# Should Price Data Be Shared?

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**Abstract**

Modern firms frequently discreetly offer consumers prices that are not visible to competitors but can be (and are often) voluntarily shared. What are the consequences of such information sharing? In this paper, we consider a model of behavior-based pricing (BBP) in which firms collect consumers' purchase history in the first period, recognize new and repeat consumers, and offer each consumer a price according to her purchase history in the second period. We analyze two regimes: the transparency regime under which firms can observe their competitors' prices and the non-transparency regime under which they cannot. We find that, first, price transparency raises the first-period prices and alleviates price competition, which benefits firms but at the expense of their consumers. Second, we find that, when firms endogenously make their data-sharing decisions, they always share their pricing data. Third, we consider a scenario with endogenous product decisions and find that price transparency increases the horizontal differentiation of products, which further alleviates market competition and benefits firms at the consumers' expense. Collectively, these results underscore the unintended negative consequences of sharing pricing data and recommend public policymakers to take a strong stance in regulating this now-common practice.

**Keywords:** Data sharing, behavior-based pricing, transparency, competition.

# 1 Introduction

In the age of big data, firms across a wide range of industries use information technologies such as internet cookies, click-stream data, loyalty rewards, automatic data-gathering devices, and facial recognition to collect, store, and analyze their consumers' digital footprints for personalized pricing. In particular, firms collect purchase history data to implement behavior-based pricing (BBP), the practice of classifying consumers as repeat or new clients and offering each a different price through, for instance, personalized mobile coupons (Fudenberg and Tirole, 2000; Fudenberg and Villas-Boas, 2006). BBP has been adopted across multiple industries, including online retailing and travel (Streitfeld, 2000; Seaney, 2013).

In practice, personalized prices are often not transparent to all market participants (Allender et al., 2021; Hajihashemi et al., 2022). For instance, the U.S. retailer Sam's Club employs checkout applications that deliver individualized prices to customers without them noticing or knowing each other's offers. The UK chain store B&Q offers electronic price tags that can change the price of an item based on the customer considering it (Rigby, 2013). The U.S. grocer Kroger is piloting a project called "Digital Shelf Edge," which uses data analytics to provide product recommendations and custom pricing discreetly through mobile devices (Allender et al., 2021; Peterson, 2018). The U.S. department store Neiman Marcus informs specific consumers of secret sales and whispered discounts through emails (Rosenbloom, 2009). In each of these situations, firms offer a consumer an individualized price unobserved by other firms or consumers.

However, new and expanding data exchange practices are beginning to shift this landscape. That is, firms can now leverage third-party platforms and associations to voluntarily share and exchange data, including actual transaction prices that consumers pay (Feasey and de Streel, 2020). For example, retailers often partner with market research companies such as Nielsen to share scanner data, which can be further acquired by other competing firms. In the car-dealing industry, TrueCar provides the actual prices of past customer transactions. The development of blockchain technology also allows firms to truthfully record and share their transaction data (Guo, 2024). And, in addition to pushing personalized prices, mobile apps can now be leveraged to directly share firms' data. For example, Android Developers Tools allow an app to send and receive data from other apps on a voluntary basis.[1] Some apps even sell their consumers' personal data to others through data brokers (Osorio, 2024).

In certain cases, e-commerce platforms now even mandate the sharing of price data among third-party sellers, providing in-platform services that reveal pricing information. Amazon's Product Opportunity Explorer, for instance, offers sellers detailed analyses of their competitors' actual prices and sales histories. Similarly, Booking.com gives hotel owners access to the *Competitive Set Report*, which delivers comprehensive insights into their competitors' pricing and promotional strategies. These practices collectively make pricing data increasingly transparent to market participants.

Despite the increasing prevalence of price data sharing, it remains unclear how this practice influences firms' pricing strategies and market competition — an area this paper seeks to explore. Specifically, we address three critical questions: (1) How does price transparency impact firms' pricing strategies, consumer surplus, and overall social welfare? (2) Are firms inclined to voluntarily share data with their competitors? (3) In what ways does price transparency influence product design decisions? By answering these questions, we aim to not only help firms refine their pricing and product design decisions but also inform platforms and public policymakers of the consequences that price data sharing has on social welfare and consumer surplus. This is particularly relevant in light of recent policy regulations such as the Data Governance Act of the European Commission.[2] This act aims to "provide a framework to enhance trust in voluntary data sharing for the benefit of businesses and citizens." However, it also acknowledges the potential competitive risks associated with sharing sensitive data, which must be regulated. For instance, Article 37 of the Act states:

