta^*_b - \theta^*_1) = \theta_1 - \frac{1}{3} + \frac{q_{ao} - q_{an} + q_{bo} - q_{bn}}{6} > 0$ when firms do not use quality discrimination (i.e., $q_{ao} = q_{an}$ and $q_{bo} = q_{bn}$) and θ_1 is in the neighborhood of $\frac{1}{2}$ that follows from a symmetric first-period equilibrium.

intuition is that quality discrimination increases firms' ability to retain repeat customers in the second period, because customers are more willing to stay to enjoy the higher-quality product features or services for repeat customers. Anticipating this effect of quality discrimination, forward-looking firms compete aggressively in the first period to build up their customer base. Thus, firms reduce prices in the first period from the level without quality discrimination.[5]

We can show this intuition in detail. Without quality discrimination, forward-looking firms anticipate that a decrease in first-period prices will expand their first-period market share. Having a higher market share in the first period will lead a firm's competitor to increase second-period quality to poach its customers (i.e., $\frac{\partial q_{b2}^*}{\partial \theta_1} > 0$), which reduces the firm's ability to retain repeat customers, and second-period profit declines accordingly (i.e., $\frac{\partial \Pi_{a2}^*}{\partial q_{b2}} < 0$). This dynamic relationship discourages forward-looking firms from reducing first-period prices to expand the segment of repeat customers. With quality discrimination, firms are better able to retain repeat customers by offering them higher quality than what new customers receive. The increase in a firm's first-period market share induces its competitor to raise quality for new customers and decrease quality for repeat customers (i.e., $\frac{\partial q_{bn}^*}{\partial \theta_1} > 0$ and $\frac{\partial q_{bo}^*}{\partial \theta_1} < 0$). These counteracting effects cancel out and have no impact on the firm's second-period profit. Anticipating this effect of quality discrimination, firms reduce first-period prices and compete more aggressively for initial customers who are more likely to stay with them to receive the better quality.

This result suggests that though quality discrimination alleviates price competition by dissuading competitive poaching in the second period, the anticipation of reduced poaching intensifies first-period competition. These effects of quality discrimination have implications on firms' total profits, consumer surplus, and social welfare, which we state in Proposition 3.

Proposition 3 ***(Overall Welfare):*** *Quality discrimination reduces firms' total profits but increases consumer surplus.*

Quality discrimination increases profits in the second period and decreases profits more

[5]Although quality discrimination reduces firms' prices in the first period, the first-period prices are still higher than those in the static game, because consumers are still less price sensitive than they are in the static game. Therefore, quality discrimination mitigates the traditional BBP's impact on consumers' price sensitivity in the first period.

in the first period. Over the two periods, firms' total profits are lower with quality discrimination than without it. BBP research (e.g., Pazgal and Soberman 2008) shows that when firms simultaneously decide whether to use BBP at the beginning of the first period, two pure-strategy equilibria exist: both firms do not use BBP or both firms use BBP while the adoption of BBP is a Pareto dominated equilibrium. However, without commitment power, firms unilaterally deviate to use BBP at the beginning of the second period, resulting in lower total profits (i.e., a prisoner's dilemma). Similarly, our analysis shows that without credible commitments, firms have incentives to unilaterally deviate to differentiate quality in the second period. Specifically, if the cost of quality differentiation is low (i.e., $\gamma < 0.55$), firms adopt quality discrimination in the second period. It is profitable for one firm to differentiate quality. However, when both firms differentiate quality, firms' total profits are lower than the profits without quality discrimination, resulting in a prisoner's dilemma problem.

With quality discrimination, both prices and quality levels decline in the first period. The first-period consumer utility increases. In the second period, repeat customers receive higher-quality product features or services at a higher price, whereas new customers receive lower-quality product features or services and pay a lower price. Repeat customers' utility increases and new customers' utility decreases. Overall, the first-period effect dominates and consumer surplus improves with quality discrimination. Social welfare increases when the cost of quality discrimination is moderate (i.e., $\gamma \in (0.35, 0.68)$). This is because with quality discrimination, customers are more willing to stay with their original firms. As a result, fewer consumers make inefficient switching between firms and social welfare increases with quality discrimination.

4 Extensions

In this section, we relax several assumptions made in the main model to show the robustness of the main results. In Section 4.1, we relax the assumption on the cost functions to generalize our results. In Section 4.2, we allow firms and consumers to discount the future payoff. In Section 4.3, we incorporate consumers' switching costs into the analysis. We summarize key findings below and show detailed analyses in the Appendix.

4.1 Alternative Cost Functions

In the main model, we assumed that firms incur costs to improve quality in the second period. Without further investment, second-period quality level does not reinitialize to zero. Here, we examine whether our key findings are robust to this assumption. Assume that quality reinitializes to zero and firms' cost function for providing quality q_{i2} in the second period is $C(q_{i2}) = q_{i2}^2$ rather than $C(q_{i2}) = (q_{i2} - q_{i1})^2$. As a result, when firms differentiate quality, their second-period profit functions become $\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - \gamma\,(q_{ao}^2 + q_{an}^2)$ and $\Pi_{b2} = p_{bo}(1-\theta_b) + p_{bn}(\theta_1 - \theta_a) - \gamma\,(q_{bo}^2 + q_{bn}^2)$. We solve the benchmark and main models and verify that all results in the main model hold (see Table 2). That is, firms provide higher-quality product features or services to repeat customers than to new customers, whereas firms charge new customers lower prices. First-period prices decline. Second-period profits increase while first-period profits decline. Total profits are lower with quality discrimination (for detailed analysis, see Section A2 in the Appendix). When second-period quality reinitializes to zero, second-period quality levels decline. This is intuitive because providing high-quality product features or services in the second period becomes more costly under the new assumption.

Moreover, when second-period quality reinitializes to zero, an increase in first-period quality does not make quality provision in the second period less costly. The investment in first-period quality only helps the firm to compete for customers in the first period rather than both periods. We would expect firms to have lower incentives to invest in quality provision in the first period if the quality does not carry into the second period. Interestingly, we find that first-period quality increases if second-period quality reinitializes to zero. The intuition is as follows. Suppose that firm A increases its first-period quality (q_{a1}) and second-period quality does not reinitializes. Consumers anticipate that firm A's second-period quality will also increase accordingly as firm A only invests in quality improvement from the level of q_{a1} in the second period. Since the first-period marginal customer switches firms, he or she has incentives to buy from firm B in the first period to enjoy firm A's higher-quality product features or services in the second period after switching firms. Consumers' second-period consideration leads first-period demand to decrease with first-period quality (i.e., $\frac{\partial \theta_1^*}{\partial q_{a1}} = -\frac{9}{166}$). Therefore, firms provide lower-quality product features or services in the first period to expand demand. By contrast, when quality reinitializes to zero in the second period, an increase in first-period quality does not affect second-period quality. First-period consumers are more willing to buy from the firm that provides higher quality in the first period and demand increases with first-period quality (i.e., $\frac{\partial \theta_1^*}{\partial q_{a1}} = \frac{441}{664}$). Therefore, firms provide higher-quality product features or services in the first period than they would if quality carries into the second period.

In the main model, we assumed away the marginal cost of quality provision to simplify exposition and analysis. Now, we generalize the cost function to allow for a marginal cost of quality provision. Specifically, let firm i's cost of providing quality q comprise of a marginal cost κq_i and a fixed cost q_i^2 as specified in the main model. We use a linear marginal cost function to ensure that a firm's total profit function is concave in quality. When firms only use BBP, their second-period profit functions become:

$$\Pi_{a2} = \theta_a(p_{ao} - \kappa q_{a2}) + (\theta_b - \theta_1)(p_{an} - \kappa q_{a2}) - (q_{a2} - q_{a1})^2 \tag{30}$$

$$\Pi_{b2} = (\theta_1 - \theta_a)(p_{bn} - \kappa q_{b2}) + (1 - \theta_b)(p_{bo} - \kappa q_{b2}) - (q_{b2} - q_{b1})^2 \tag{31}$$

When firms use quality discrimination, their second-period profit functions become

$$\Pi_{a2} = \theta_a(p_{ao} - \kappa q_{ao}) + (\theta_b - \theta_1)(p_{an} - \kappa q_{an}) - \gamma[(q_{ao} - q_{a1})^2 + (q_{an} - q_{a1})^2] \tag{32}$$

$$\Pi_{b2} = (\theta_1 - \theta_a)(p_{bn} - \kappa q_{bn}) + (1 - \theta_b)(p_{bo} - \kappa q_{bo}) - \gamma[(q_{bo} - q_{b1})^2 + (q_{bn} - q_{b1})^2] \tag{33}$$

We solve the models with and without quality discrimination (for details, see Section A3 in the Appendix). We verify that our results in the main model continue to hold. Specifically, firms reward repeat customers with a higher quality level and reward new customers with lower prices. More customers stay with their original firm to enjoy the higher quality. Strategic firms anticipate an increase in second-period customer retention and reduce first-period prices to acquire initial customers. Competition in the first period intensifies, which reduces firms' total profits over two periods to be lower than the profits without quality discrimination.

In addition, our base model assumed that firms incur the same cost to serve repeat and new customers, which may not be true in realty. For example, firms may have better understanding about repeat customers' preferences and therefore it can become more efficient to improve quality provision for them than for new customers. Let γ_o and γ_n indicate the cost of quality provision for repeat and new customers, respectively. Let $\delta = \frac{\gamma_o}{\gamma_n} > 0$ represent the cost efficiency of serving repeat customers relative to new customers. To simplify analysis and exposition, we assume that the second-period quality reinitializes to zero. We solve the equilibrium as in the main model (for details, please see the Appendix). Proposition 4 summarizes our new findings. We focus on situations when the cost of serving customers is not negligible (i.e., $\gamma_n, \gamma_o > \frac{1}{12}$).