[1] https://developer.android.com/training/sharing/send

[2] https://digital-strategy.ec.europa.eu/en/policies/data-governance-act

> *"Data intermediation services providers should also take measures to ensure compliance with competition law and have procedures in place to that effect. This applies in particular in situations where data sharing enables undertakings to become aware of market strategies of their actual or potential competitors. Competitively sensitive information typically includes information on customer data, future prices, production costs, quantities, turnovers, sales or capacities."*

While future prices are explicitly categorized as competitively sensitive, the Data Governance Act does not inform the sharing of price data from past or existing transactions. Similarly, in the U.S., sharing future prices is a clear violation under the Sherman Antitrust Act, but antitrust laws do not appear to take a position on the sharing of past prices. This paper aims to fill this gap by examining the relationship between price data sharing and market competition, offering guidance on whether sharing should be regulated and, if so, how.

To study the role of price transparency, we develop a game-theoretic model in which two duopolistic firms compete over two periods. We consider two regimes, a transparency regime and a non-transparency regime, depending on whether or not the firms' first-period prices are transparent. In the first period, each firm charges a specific price to each new consumer. Under the transparency regime, one firm's first-period price is observed by its rival. Under the non-transparency regime, however, the first-period price remains unrevealed and unobserved. In the second period, both firms observe their consumers' first-period purchase decisions and each other's first-period price under the transparency regime (but not under the non-transparency regime) and offer each customer a personalized price once more. We then compare equilibrium outcomes across the two regimes to investigate the implications of price transparency on firm profits and consumer surplus.

Note that, under the transparency regime, a firm's second-period price hinges on both the consumer's first-period purchase decision and its rival's first-period price while, under the non-transparency regime, a firm's second-period price cannot depend on its rival's first-period price, which is unobserved by the focal firm.

Using our model characteristics, we make a number of noteworthy findings. We first find that, while price transparency has no effect on the second-period equilibrium outcome, it alleviates price competition in the first period. Under the transparency regime, if a consumer purchases at a high price in the first period, then both firms compete more fiercely for this consumer in the second period. Therefore, a consumer is more tolerant of a high first-period price to benefit from the fierce price competition in the second-period. Under the non-transparency regime, however, the firms do not respond as much to the first-period prices in the second period, so consumers are less tolerant of a high first-period price. As a result, both first-period prices and firm profits are higher but consumer surplus is lower under the transparency regimes. When market participants are patient and uniformly distributed, price transparency can lead to a 36% improvement in firm profits.

Second, we endogenize the firms' data-sharing decisions by allowing them to choose whether to share their price data with their rivals before engaging in price competition. We find that both firms voluntarily share their price data. The rationale is that, when revealing its price data, a firm has less incentive to cut its first-period price, which is observed by its rival. In this case, price transparency helps the firm commit to a higher price, thus softening price competition and benefiting both firms. This result explains why a growing number of firms voluntarily engage in price data sharing and suggests that regulatory measures should be taken to protect consumers against this practice.

Third, we extend the model by allowing firms to endogenously choose their product positioning before selling to consumers. We find that price transparency once again damages consumer surplus. When prices are transparent, firms design more differentiated products that distance themselves from consumer tastes. This effect not only hurts consumer surplus but also decreases total social welfare. Our results suggest that the exchange of price information between firms (e.g., through blockchain technologies or data platforms) can undermine consumer surplus, and, as such, public policymakers should take a firm stance against it. Collectively, our results underscore the non-trivial effects of price transparency.

## 2 Related Literature

This study builds on the literature on information transparency. McAfee and Schwartz (1994) study the effect of contract (non)transparency on an upstream firm's pricing decision and find that, when a downstream firm cannot observe the contracts offered to other downstream firms, it will have an opportunistic incentive to cut prices, which backfires on its own profit. Meanwhile, Allender et al. (2021) analyze the effect of price nontransparency on consumers' perception of price fairness and observe that price nontransparency effectively reduces peer-induced fairness concerns and increases firms' pricing power. Considering the pricing of network goods under personalized pricing, Hajihashemi et al. (2022) show that, with nontransparent prices, personalization can reduce consumer demand and hurt firm profits. Examining the implication of transparent transaction records on negotiations surrounding transfer prices in a supply chain, Guo (2024) shows that transparency can serve as a commitment device and endogenously yield a first-mover advantage in the timing of negotiations. Rossi and Chintagunta (2016) empirically investigate how mandatory price-posting affects the pricing behaviors of competing gas stations on an Italian highway system and find that transparency intensifies market competition and lowers prices.