Proposition 4 *As serving repeat customers becomes more costly relative to serving new customers (i.e., δ increases), firms' second-period profits decrease, first-period profits increase, and total profits increase.*

Our analysis yields several interesting findings. First, we find that as long as serving repeat customers is not twice more costly than serving new customers (i.e., $\delta < 2$), firms still provide a higher quality level to repeat customers than to new customers (i.e., $q^*_{ao} > q^*_{an}$). In this case, firms still reward new customers with a discounted price (i.e., $p^*_{ao} > p^*_{an}$). Second, intuitively, as δ increases, it becomes relatively more costly to serve repeat customers than new customers. Thus, firms reduce quality provision for repeat customers and increase quality provision for new customers. Third, our analysis shows that as it becomes more costly to serve repeat customers than new customers (i.e., δ increases), firms' second-period profits decline. This is because cost inefficiency of serving repeat than new customers constrained firm's ability to use quality discrimination to deter competitive poaching and soften price competition. Firms' second-period profits decline accordingly. Fourth, we also find that firm's first-period profits increase with δ. This is because as δ increases, it becomes more costly to perform behavior-based quality discrimination in the second period as providing a higher quality to repeat customers becomes relatively more costly. As firms reduce quality discrimination in the second period, customer retention decreases. Anticipating this, firms in the first period have less incentives to cut prices to acquire initial customers. Therefore, profits in the first period increase. Lastly, as δ increases, firms become less engaged in the behavior-based quality discrimination that reduces total profits. As a result, a higher cost of serving repeat customers than new customers serves as a commitment device for firms to reduce quality discrimination and increase total profits.

4.2 Firm and Consumer Patience

In our main model, we assumed that firms and consumers did not discount the second-period payoff. This assumption is plausible when the time distance between the two periods is short. Given that some of the results in our main model arise from firms' and consumers' strategic forward-looking behavior, we relax the main model to consider how firm and consumer patience (i.e., their discounting factor) may affect our results. To simplify analysis, we set $\gamma = \frac{1}{2}$. Let $\delta_f, \delta_c \in [0, 1]$ represent firms' and consumers' discount factor, respectively. A higher value means that firms or consumers are more forward-looking or patient so that the future utility weighs more heavily in their first-period decision making. Given that firm and consumer patience only affects first-period decisions, results pertaining to the second-period outcomes in Proposition 1 continue to hold.

Proposition 5 *When firms only use BBP, firm and consumer patience increases first-period prices. When firms use BBP and quality discrimination, consumer patience decreases first-period prices.*

Proposition 5 reflects the opposite effects of firm and consumer patience on firms' first-period pricing decisions. When firms only use BBP, as firms and consumer become more patient, firms raise first-period prices. This is because consumers are willing to pay a higher price in the first period when they anticipate receiving a better deal in the second period. This forward-looking behavior leads first-period demand to become less price sensitive and results in a higher first-period price. This effect becomes stronger when consumers are more patient. Therefore, consumer patience increases first-period prices. At the same time, when firms use BBP, their first-period market share reduces their second-period profit. This is because as a firm obtains a larger market share from the first-period competition, its competitor will increase second-period quality level to attract its customers, which reduces its second-period profit. Anticipating this effect, firms strategically raise first-period prices to reduce first-period market share and increase second-period profit. The more patient firms are, the higher they raise first-period prices for the second-period benefit. Therefore, as firms become more patient, their first-period prices increase.

However, when firms also differentiate quality for the two segments of repeat and new customers, the effect of consumer patience flips and the effect of firm patience no longer exists.

Consumer patience reduces first-period prices because consumers anticipate less willingness to switch in the second period because firms reward repeat customers. This anticipation makes consumers more price sensitive in the first period. Therefore, consumer patience increases consumers' price sensitivity and reduces prices in the first period. Firm patience no longer has impact on first-period pricing, because as a firm expands its first-period market share, its competitor provides higher-quality product features or services for new customers and lower-quality product features or services for repeat customers. These counteracting changes in second-period quality levels result in no impact on second-period profits. Therefore, firms' forward-looking behavior has no impact on their first-period prices.

When firms and consumers are myopic (i.e., $\delta_f = \delta_c = 0$), the game reduces to the static game without behavior-based targeting. In this case, prices and firm profits are the same with or without quality differentiation. when firms and consumers are somewhat patient (i.e., $\delta_f > 0$ and $\delta_c > 0$), Proposition 5 suggests that first-period prices would be lower with quality differentiation. Consequently, first-period profits decline with quality differentiation, which leads firms' profits to be lower with quality differentiation than without it. Thus, our results pertaining to the first-period prices and profits as well as the total profits and welfare continue to hold.

4.3 Switching Costs

When consumers switch firms in the second period, they may incur switching costs. The switching costs could arise from physical learning costs or psychological factors such as inertia (Klemperer 1987, 1995, Farrell and Klemperer 2007). Let s denote switching costs. If switching costs are prohibitive, no consumers switch firms. Thus, we focus our analysis on the case when $s < \frac{2}{3}$, such that both firms poach competitors' customers when they use BBP and quality discrimination and consumers switch firms in equilibrium. We solve the benchmark and main models and present the equilibrium outcomes in Table 3.

Our analysis shows that switching costs enhance the key results that we present in the main model. Specifically, with switching costs, firms increase quality level for repeat customers and decrease quality level for new customers. This result is counterintuitive because repeat customers are locked in with their firm, which seems to suggest that firms do not have incentives to provide higher-quality product features or services to them. The reason is that when repeat customers face a higher switching cost, it is harder for firms to poach their competitor's customers. As a result, firms offer lower prices to poach customers, which makes competitive poaching more harmful for firms. Firms have greater incentives to attenuate competitive poaching by securing their repeat customers with an even higher quality level. Thus, firms continue to reward repeat (new) customers on the quality (price) dimension and the quality (price) difference increases with switching costs.

Switching costs lead firms to reduce prices in the first period to attract customers as customers will be locked in with them in the second period. Firms exploit the switching costs by raising prices for repeat customers and second-period profits increase. However, first-period profits decrease more and firms' total profits decline with switching costs. In addition, when switching costs are sufficiently high, firms have incentives to raise first-period prices to depress their first-period market share, so that the competitor does not poach its customers in the second period. Even in this scenario, our key results presented in the propositions continue to hold (for detailed analysis, see Section A4 in the Appendix).

5 Conclusion

New information technology makes it possible for firms to differentiate quality and prices for repeat and new customers. Firms' practice of behavior-based quality discrimination has become increasingly common in various industries. Existing research has focused on firms' pricing decisions and established the effects of BBP (Fudenberg and Villas-Boas 2006). The current research contributes to the BBP literature by allowing firms to differentiate both quality and prices on the basis of purchase histories and examining the unique effects of behavior-based quality discrimination. Our key findings address the research questions we initially posited and, in turn, provide theoretical and managerial insights.

Should firms reward new customers or repeat customers? Our analysis suggests that the answer to this question is not simply determining which types of customers should receive rewards. Instead, firms should reward different types of customers with different attributes. Specifically, our results show that firms should reward repeat customers on the quality dimension by providing them higher-quality product features or services. At the same time, firms should reward new customers on the price dimension by offering them a switching discount. Therefore, firms should provide the right reward to the right type of customers.

What is the fundamental difference between quality discrimination and price discrimination? Our analysis reveals that quality discrimination and price discrimination have two main differences. First, quality discrimination is costly. Second, firms make quality decisions before making pricing decisions. By quality discrimination and rewarding repeat customers with better quality, firms reduce competitive poaching. Thus, quality discrimination is a coordination device that alleviates competition associated with price discrimination in the second period.

How should firms adjust first-period prices to compete for initial customers? Our results show that forward-looking firms anticipate higher customer retention with quality discrimination. Such anticipation leads firms to reduce prices in the first period to aggressively compete for initial customers and build up customer base.

How does quality discrimination affect firm profits, consumer surplus, and social welfare? We find that quality discrimination alleviates competitive poaching in the second period and increases second-period profits. However, quality discrimination intensifies price competition in the first period and decreases first-period profits. Firms' total profits decline, though consumer surplus and social welfare tend to improve with quality discrimination.

This article provides several directions for future research. First, we focused on firms' behavior-based quality decisions. Future research could examine how firms differentiate other important strategies on the basis of consumers' purchase histories to glean qualitatively new insights. Second, firms have begun using big data to improve their decisions. Thus, it would be worthwhile to examine how firms use other types of consumer data and the resultant implications on firm profits, consumer surplus, and social welfare. Third, this article reveals the theoretical insights that firms should reward repeat customers on the quality dimension and reward new customers on the price dimension. Future research could empirically examine how firms' practice of quality and price discrimination between repeat and new customers affects firm profits and financial performance.

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Table 1: Equilibrium Outcomes ($\gamma = \frac{1}{2}$)

	Benchmark Model	Main Model
Second-Period Quality	q^*_{a2}: 0.420	q^*_{ao}: 0.487 q^*_{an}: 0.344
First-Period Quality	q^*_{a1}: 0.253	q^*_{a1}: 0.249
Second-Period Prices	p^*_{ao}: 0.667 p^*_{an}: 0.333	p^*_{ao}: 0.714 p^*_{an}: 0.286
First-Period Prices	p^*_{a1}: 1.333	p^*_{a1}: 0.952
Second-Period Profits (Π^*_{a2})	0.250	0.263
First-Period Profits (Π^*_{a1})	0.602	0.414
Total Profits (Π^*_{at})	0.852	0.677
Consumer Surplus (CS^*)	18.229	18.610
Social Welfare (SW^*)	19.934	19.965

Table 2: Equilibrium Outcomes when Second-Period Quality Reinitializes to Zero ($\gamma = \frac{1}{2}$)

	Benchmark Model	Main Model
Second-Period Quality	q^*_{a2}: 0.167	q^*_{ao}: 0.238 q^*_{an}: 0.095
First-Period Quality	q^*_{a1}: 0.230	q^*_{a1}: 0.283
Second-Period Prices	p^*_{ao}: 0.667 p^*_{an}: 0.333	p^*_{ao}: 0.714 p^*_{an}: 0.286
First-Period Prices	p^*_{a1}: 1.333	p^*_{a1}: 0.952
Second-Period Profits (Π^*_{a2})	0.250	0.263
First-Period Profits (Π^*_{a1})	0.614	0.396
Total Profits (Π^*_{at})	0.864	0.659
Consumer Surplus (CS^*)	17.952	18.395
Social Welfare (SW^*)	19.680	19.714

Table 3: Equilibrium Outcomes with Switching Costs ($\gamma = \frac{1}{2}$)

	Benchmark Model	Main Model
Second-Period Quality	q^*_{a2}: 0.420	q^*_{ao}: $0.487 + 0.143s$ q^*_{an}: $0.344 - 0.143s$
First-Period Quality	q^*_{a1}: 0.253	q^*_{a1}: 0.249
Second-Period Prices	p^*_{ao}: $0.667 + 0.333s$ p^*_{an}: $0.333 - 0.333s$	p^*_{ao}: $0.714 + 0.429s$ p^*_{an}: $0.286 - 0.429s$
First-Period Prices	p^*_{a1}: $1.333 - 0.667s$	p^*_{a1}: $0.952 - 0.762s$
Second-Period Profits (Π^*_{a2})	$0.250 + 0.111s + 0.111s^2$	$0.263 + 0.163s + 0.163s^2$
First-Period Profits (Π^*_{a1})	$0.602 - 0.333s$	$0.414 - 0.381s$
Total Profits (Π^*_{at})	$0.852 - 0.222s + 0.111s^2$	$0.677 - 0.218s + 0.163s^2$
Consumer Surplus (CS^*)	$18.229 + 0.222s + 0.056s^2$	$18.610 + 0.354s + 0.092s^2$
Social Welfare (SW^*)	$19.934 - 0.222s + 0.278s^2$	$19.965 - 0.082s + 0.418s^2$

Figure 1: Benchmark Model: Without Quality Discrimination

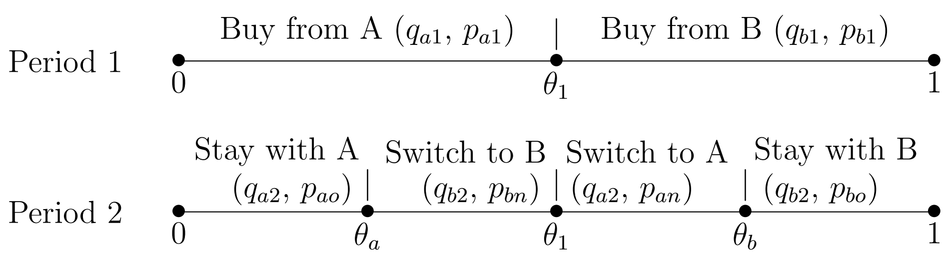
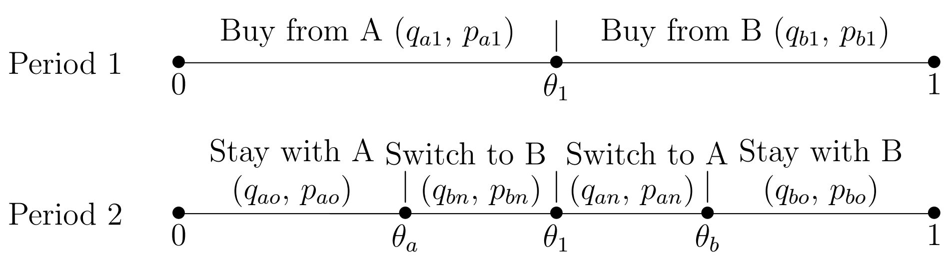


Figure 2: Main Model: With Quality Discrimination



Technical Appendix

Proof of Proposition 1

When firms adopt quality discrimination, second-period equilibrium quality levels are:

$$q_{ao}^* = \frac{75816\gamma^5 - 15552\gamma^4 - 8658\gamma^3 + 2574\gamma^2 - 233\gamma + 7}{12(9\gamma - 1)\gamma(2592\gamma^3 - 1278\gamma^2 + 171\gamma - 7)} \quad \text{(A1)}$$

$$q_{an}^* = \frac{75816\gamma^5 - 31104\gamma^4 - 990\gamma^3 + 1548\gamma^2 - 191\gamma + 7)}{12(9\gamma - 1)\gamma(2592\gamma^3 - 1278\gamma^2 + 171\gamma - 7)} \quad \text{(A2)}$$

It follows that $q_{ao}^* - q_{an}^* = \frac{1}{2(9\gamma-1)} > 0$ for $\gamma > \frac{1}{3}$, the region that we consider. Therefore, firms reward repeat customers on the quality dimension. Second-period equilibrium prices are:

$$p_{ao}^* = \frac{12\gamma - 1}{2(9\gamma - 1)} \quad \text{(A3)}$$

$$p_{an}^* = \frac{6\gamma - 1}{2(9\gamma - 1)} \quad \text{(A4)}$$

We can obtain that $p_{ao}^* - p_{an}^* = \frac{3\gamma}{9\gamma-1} > 0$ for $\gamma > \frac{1}{3}$, the region that we consider. Therefore, firms reward new customers on the price dimension. The second-period equilibrium profits are

$$\Pi_{a2}^* = \Pi_{b2}^* = \frac{(18\gamma - 1)(90\gamma^2 - 18\gamma + 1)}{72\gamma(9\gamma - 1)^2} \quad \text{(A5)}$$

which is higher than the second-period profit (i.e., $\frac{1}{4}$) without quality differentiation.

Proof of Proposition 2

When firms adopt quality discrimination, first-period prices are

$$p_{a1}^* = \frac{(12\gamma - 1)(6\gamma - 1)}{6\gamma(9\gamma - 1)} \quad \text{(A6)}$$

which is lower than the first-period price ($\frac{4}{3}$) without quality customization when $\gamma > \frac{1}{3}$. First-period profits are

$$\Pi_{a1}^* = \frac{U_1}{36\gamma(9\gamma - 1)(2592\gamma^3 - 1278\gamma^2 + 171\gamma - 7)^2} \quad \text{(A7)}$$

where $U_1 = 1291519728\gamma^8 - 1615055760\gamma^7 + 842531544\gamma^6 - 239826096\gamma^5 + 40902651\gamma^4 - 4302567\gamma^3 + 274032\gamma^2 - 9707\gamma + 147$. The profits are lower than the first-period profits ($\frac{3389}{5625}$) without quality customization.

Proof of Proposition 3

Let superscript PP and CC indicate the models with BBP only and with quality discrimination. We compare firms' total profits over two periods, consumer surplus, and social welfare between these two cases.

$$\Pi_{at}^{*CC} - \Pi_{at}^{*PP} = \frac{U_2}{72(9\gamma-1)^2\gamma(2592\gamma^3-1278\gamma^2+171\gamma-7)^2} - \frac{19181}{22500} \tag{A8}$$

where $U_2 = 34131266784\gamma^9 - 45168233472\gamma^8 + 25462348704\gamma^7 - 8057182104\gamma^6 + 1585564146\gamma^5 - 202203702\gamma^4 + 16778358\gamma^3 - 876393\gamma^2 + 26218\gamma - 343$. The above equation is negative for $\gamma > \frac{1}{3}$, the region we consider. Therefore, quality discrimination decreases firm's total profits over two periods.

$$\begin{aligned}
CS_{at}^{*CC} &= 2\int_0^{\theta_a^*}(v+q_{a1}^*-\theta-p_{a1}^*+v+q_{a2}^*-\theta-p_{ao}^*)d\theta \\
&\quad +2\int_{\theta_a^*}^{\theta_1^*}(v+q_{a1}^*-\theta-p_{a1}^*+v+q_{b2}^*-1+\theta-p_{bn}^*)d\theta \\
&\quad = 2v - \frac{9587808\gamma^6-8195904\gamma^5+2759832\gamma^4-473922\gamma^3+44181\gamma^2-2135\gamma+42}{24\gamma(9\gamma-1)^2(2592\gamma^3-1278\gamma^2+171\gamma-7)} \\
CS_{at}^{*PP} &= 2\int_0^{\theta_a^*}(v+q_{a1}^*-\theta-p_{a1}^*+v+q_{ao}^*-\theta-p_{ao}^*)d\theta \\
&\quad +2\int_{\theta_a^*}^{\theta_1^*}(v+q_{a1}^*-\theta-p_{a1}^*+v+q_{bn}^*-1+\theta-p_{bn}^*)d\theta \\
&= 2v - \frac{797}{450}
\end{aligned} \tag{A9}$$

$$CS_{at}^{*CC} - CS_{at}^{*PP} = \frac{U_3}{1800\gamma(9\gamma-1)^2(2592\gamma^3-1278\gamma^2+171\gamma-7)} > 0 \tag{A10}$$

for $\gamma > \frac{1}{3}$, where $U_3 = -(49758624\gamma^6 - 135938088\gamma^5 + 81230364\gamma^4 - 19849626\gamma^3 + 2366739\gamma^2 - 137809\gamma + 3150)$. Therefore, quality discrimination increases consumer surplus.

$$\begin{aligned}
SW_{at}^{*CC} &= CS_{at}^{*CC} + \Pi_{at}^{*CC} = 2v - \frac{U_4}{72\gamma(9\gamma-1)^2(2592\gamma^3-1278\gamma^2+171\gamma-7)^2} \\
SW_{at}^{*PP} &= CS_{at}^{*PP} + \Pi_{at}^{*PP} = 2v - \frac{124}{1875}
\end{aligned} \tag{A11}$$

where $U_4 = 6292261440\gamma^9 - 10154538432\gamma^8 + 6877397664\gamma^7 - 2557891872\gamma^6 + 577347912\gamma^5 - 82662768\gamma^4 + 7572681\gamma^3 - 431298\gamma^2 + 13945\gamma - 196$.

$$SW_{at}^{*CC} - SW_{at}^{*PP} = -\frac{U_5}{45000(9\gamma-1)^2\gamma(2592\gamma^3-1278\gamma^2+171\gamma-7)^2} \tag{A12}$$

where $U_5 = 2313137342016\gamma^9 - 4389659199936\gamma^8 + 3316082874912\gamma^7 - 1329880874400\gamma^6 + 316624819752\gamma^5 - 47153590128\gamma^4 + 4452604281\gamma^3 - 259811874\gamma^2 + 8569801\gamma - 122500$. Equation A12 is positive if $\gamma \in (0.35, 0.68)$. Therefore, quality discrimination increases social welfare when quality discrimination is moderately costly.

Proof of Proposition 4

Let γ_o and γ_n indicate the cost of quality provision for repeat and new customers, respectively and $\delta = \frac{\gamma_o}{\gamma_n} > 0$ represent the cost efficiency of serving repeat customers relative to new customers. Then $\gamma_o = \delta\gamma_n$. We solve the main model as follows.

The second-period marginal consumers are located at θ_a and θ_b which take the same forms as in the main model.

$$v - \theta_a + q_{ao} - p_{ao} = v - (1 - \theta_a) + q_{bn} - p_{bn}, \tag{A13}$$

$$\theta_a = \frac{1}{2} + \frac{q_{ao} - q_{bn}}{2} - \frac{p_{ao} - p_{bn}}{2}. \tag{A14}$$

and

$$v - \theta_b + q_{an} - p_{an} = v - (1 - \theta_b) + q_{bo} - p_{bo}, \tag{A15}$$

$$\theta_b = \frac{1}{2} + \frac{q_{an} - q_{bo}}{2} - \frac{p_{an} - p_{bo}}{2}. \tag{A16}$$

Firms' profit functions in the second period are

$$\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - \gamma_o q_{ao}^2 - \gamma_n q_{an}^2, \tag{A17}$$

$$\Pi_{b2} = p_{bo}(1 - \theta_b) + p_{bn}(\theta_1 - \theta_a) - \gamma_o q_{bo}^2 - \gamma_n q_{bn}^2. \tag{A18}$$

We solve for second-period prices and obtain $p_{ao}^* = \frac{q_{ao} - q_{bn}}{3} + \frac{2\theta_1}{3} + \frac{1}{3}$, $p_{an}^* = \frac{q_{an} - q_{bo}}{3} - \frac{4\theta_1}{3} + 1$, $p_{bo}^* = \frac{q_{bo} - q_{an}}{3} - \frac{2\theta_1}{3} + 1$, and $p_{bn}^* = \frac{q_{bn} - q_{ao}}{3} + \frac{4\theta_1}{3} - \frac{1}{3}$. Then, we solve for the second-period quality and obtain $q_{an}^* = \frac{\theta_1 - 1 + 9\delta\gamma_n - 12\delta\gamma_n\theta_1}{3\gamma_n(18\delta\gamma_n - \delta - 1)}$, $q_{ao}^* = \frac{6\gamma_n\theta_1 + 3\gamma_n - \theta_1}{3\gamma_n(18\delta\gamma_n - \delta - 1)}$, $q_{bn}^* = \frac{12\delta\gamma_n\theta_1 - 3\delta\gamma_n - \theta_1}{3\gamma_n(18\delta\gamma_n - \delta - 1)}$, and $q_{bo}^* = \frac{\theta_1 - 1 + 9\gamma_n - 6\gamma_n\theta_1}{3\gamma_n(18\delta\gamma_n - \delta - 1)}$. The first-period consumer is located at θ_1. We must have that

$$v - \theta_1 - p_{a1} + [v - (1 - \theta_1) + q_{bn}^{e*} - p_{bn}^{e*}] = v - (1 - \theta_1) - p_{b1} + [v - \theta_1 + q_{an}^{e*} - p_{an}^{e*}]. \tag{A19}$$

We obtain

$$\theta_1 = \frac{1 - 6\gamma_n + 3\gamma_n(p_{a1} - p_{b1}) - 12\delta\gamma_n + 72\delta\gamma_n^2 + 3\delta\gamma_n(p_{a1} - p_{b1}) - 54\delta\gamma_n^2(p_{a1} - p_{b1})}{2(1 - 6\gamma_n + 72\delta\gamma_n^2 - 12\delta\gamma_n)} \tag{A20}$$

Firms' profit functions to maximize in the first period are:

$$\Pi_{at} = p_{a1}\theta_1 + \Pi_{a2}^*, \tag{A21}$$

$$\Pi_{bt} = p_{b1}(1 - \theta_1) + \Pi_{b2}^*. \tag{A22}$$

We obtain first-period prices:

$$p_{a1}^* = p_{b1}^* = \frac{2(1944\delta^2\gamma_n^3 - 306\delta^2\gamma_n^2 + 9\delta^2\gamma_n - 396\delta\gamma_n^2 + 54\delta\gamma_n - \delta + 18\gamma_n - 2)}{9\gamma_n(18\delta\gamma_n - \delta - 1)^2} \tag{A23}$$

In equilibrium, firms' second-period profits are

$$\Pi_{a2}^* = \Pi_{b2}^* = \frac{3240\delta^2\gamma_n^3 - 468\delta^2\gamma_n^2 + 18\delta^2\gamma_n - 360\delta\gamma_n^2 + 36\delta\gamma_n - \delta + 18\gamma_n - 1}{36\gamma_n(18\delta\gamma_n - \delta - 1)^2} \tag{A24}$$

firms' total profits over two periods are

$$\Pi_{at}^* = \Pi_{bt}^* = \frac{11016\delta^2\gamma_n^3 - 1692\delta^2\gamma_n^2 + 54\delta^2\gamma_n - 1944\delta\gamma_n^2 + 252\delta\gamma_n - 5\delta + 90\gamma_n - 9}{36\gamma_n(18\delta\gamma_n - \delta - 1)^2} \tag{A25}$$

The impact of δ on profits are as follows:

$$\frac{\partial \Pi_{a2}^*}{\partial \delta} = -\frac{(12\gamma_n - 1)(6\delta\gamma_n - \delta + 24\gamma_n - 1)}{36\gamma_n(18\delta\gamma_n - \delta - 1)^3} < 0 \tag{A26}$$

$$\frac{\partial \Pi_{at}^*}{\partial \delta} = \frac{12960\delta\gamma_n^3 - 3096\delta\gamma_n^2 + 234\delta\gamma_n - 1296\gamma_n^2 - 5\delta + 252\gamma_n - 13}{36\gamma_n(18\delta\gamma_n - \delta - 1)^3} > 0 \tag{A27}$$

in the region of parameters that we consider. Since total profits increase with δ but second-period profits decrease with δ, it follows that first-period profits increase with δ.

Proof of Proposition 5

Let superscript PP and CC indicate the models with BBP only and with quality differentiation. We solve the two models in Section A5. We have $p_{a1}^{*PP} = 1 + \frac{2\delta_c}{7} + \frac{\delta_f}{21}$ increasing in δ_c and δ_f. $p_{a1}^{*CC} = 1 - \frac{\delta_c}{21}$ decreasing in δ_c.

A1 Footnote 2: Firms Do Not Target Customers

For completeness, we consider the case in which firms do not target consumers with BBP or quality customization. In this case, firms set dynamic quality and prices but do not condition second-period quality and prices on consumers' purchase histories. They offer a standardized service with uniform quality and price to all consumers in each period (for the consumption pattern, see Figure A1). Let θ_2 denote the location of the marginal customer who is indifferent between consuming two firms' services in the second period. We have that

$$v - \theta_2 + q_{a2} - p_{a2} = v - (1 - \theta_2) + q_{b2} - p_{b2} \tag{A28}$$

$$\theta_2 = \frac{1}{2} + \frac{q_{a2} - q_{b2}}{2} - \frac{p_{a2} - p_{b2}}{2} \tag{A29}$$

The second-period profit functions are

$$\Pi_{a2} = p_{a2}\theta_2 - (q_{a2} - q_{a1})^2 \tag{A30}$$
$$\Pi_{b2} = p_{b2}(1-\theta_2) - (q_{b2} - q_{b1})^2 \tag{A31}$$

Using first-order conditions, we obtain that

$$p^*_{a2} = 1 + \frac{q_{a2} - q_{b2}}{3} \tag{A32}$$
$$p^*_{b2} = 1 - \frac{q_{a2} - q_{b2}}{3} \tag{A33}$$

The second-order conditions are satisfied. Then, we solve for second-period quality and obtain that

$$q^*_{a2} = \frac{1}{6} + \frac{17q_{a1} - q_{b1}}{16} \tag{A34}$$
$$q^*_{b2} = \frac{1}{6} + \frac{17q_{b1} - q_{a1}}{16} \tag{A35}$$

Similarly, let θ_1 denote the location of the first-period marginal consumer. We have that

$$v - \theta_1 + q_{a1} - p_{a1} = v - (1-\theta_1) + q_{b1} - p_{b1} \tag{A36}$$
$$\theta_1 = \frac{1}{2} + \frac{q_{a1} - q_{b1}}{2} - \frac{p_{a1} - p_{b1}}{2} \tag{A37}$$

Firms set first-period prices and quality levels to maximize total profits over two periods. The profit functions are

$$\Pi_{at} = p_{a1}\theta_1 - q_{a1}^2 + \Pi^*_{a2} \tag{A38}$$
$$\Pi_{bt} = p_{b1}(1-\theta_1) - q_{b1}^2 + \Pi^*_{b2} \tag{A39}$$

We obtain first-period prices:

$$p^*_{a1} = 1 + \frac{q_{a1} - q_{b1}}{3} \tag{A40}$$
$$p^*_{b1} = 1 - \frac{q_{a1} - q_{b1}}{3} \tag{A41}$$

First-period quality levels are $q^*_{a1} = q^*_{b1} = \frac{11}{32}$. We summarize the equilibrium outcomes in Table A2.

Comparison of equilibrium outcomes in this case and the benchmark model in which firms use BBP (see Table A2) reflects the effect of BBP on dynamic quality levels, prices, profits, consumer surplus, and social welfare. We summarize BBP's effects in Lemma A1.

Lemma A1. ***(Effects of BBP)*** *Compared to the case when firms do not target customers (i.e., without targeting), BBP leads to lower quality levels in both periods, lower prices in the second period, higher prices in the first period, lower total profits, consumer surplus, and social welfare.*

Proof. We use superscript NN to denote the case when both firms do not target customers and PP to denote the case when both firms use BBP.

$$q_{a1}^{*PP} - q_{a1}^{*NN} = q_{a2}^{*PP} - q_{a2}^{*NN} = -\frac{217}{2400} < 0 \tag{A42}$$

Therefore, firms reduce quality levels when they use BBP.

$$p_{ao}^{*PP} - p_{a2}^{*NN} = -\frac{1}{3} < 0 \tag{A43}$$

$$p_{an}^{*PP} - p_{a2}^{*NN} = -\frac{2}{3} < 0 \tag{A44}$$

$$p_{a1}^{*PP} - p_{a1}^{*NN} = \frac{1}{3} > 0 \tag{A45}$$

Thus, second-period prices are lower with BBP. First-period prices are higher.

$$\Pi_{at}^{*PP} - \Pi_{at}^{*NN} = -\frac{3013}{1920000} < 0 \tag{A46}$$

$$SW^{*PP} - SW^{*NN} = -\frac{369839}{2880000} < 0 \tag{A47}$$

$$CS^{*PP} - CS^{*NN} = -\frac{451}{3600} < 0 \tag{A48}$$

Therefore, total profits, consumer surplus, and social welfare are lower with BBP; □

Quality levels decline after firms adopt BBP, because BBP reduces consumers' willingness to buy from the higher-quality firm in the first period. With BBP, the first-period marginal consumer switches firms in the second period. If a firm increases its first-period quality level, the marginal consumer is more willing to buy from this firm because of the increase in the first-period quality. However, the forward-looking consumer also realizes that when everything else is held constant, the firm that provides a higher-quality service in the first period will also provide a higher-quality service in the second period. To receive the higher-quality service from this firm in the second period, the marginal consumer has incentive to buy from the competing firm in the first period. Therefore, the anticipated increase in a firm's second-period quality as a result of its investment in its first-period quality reduces consumers' willingness to buy from the firm in the first period. As a result, BBP leads firms to reduce quality levels in the first period. As first-period quality levels decline, it is more costly to improve quality to a high level in the second period. Therefore, the cost of providing high-quality services in the second period increases, and firms provide lower quality services in the second period with than without BBP.

The other results in Lemma A1 are consistent with findings in the BBP literature. BBP intensifies price competition, resulting in lower prices in the second period. Forward-looking consumers in the first period become less price sensitive because they anticipate better deals when they switch firms in the second period. This effect leads to higher prices in the first period (Fudenberg and Tirole 2000). BBP leads to lower profits for firms, and consumers' inefficient switching reduces social welfare. Lower service quality and higher prices in the first period reduce consumer surplus.

A2 Second-Period Quality Reinitializes to Zero

Suppose that quality reinitializes to zero so that the cost of providing quality q_{i2} in period 2 is a quadratic function of q_{i2} rather than the quality improvement $q_{i2} - q_{i1}$. We can modify the cost function in the models accordingly. Specifically, firms' profit functions when they do not customize quality are:

$$\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - q_{a2}^2, \tag{A49}$$

$$\Pi_{b2} = p_{bo}(1-\theta_b) + p_{bn}(\theta_1 - \theta_a) - q_{b2}^2. \tag{A50}$$

Second-period prices are $p_{an}^* = 1 - \frac{4\theta_1}{3} + \frac{q_{a2}-q_{b2}}{3}$, $p_{ao}^* = \frac{1+2\theta_1}{3} + \frac{q_{a2}-q_{b2}}{3}$, $p_{bn}^* = \frac{4\theta_1-1}{3} - \frac{q_{a2}-q_{b2}}{3}$, and $p_{bo}^* = 1 - \frac{2\theta_1}{3} - \frac{q_{a2}-q_{b2}}{3}$. Second-period quality levels are $q_{a2}^* = \frac{5}{21} - \frac{\theta_1}{7}$ and $q_{b2}^* = \frac{2}{21} + \frac{\theta_1}{7}$.

The marginal consumer at θ_1 faces the same trade-off as in the main model. We have

$$v - \theta_1 + q_{a1} - p_{a1} + [v - (1-\theta_1) + q_{b2}^{e*} - p_{bn}^{e*}] = v - (1-\theta_1) + q_{b1} - p_{b1} + [v - \theta_1 + q_{a2}^{e*} - p_{an}^{e*}]. \tag{A51}$$

With the second-period equilibrium quality and prices, we obtain

$$\theta_1 = \frac{1}{2} - \frac{7(p_{a1}-p_{b1})}{18} + \frac{7(q_{a1}-q_{b1})}{18}. \tag{A52}$$

Firms' profit functions at the beginning of the first period are

$$\Pi_{at} = p_{a1}\theta_1 + \Pi_{a2}^* - q_{a1}^2, \tag{A53}$$

$$\Pi_{bt} = p_{b1}(1-\theta_1) + \Pi_{b2}^* - q_{b1}^2. \tag{A54}$$

First-period prices are $p_{a1}^* = \frac{4}{3} + \frac{2(q_{a1}-q_{b1})}{25}$ and $p_{b1}^* = \frac{4}{3} - \frac{2(q_{a1}-q_{b1})}{25}$. We obtain first-period quality levels $q_{a1}^* = q_{b1}^* = 0.23$. The rest of the equilibrium outcomes are summarized in Table 2.

When firms customize quality, their second-period profit functions are

$$\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - \gamma\left(q_{ao}^2 + q_{an}^2\right), \tag{A55}$$

$$\Pi_{b2} = p_{bo}(1-\theta_b) + p_{bn}(\theta_1 - \theta_a) - \gamma\left(q_{bo}^2 + q_{bn}^2\right). \tag{A56}$$

Second-period prices are $p_{an}^* = 1 - \frac{4\theta_1}{3} + \frac{q_{an}-q_{bo}}{3}$, $p_{ao}^* = \frac{1+2\theta_1}{3} + \frac{q_{ao}-q_{bn}}{3}$, $p_{bn}^* = \frac{4\theta_1-1}{3} - \frac{q_{ao}-q_{bn}}{3}$, and $p_{bo}^* = 1 - \frac{2\theta_1}{3} - \frac{q_{an}-q_{bo}}{3}$. Second-period quality levels are $q_{ao}^* = \frac{4\theta_1}{21} + \frac{1}{7}$, $q_{an}^* = \frac{1}{3} - \frac{10\theta_1}{21}$, $q_{bo}^* = \frac{1}{3} - \frac{4\theta_1}{21}$, $q_{bn}^* = \frac{10\theta_1}{21} - \frac{1}{7}$.

We solve for first-period marginal consumer as before:

$$\begin{aligned} v - \theta_1 + q_{a1} - p_{a1} + [v - (1-\theta_1) + q_{bn}^{e*} - p_{bn}^{e*}] &= v - (1-\theta_1) + q_{b1} - p_{b1} + [v - \theta_1 + q_{an}^{e*} - p_{an}^{e*}], \\ \theta_1 &= \frac{1}{2} - \frac{21(p_{a1}-p_{b1})}{40} + \frac{21(q_{a1}-q_{b1})}{40}. \end{aligned} \tag{A57}$$

Firms' profit functions at the beginning of the first period are

$$\begin{aligned}\Pi_{at} &= p_{a1}\theta_1 + \Pi^*_{a2} - q^2_{a1}, &\text{(A58)}\\ \Pi_{bt} &= p_{b1}(1-\theta_1) + \Pi^*_{b2} - q^2_{b1}. &\text{(A59)}\end{aligned}$$

First-period prices are $p^*_{a1} = \frac{20}{21} + \frac{11(q_{a1}-q_{b1})}{83}$ and $p^*_{b1} = \frac{20}{21} - \frac{11(q_{a1}-q_{b1})}{83}$. We obtain first-period quality levels $q^*_{a1} = q^*_{b1} = \frac{47}{166} \approx 0.283$. The rest of the equilibrium outcomes are summarized in Table 2 of the paper. Comparison of equilibrium outcomes show that all propositions in the main model continue to hold.

A3 A Marginal Cost of Quality Provision

We generalize the cost functions to allow for a marginal cost of quality provision. We solve the benchmark model without quality discrimination and the main model with quality discrimination separately below.

A3.1 Benchmark Model: Without Quality Discrimination

The marginal consumers are located at the same places as before. We have

$$v - \theta_a + q_{a2} - p_{ao} = v - (1-\theta_a) + q_{b2} - p_{bn}, \tag{A60}$$

$$\theta_a = \frac{1}{2} + \frac{q_{a2}-q_{b2}}{2} - \frac{p_{ao}-p_{bn}}{2}. \tag{A61}$$

$$v - \theta_b + q_{a2} - p_{an} = v - (1-\theta_b) + q_{b2} - p_{bo}, \tag{A62}$$

$$\theta_b = \frac{1}{2} + \frac{q_{a2}-q_{b2}}{2} - \frac{p_{an}-p_{bo}}{2}. \tag{A63}$$

Firms' profit functions in the second period are

$$\begin{aligned}\Pi_{a2} &= (p_{ao} - \kappa q_{a2})\theta_a + (p_{an} - \kappa q_{a2})(\theta_b - \theta_1) - q^2_{a2}, &\text{(A64)}\\ \Pi_{b2} &= (p_{bo} - \kappa q_{b2})(1-\theta_b) + (p_{bn} - \kappa q_{b2})(\theta_1 - \theta_a) - q^2_{b2}. &\text{(A65)}\end{aligned}$$

We obtain second-period prices:

$$\begin{aligned}p^*_{an} &= 1 - \frac{4\theta_1}{3} + \frac{q_{a2} - q_{b2} + \kappa(q_{b2} + 2q_{a2})}{3} &\text{(A66)}\\ p^*_{ao} &= \frac{1}{3} + \frac{2\theta_1}{3} + \frac{q_{a2} - q_{b2} + \kappa(2q_{a2} + q_{b2})}{3} &\text{(A67)}\\ p^*_{bn} &= \frac{4\theta_1}{3} - \frac{1}{3} + \frac{q_{b2} - q_{a2} + \kappa(q_{a2} + 2q_{b2})}{3} &\text{(A68)}\\ p^*_{bo} &= 1 - \frac{2\theta_1}{3} + \frac{q_{b2} - q_{a2} + \kappa(q_{a2} + 2q_{b2})}{3} &\text{(A69)}\end{aligned}$$

The second-period quality levels are

$$q_{a2}^* = \frac{\kappa(\kappa^2 - 3\kappa - 3) + 3\theta_1(\kappa - 1) + 5}{3(7 + 4\kappa - 2\kappa^2)} \tag{A70}$$

$$q_{b2}^* = \frac{\kappa^2(\kappa - 3) + 3\theta_1(1 - \kappa) + 2}{3(7 + 4\kappa - 2\kappa^2)} \tag{A71}$$

The first-period marginal consumer is located at θ_1. We have that

$$v - \theta_1 - p_{a1} + [v - (1 - \theta_1) + q_{b2}^{e*} - p_{bn}^{e*}] = v - (1 - \theta_1) - p_{b1} + (v - \theta_1 + q_{a2}^{e*} - p_{an}^{e*}) \tag{A72}$$

$$\theta_1 = \frac{9 + 7(p_{b1} - p_{a1}) + 2\kappa^2(p_{a1} - p_{b1}) - 3\kappa^2 + 4\kappa(p_{b1} - p_{a1}) + 6\kappa}{6(3 + 2\kappa - \kappa^2)} \tag{A73}$$

The total profits that firms maximize in the first period are

$$\Pi_{at} = p_{a1}\theta_1 + \Pi_{a2}^*, \tag{A74}$$

$$\Pi_{bt} = p_{b1}(1 - \theta_1) + \Pi_{b2}^*. \tag{A75}$$

We obtain first-period prices that $p_{a1}^* = p_{b1}^* = \frac{4}{3}$. Table A1 summarizes the equilibrium outcomes.

A3.2 Main Model: With Quality Discrimination

When firms offer different quality levels to repeat and new customers in the second period, the second-period marginal consumers are located at

$$v - \theta_a + q_{ao} - p_{ao} = v - (1 - \theta_a) + q_{bn} - p_{bn}, \tag{A76}$$

$$\theta_a = \frac{1}{2} + \frac{q_{ao} - q_{bn}}{2} - \frac{p_{ao} - p_{bn}}{2}. \tag{A77}$$

$$v - \theta_b + q_{an} - p_{an} = v - (1 - \theta_b) + q_{bo} - p_{bo}, \tag{A78}$$

$$\theta_b = \frac{1}{2} + \frac{q_{an} - q_{bo}}{2} - \frac{p_{an} - p_{bo}}{2}. \tag{A79}$$

With the general cost function, firms' profit functions in the second period are

$$\Pi_{a2} = (p_{ao} - \kappa q_{ao})\theta_a + (p_{an} - \kappa q_{an})(\theta_b - \theta_1) - \gamma\left(q_{ao}^2 + q_{an}^2\right), \tag{A80}$$

$$\Pi_{b2} = (p_{bo} - \kappa q_{bo})(1 - \theta_b) + (p_{bn} - \kappa q_{bn})(\theta_1 - \theta_a) - \gamma\left(q_{bo}^2 + q_{bn}^2\right). \tag{A81}$$

We obtain the second-period equilibrium prices:

$$p_{an}^* = 1 - \frac{4\theta_1}{3} + \frac{q_{an} - q_{bo} + \kappa(q_{bo} + 2q_{an})}{3} \tag{A82}$$

$$p_{ao}^* = \frac{1}{3} + \frac{2\theta_1}{3} + \frac{q_{ao} - q_{bn} + \kappa(2q_{ao} + q_{bn})}{3} \tag{A83}$$

$$p^*_{bn} = \frac{4\theta_1}{3} - \frac{1}{3} + \frac{q_{bn} - q_{ao} + \kappa(q_{ao} + 2q_{bn})}{3} \tag{A84}$$

$$p^*_{bo} = 1 - \frac{2\theta_1}{3} + \frac{q_{bo} - q_{an} + \kappa(q_{an} + 2q_{bo})}{3} \tag{A85}$$

Then, we solve for second-period quality levels

$$q^*_{an} = \frac{(1-\kappa)(1-\theta_1-9\gamma-\kappa^2\theta_1+\kappa^2+2\kappa\theta_1+12\gamma\theta_1-2\kappa)}{6\gamma(\kappa^2-2\kappa-9\gamma+1)} \tag{A86}$$

$$q^*_{ao} = \frac{(1-\kappa)(\theta_1-3\gamma+\kappa^2\theta_1-2\kappa\theta_1-6\gamma\theta_1)}{6\gamma(\kappa^2-2\kappa-9\gamma+1)} \tag{A87}$$

$$q^*_{bn} = \frac{(1-\kappa)(\theta_1+3\gamma+\kappa^2\theta_1-2\kappa\theta_1-12\gamma\theta_1)}{6\gamma(\kappa^2-2\kappa-9\gamma+1)} \tag{A88}$$

$$q^*_{bo} = \frac{(1-\kappa)(1-\theta_1-9\gamma-2\kappa+6\gamma\theta_1-\kappa^2\theta_1+\kappa^2+2\kappa\theta_1)}{6\gamma(\kappa^2-2\kappa-9\gamma+1)} \tag{A89}$$

The first-period marginal consumers are located at θ_1. We have that

$$v - \theta_1 - p_{a1} + [v - (1-\theta_1) + q^{e*}_{bn} - p^{e*}_{bn}] = v - (1-\theta_1) - p_{b1} + [v - \theta_1 + q^{e*}_{an} - p^{e*}_{an}] \tag{A90}$$

$$\theta_1 = \frac{1}{2} + \frac{3\gamma(p_{a1}-p_{b1})(\kappa^2-2\kappa-9\gamma+1)}{(\kappa^2-2\kappa-12\gamma+1)(\kappa^2-2\kappa-6\gamma+1)} \tag{A91}$$

Firms set first-period prices to maximize total profits over two periods. The profit functions are

$$\Pi_{at} = p_{a1}\theta_1 + \Pi^*_{a2}, \tag{A92}$$

$$\Pi_{bt} = p_{b1}(1-\theta_1) + \Pi^*_{b2}. \tag{A93}$$

We obtain first-period prices:

$$p^*_{a1} = p^*_{b1} = \frac{(1-6\gamma+\kappa^2-2\kappa)(12\gamma-1-\kappa^2+2\kappa)}{6\gamma(1-9\gamma+\kappa^2-2\kappa)} \tag{A94}$$

Table A1 summarizes the equilibrium outcomes.

A3.3 Verification of Main Results

We focus on the region of κ and γ in which the profit functions are concave in quality and prices. We verify that main results in the paper continue to hold.

$$q^*_{ao} - q^*_{an} = \frac{1-\kappa}{2(9\gamma-1+2\kappa-\kappa^2)} > 0 \tag{A95}$$

$$p^*_{ao} - p^*_{an} = \frac{6\gamma+\kappa-\kappa^2}{2(9\gamma-1+2\kappa-\kappa^2)} > 0 \tag{A96}$$

Table A1: Equilibrium Outcomes with Marginal Cost

	Benchmark Model	Main Model
Second-Period Quality	q_{a2}^{*}: $\frac{1-\kappa}{6}$	q_{ao}^{*}: $\frac{(1-\kappa)(1-12\gamma+\kappa^2-2\kappa)}{12\gamma(1-9\gamma+\kappa^2-2\kappa)}$ q_{an}^{*}: $\frac{(1-\kappa)(1-6\gamma+\kappa^2-2\kappa)}{12\gamma(1-9\gamma+\kappa^2-2\kappa)}$
Second-Period Prices	p_{ao}^{*}: $\frac{2}{3}+\frac{\kappa(1-\kappa)}{6}$ p_{an}^{*}: $\frac{(\kappa+1)(2-\kappa)}{6}$	p_{ao}^{*}: $\frac{(1-12\gamma+\kappa^2-2\kappa)(6\gamma-\kappa^2+\kappa)}{12\gamma(1-9\gamma+\kappa^2-2\kappa)}$ p_{an}^{*}: $\frac{(1-6\gamma+\kappa^2-2\kappa)(6\gamma-\kappa^2+\kappa)}{12\gamma(1-9\gamma+\kappa^2-2\kappa)}$
First-Period Prices	p_{a1}^{*}: $\frac{4}{3}$	p_{a1}^{*}: $\frac{(1-12\gamma+\kappa^2-2\kappa)(6\gamma-1-\kappa^2+2\kappa)}{6\gamma(1-9\gamma+\kappa^2-2\kappa)}$
Second-Period Profits (Π_{a2}^{*})	$\frac{1}{4}+\frac{\kappa(2-\kappa)}{36}$	$\frac{(1-18\gamma+\kappa^2-2\kappa)(\kappa^4-4\kappa^3-18\kappa^2\gamma+6\kappa^2+36\kappa\gamma+90\gamma^2-4\gamma-18\gamma+1)}{72\gamma(1-9\gamma+\kappa^2-2\kappa)^2}$
First-Period Profits (Π_{a1}^{*})	$\frac{2}{3}$	$\frac{(1-12\gamma+\kappa^2-2\kappa)(6\gamma-1-\kappa^2+2\kappa)}{12\gamma(1-9\gamma+\kappa^2-2\kappa)}$
Total Profits (Π_{at}^{*})	$\frac{11}{12}+\frac{\kappa(2-\kappa)}{36}$	$\frac{U_1}{72\gamma(1-9\gamma+\kappa^2-2\kappa)^2}$
Consumer Surplus (CS^{*})	$\frac{319}{18}+\frac{\kappa(\kappa-2)}{6}$	$\frac{U_2}{8\gamma(1-9\gamma+\kappa^2-2\kappa)^2}$
Social Welfare (SW^{*})	$\frac{176}{9}+\frac{\kappa(\kappa-2)}{9}$	$\frac{U_3}{72\gamma(1-9\gamma+\kappa^2-2\kappa)^2}$

$U_1 = 7\kappa^6 - 42\kappa^5 - 198\kappa^4\gamma + 105\kappa^4 + 792\kappa^3\gamma + 1818\kappa^2\gamma^2 - 140\kappa^3 - 1188\kappa^2\gamma - 3636\kappa\gamma^2 - 5508\gamma^3 + 105\kappa^2 + 792\kappa\gamma + 1818\gamma^2 - 42\kappa - 198\gamma + 7.$
$U_2 = 2\kappa^6 - 12\kappa^5 + 103\kappa^4\gamma + 30\kappa^4 - 412\kappa^3\gamma - 2352\kappa^2\gamma^2 - 40\kappa^3 + 618\kappa^2\gamma + 4704\kappa\gamma^2 + 11376\gamma^3 + 30\kappa^2 - 412\kappa\gamma - 2352\gamma^2 - 12\kappa + 103\gamma + 2.$
$U_3 = 4\kappa^6 - 24\kappa^5 + 1323\kappa^4\gamma + 60\kappa^4 - 5292\kappa^3\gamma - 24804\kappa^2\gamma^2 - 80\kappa^3 + 7938\kappa^2\gamma + 49608\kappa\gamma^2 + 113400\gamma^3 + 60\kappa^2 - 5292\kappa\gamma - 24804\gamma^2 - 24\kappa + 1323\gamma + 4.$

Therefore, firms reward repeat customers on the quality dimension and reward new customers on the price dimension. Next, we compare firms' first-period prices and profits with (denoted by superscript CC) versus without (denoted by superscript PP) quality discrimination

$$\theta_a^{*CC} - \theta_a^{*PP} = \frac{(1-\kappa)^2}{12(9\gamma - 1 - \kappa^2 + 2\kappa)} > 0 \tag{A97}$$

$$p_{a1}^{*CC} - p_{an}^{*PP} = -\frac{(1-\kappa)^2(1-10\gamma+\kappa^2-2\kappa)}{6\gamma(1-9\gamma+\kappa^2-2\kappa)} < 0 \tag{A98}$$

Therefore, more customers stay with their original firms when firms use quality discrimination. Firms reduce first-period prices with quality discrimination.

$$\Pi_{at}^{*CC} - \Pi_{at}^{*PP} = \frac{(1-\kappa)^2 U_4}{72\gamma(1-9\gamma+\kappa^2-2\kappa)^2} < 0 \tag{A99}$$

where $U_4 = 2\kappa^4\gamma - 7\kappa^4 - 8\kappa^3\gamma - 36\kappa^2\gamma^2 + 28\kappa^3 + 142\kappa^2\gamma + 72\kappa\gamma^2 + 162\gamma^3 - 42\kappa^2 - 268\kappa\gamma - 630\gamma^2 + 28\kappa + 132\gamma - 7$. Therefore, firms' total profits decrease with quality discrimination. All results in the main model continue to hold.

A4 Switching Costs

Let s denote the switching cost. We analyze the benchmark model and main model with switching costs.

A4.1 Benchmark Model

When firms use BBP and consumers incur switching costs, the marginal consumers in the second period become:

$$v - \theta_a + q_{a2} - p_{ao} = v - (1-\theta_a) + q_{b2} - p_{bn} - s, \tag{A100}$$
$$\theta_a = \frac{1+s}{2} + \frac{q_{a2}-q_{b2}}{2} - \frac{p_{ao}-p_{bn}}{2}. \tag{A101}$$

$$v - \theta_b + q_{a2} - p_{an} - s = v - (1-\theta_b) + q_{b2} - p_{bo}, \tag{A102}$$
$$\theta_b = \frac{1-s}{2} + \frac{q_{a2}-q_{b2}}{2} - \frac{p_{an}-p_{bo}}{2}. \tag{A103}$$

Firms maximize second-period profit functions:

$$\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - (q_{a2}-q_{a1})^2, \tag{A104}$$
$$\Pi_{b2} = p_{bo}(1-\theta_b) + p_{bn}(\theta_1 - \theta_a) - (q_{b2}-q_{b1})^2. \tag{A105}$$

Second-period prices are $p^*_{an} = \frac{3-4\theta_1-s}{3} + \frac{q_{a2}-q_{b2}}{3}$, $p^*_{ao} = \frac{1+s+2\theta_1}{3} + \frac{q_{a2}-q_{b2}}{3}$, $p^*_{bn} = \frac{4\theta_1-1-s}{3} + \frac{q_{b2}-q_{a2}}{3}$, and $p^*_{bo} = \frac{3-2\theta_1+s}{3} + \frac{q_{b2}-q_{a2}}{3}$. Second-period quality levels are $q^*_{a2} = \frac{5}{21} - \frac{\theta_1}{7} + \frac{8q_{a1}-q_{b1}}{7}$ and $q^*_{b2} = \frac{2}{21} + \frac{\theta_1}{7} + \frac{8q_{b1}-q_{a1}}{7}$. The first-period marginal consumer is located at θ_1. We have

$$\begin{aligned} v - \theta_1 + q_{a1} - p_{a1} + [v - (1-\theta_1) + q^{e*}_{b2} - p^{e*}_{bn} - s] &= v - (1-\theta_1) + q_{b1} - p_{b1} + [v - \theta_1 + q^{e*}_{a2} - p^{e*}_{an} - s] \\ \theta_1 &= \frac{1}{2} + \frac{2(q_{a1}-q_{b1})}{9} + \frac{7(p_{b1}-p_{a1})}{18}. \end{aligned} \tag{A106}$$

The total profits that firms maximize in the first period are

$$\Pi_{at} = p_{a1}\theta_1 + \Pi^*_{a2} - q^2_{a1}, \tag{A107}$$
$$\Pi_{bt} = p_{b1}(1-\theta_1) + \Pi^*_{b2} - q^2_{b1}. \tag{A108}$$

We solve for the first-period equilibrium prices and obtain $p^*_{a1} = \frac{4}{3} + \frac{8(q_{a1}-q_{b1})}{25} - \frac{2s}{3}$ and $p^*_{b1} = \frac{4}{3} + \frac{8(q_{b1}-q_{a1})}{25} - \frac{2s}{3}$. The first-period equilibrium quality levels are $q^*_{a1} = q^*_{b1} = \frac{19}{75}$. We summarize the rest of the equilibrium outcomes in Table 3 of the paper.

A4.2 Main Model

When both firms customize quality and consumers incur switching costs, the second-period marginal consumers are

$$v - \theta_a + q_{ao} - p_{ao} = v - (1-\theta_a) + q_{bn} - p_{bn} - s, \tag{A109}$$
$$\theta_a = \frac{1+s}{2} + \frac{q_{ao}-q_{bn}}{2} - \frac{p_{ao}-p_{bn}}{2}. \tag{A110}$$

$$v - \theta_b + q_{an} - p_{an} - s = v - (1-\theta_b) + q_{bo} - p_{bo}, \tag{A111}$$

$$\theta_b = \frac{1-s}{2} + \frac{q_{an} - q_{bo}}{2} - \frac{p_{an} - p_{bo}}{2}. \tag{A112}$$

Firms' profit functions in the second period are

$$\Pi_{a2} = p_{ao}\theta_a + p_{an}(\theta_b - \theta_1) - \gamma\left[(q_{ao} - q_{a1})^2 + (q_{an} - q_{a1})^2\right], \tag{A113}$$
$$\Pi_{b2} = p_{bo}(1-\theta_b) + p_{bn}(\theta_1 - \theta_a) - \gamma\left[(q_{bo} - q_{b1})^2 + (q_{bn} - q_{b1})^2\right]. \tag{A114}$$

Second-period prices are $p^*_{ao} = \frac{q_{ao}-q_{bn}}{3} + \frac{2\theta_1}{3} + \frac{1+s}{3}$, $p^*_{an} = \frac{q_{an}-q_{bo}}{3} - \frac{4\theta_1+s}{3} + 1$, $p^*_{bo} = \frac{q_{bo}-q_{an}}{3} - \frac{2\theta_1}{3} + 1 + \frac{s}{3}$, and $p^*_{bn} = \frac{q_{bn}-q_{ao}}{3} + \frac{4\theta_1}{3} - \frac{1+s}{3}$. Then, we solve for the second-period quality and obtain $q^*_{ao} = \frac{8q_{a1}-q_{b1}+1+s}{7} + \frac{4\theta_1}{21}$, $q^*_{an} = \frac{8q_{a1}-q_{b1}-s}{7} + \frac{1}{3} - \frac{10\theta_1}{21}$, $q^*_{bo} = \frac{8q_{b1}-q_{a1}+s}{7} + \frac{1}{3} - \frac{4\theta_1}{21}$, and $q^*_{bn} = \frac{8q_{b1}-q_{a1}-1-s}{7} + \frac{10\theta_1}{21}$.

The first-period marginal consumer at θ_1 is solved as follows:

$$v - \theta_1 + q_{a1} - p_{a1} + [v - (1-\theta_1) + q^{e*}_{bn} - p^{e*}_{bn}] = v - (1-\theta_1) + q_{b1} - p_{b1} + [v - \theta_1 + q^{e*}_{an} - p^{e*}_{an}],$$
$$\theta_1 = \frac{1}{2} - \frac{21(p_{a1} - p_{b1})}{40} + \frac{3(q_{a1} - q_{b1})}{10}. \tag{A115}$$

Firms set first-period quality and prices to maximize the following profit functions:

$$\Pi_{at} = p_{a1}\theta_1 + \Pi^*_{a2} - q^2_{a1}, \tag{A116}$$
$$\Pi_{bt} = p_{b1}(1-\theta_1) + \Pi^*_{b2} - q^2_{b1}. \tag{A117}$$

First-period prices are $p^*_{a1} = \frac{20-16s}{21} + \frac{28(q_{a1}-q_{b1})}{83}$ and $p^*_{b1} = \frac{20-16s}{21} - \frac{28(q_{a1}-q_{b1})}{83}$. First-period quality levels are $q^*_{a1} = q^*_{b1} = \frac{62}{249}$. The rest of the equilibrium outcomes are summarized in Table 3. In equilibrium, $\theta^*_a = \frac{5+3s}{15}$, $\theta^*_1 = \frac{1}{2}$, and $\theta^*_b = \frac{9-3s}{15}$. The equilibrium consumption pattern holds if $\theta^*_a < \theta^*_1 < \theta^*_b$ that requires $s < \frac{2}{3}$.

We can verify that $q^*_{ao} - q^*_{an} = \frac{1+2s}{7}$ and $p^*_{ao} - p^*_{an} = \frac{3+6s}{7}$. Thus, firms reward repeat customers on the quality dimension and reward new customers on the price dimension. Comparison of profits in two periods show that second-period profits are higher, first-period profits are lower, and total profits are lower with quality customization. Therefore, all results in the main model continue to hold.

A5 Firm and Consumer Patience

Let δ_f and δ_c represent the discounting factor of the firms and consumers. We analyze the benchmark model with BBP and main model with quality differentiation. When firms and consumers discount the second-period outcome, the second-period equilibrium stay the same as without discounting. Thus, we focus on analyzing the first-period decisions.

A5.1 Benchmark Model

The first-period marginal consumer is located at θ_1. With consumer discounting, we have

$$v - \theta_1 + q_{a1} - p_{a1} + \delta_c\left[v - (1-\theta_1) + q^{e*}_{b2} - p^{e*}_{bn} - s\right] =$$

$$\begin{aligned} v-(1-\theta_1)+q_{b1}-p_{b1}+\delta_c\left[v-\theta_1+q^{e*}_{a2}-p^{e*}_{an}-s\right] \\ \theta_1=\frac{1}{2}-\frac{3\delta_c(q_{a1}-q_{b1})+7(p_{a1}-p_{b1}+q_{b1}-q_{a1})}{7+2\delta_c} \end{aligned} \tag{A118}$$

The total profits that firms maximize in the first period are

$$\Pi_{at} = p_{a1}\theta_1+\Pi^*_{a2}-q^2_{a1}, \tag{A119}$$
$$\Pi_{bt} = p_{b1}(1-\theta_1)+\Pi^*_{b2}-q^2_{b1}. \tag{A120}$$

We solve for the first-period equilibrium prices and quality and obtain $q^*_{a1}=q^*_{b1}=\frac{686+273\delta_f-98\delta_c-608\delta_f^2+363\delta_c\delta_f-84\delta_c^2}{84(49+14\delta_c-38\delta_f)}$. In equilibrium, the first-period price is $p^*_{a1}=p^*_{b1}=\frac{2\delta_c}{7}+\frac{\delta_f}{21}+1$.

A5.2 Main Model

Again, the second-period analysis is the same as in the main model because firm and consumer discounting does not affect the second-period decisions. The first-period marginal consumer at θ_1 is solved as follows:

$$\begin{aligned} v-\theta_1+q_{a1}-p_{a1}+\delta_c\left[v-(1-\theta_1)+q^{e*}_{bn}-p^{e*}_{bn}\right] &= v-(1-\theta_1)+q_{b1}-p_{b1}+\delta_c\left[v-\theta_1+q^{e*}_{an}-p^{e*}_{an}\right], \\ \theta_1=\frac{1}{2}-\frac{3\left[3\delta_c(q_{a1}-q_{b1})+7(p_{a1}-p_{b1}+q_{b1}-q_{a1})\right]}{21-\delta_c} \end{aligned} \tag{A121}$$

Firms set first-period quality and prices to maximize the following profit functions:

$$\Pi_{at} = p_{a1}\theta_1+\Pi^*_{a2}-q^2_{a1}, \tag{A122}$$
$$\Pi_{bt} = p_{b1}(1-\theta_1)+\Pi^*_{b2}-q^2_{b1}. \tag{A123}$$

First-period equilibrium quality levels are $q^*_{a1}=q^*_{b1}=\frac{9261+189\delta_c^2+1656\delta_c\delta_f-7424\delta_f^2-4410\delta_c+4200\delta_f}{42(1323-63\delta_c-928\delta_f)}$. Equilibrium first-period prices are $p^*_{a1}=p^*_{b1}=1-\frac{\delta_c}{21}$.

A5.3 Verification of Main Results

With firm and consumer patience, proposition 1 remains the same as the second-period outcomes do not change. To see this, $q^{*CC}_{ao}-q^{*CC}_{an}=\frac{1}{7}$, $p^{*CC}_{ao}-p^{*CC}_{an}=\frac{3}{7}$, and $\Pi^{*CC}_{a2}-\Pi^{*PP}_{a2}=\frac{23}{1764}$. Proposition 2 holds as $p^{*CC}_{a1}-p^{*PP}_{a1}=-\frac{\delta_c}{3}-\frac{\delta_f}{21}<0$ and $\Pi^{*CC}_{at}-\Pi^{*PP}_{at}=\frac{U_1}{7056(63\delta_c+928\delta_f-1323)^2(14\delta_c-38\delta_f+49)^2}<0$, where $U_1=244268136\delta_c^5\delta_f+2382098985\delta_c^4\delta_f^2-115298991136\delta_c^3\delta_f^3+3807147008\delta_c^2\delta_f^4+396852592264\delta_c\delta_f^5-9148386246\delta_c^5-27535138596\delta_c^4\delta_f-461875993332\delta_c^3\delta_f^2+905390869712\delta_c^2\delta_f^3-15415744296 96\delta_c\delta_f^4-1068956221440\delta_f^5+319477828320\delta_c^4+19148285620 8\delta_c^3\delta_f-3752254963786\delta_c^2\delta_f^2+7858122606432\delta_c\delta_f^3+4408688414720\delta_f^4-143183135592\delta_c^3+515640656790 0\delta_c^2\delta_f-15993413416036\delta_c\delta_f^2-452079659696\delta_f^3-2364819724764\delta_c^2+14728301634816\delta_c\delta_f-3500373505510\delta_f^2-5126298229584\delta_c+8531886656160\delta_f-386633673468<0$. $CS^{*CC}-CS^{*PP}=\frac{U_2}{1764(63\delta_c+928\delta_f-1323)(14\delta_c-38\delta_f+49)}>0$, where $U_2=484659\delta_c^3\delta_f+738528\delta_c^2\delta_f^2+532728\delta_c^3+5677805\delta_c^2\delta_f-19901192\delta_c\delta_f^2-2962176\delta_f^3-9322740\delta_c^2+55604857\delta_c\delta_f+7812168\delta_f^2-$

$391555508\delta_c - 5092521\delta_f$. $SW^{*CC} - SW^{*PP} = \frac{U_3}{3528(63\delta_c+928\delta_f-1323)^2(14\delta_c-38\delta_f+49)^2} > 0$, where $U_3 = 1099206612\delta_c^5\delta_f + 13957694541\delta_c^4\delta_f^2 - 30058089600\delta_c^3\delta_f^3 - 48279755776\delta_c^2\delta_f^4 + 396852259264\delta_c\delta_f^5 + 24893568\delta_c^5 - 211892112l8\delta_c^4\delta_f + 714911742 44\delta_c^3\delta_f^2 + 219317898352\delta_c^2\delta_f^3 - 2007694442816\delta_c\delta_f^4 + 1020207267784\delta_f^5 - 871274880\delta_c^4 - 424137130 20\delta_c^3\delta_f - 2918983254 18\delta_c^2\delta_f^2 + 3137673510 72\delta_c\delta_f^3 - 5629341777792\delta_f^4 + 3964300704\delta_c^3 + 65020703076\delta_c^2\delta_f - 659430090444\delta_c\delta_f^2 + 11658561054 56\delta_f^3 + 640387036 80\delta_c^2 - 2201881036 32\delta_c\delta_f - 10740670159 31\delta_f^2 + 1344812777 28\delta_c + 3713800100 22\delta_f > 0$ for $\delta_c, \delta_f \in [0, 1]$.

Table A2: Equilibrium Outcomes ($\gamma = \frac{1}{2}$)

	Without Targeting	Benchmark Model (BBP)	Main Model
Second-Period Quality	q^*_{a2}: 0.510	q^*_{a2}: 0.420	q^*_{ao}: 0.487 q^*_{an}: 0.344
First-Period Quality	q^*_{a1}: 0.344	q^*_{a1}: 0.253	q^*_{a1}: 0.249
Second-Period Prices	p^*_{a2}: 1.000	p^*_{ao}: 0.667 p^*_{an}: 0.333	p^*_{ao}: 0.714 p^*_{an}: 0.286
First-Period Prices	p^*_{a1}: 1.000	p^*_{a1}: 1.333	p^*_{a1}: 0.952
Second-Period Profits(Π^*_{a2})	0.472	0.250	0.263
First-Period Profits (Π^*_{a1})	0.382	0.602	0.414
Total Profits (Π^*_{at})	0.854	0.852	0.677
Consumer Surplus (CS^*)	18.354	18.229	18.610
Social Welfare (SW^*)	20.062	19.934	19.965

Figure A1: Firms Do Not Target Customers