In addition to price transparency, researchers have investigated the effects of transparency on other sources of information. For instance, Gavazza and Lizzeri (2009) consider a model of political competition in which voters imperfectly observe the electoral promises made to other voters; they show that imperfect observability results in excessive transfers and government spending, thereby offering one explanation for fiscal churning. Xiong and Yang (2020) consider the transparency of information acquisition in final markets, revealing that, depending on the information acquisition cost, competing investors may more or less acquire information when that acquisition is transparent. Finally, Mohan et al. (2020) argue that cost transparency fosters trust and increases consumers' willingness to pay.

Our paper is also related to the literature on BBP. A series of research has established that BBP works to a firm's detriment, be it in a monopoly or a duopoly. The rationale is that, in a monopoly, consumers with high valuations purchase early, and the firm finds it optimal to charge such consumers a higher price in a later period. Anticipating this, consumers have incentives to postpone their purchases to enjoy a low price offered to new consumers in the second period, a result known as the ratchet effect. Thus, the firm must reduce its first-period prices to induce strategic consumers to buy early, which decreases the firm's profit to the point that it would have been better off not using consumer data at all (Villas-Boas, 2004; Acquisti and Varian, 2005). Li et al. (2020) investigate a monopolistic firm's incentive to implement BBP when this decision is not observed by consumers; they show that, when the implementation cost is low, the firm cannot help but implement BBP even if doing so ultimately backfires on its profit. While Li et al. (2020) focuses on the transparency of BBP's implementation decision, we examine the transparency of competing firms' pricing decisions under market competition. To the best of our knowledge, Choe et al. (2022) is the only other paper that has examined data sharing in a market with BBP, although they focus on the sharing of consumers' horizontal preference (location) data while we examine the sharing of pricing data.

In a duopoly, BBP leads competing firms to poach each other's consumers. Competition intensifies in the second period, and total firm profits decline from what would have been without BBP (Villas-Boas, 1999; Fudenberg and Tirole, 2000). Zhang (2011) further shows that, when firms customize their products' horizontal attributes, profits become even lower than when firms only practice BBP.

Research has also identified scenarios in which BBP can be profitable for firms, namely when consumers have heterogeneous demand and their preferences change over time (Shin and Sudhir, 2010), asymmetric firms determine product quality (Jing, 2017), consumers care about price fairness (Li and Jain, 2020), competing products are vertically differentiated (Rhee and Thomadsen, 2017), both manufacturers and retailers use BBP (Li, 2018), consumers are sufficiently averse to loss on match quality (Amaldoss and He, 2019). The above-mentioned papers all assume that prices are transparent, i.e., a firm's price offers are public information and observed by all market participants. We diverge from this assumption by directly considering the effects of price transparency on market competition, firm profits, and consumer surplus.

# 3 The Model

We consider a simplistic model in which two firms sell repeat-purchase products to a consumer over two periods.[3] For the moment, we assume that the designs (or locations) of the products are exogenously given. This situation is better suited for established products entering a new market or products with inflexible designs. The consumer has unit demand for either product per period. Let $v$ denote the consumer's base value of the product. Following the literature, we assume that $v$ is sufficiently large to ensure complete market coverage (Fudenberg and Tirole, 2000; Zhang, 2011).

The consumer's location, $x$, is randomly drew from a uniform distribution over a Hotelling interval between 0 and 1. The two firms, $A$ and $B$, are located symmetrically on the Hotelling interval. Assume without loss of generality that firm $A$ is located at $y < \frac{1}{2}$ and firm $B$ is located at $1 - y$.[4] The consumer incurs a disutility of taste misfit (or a transportation cost) when consuming a product that is away from her ideal location. More specifically, if the consumer purchases from firm $A$ at price $a$, she derives a utility, $v - \theta(x - y)^2 - a$, in that period, where $\theta \geq 0$ represents the extent of product misfit.[5] If

[3] As the firms can offer customized prices to individual consumers, each consumer represents a separate market and it suffices to consider one representative consumer. All our results go through when the market contains a finite number of consumers.

[4] When $y = 0$, this model reverts to a standard model in which the two firms are located at either end of the Hotelling interval. Although the assumption of symmetric locations is not necessary to obtain our results, it does simplify our analysis substantially.

[5] The quadratic taste misfit cost guarantees the flexibility of firm locations, which is commonly used in

the consumer purchases from firm $B$ at price $b$, she derives a utility, $v - \theta(1 - y - x)^2 - b$, in that period. We assume that the firms and consumer discount future payoffs at the same rate and let $0 < \delta \leq 1$ denote the common discount factor. Our results remain qualitatively unchanged when the firms and consumer discount future payoffs at different rates.

**Behavior-based Pricing**. In the first period, neither firm can assess the consumer's preference beyond prior distribution. Let $a_1$ and $b_1$ be the first-period prices offered to the consumer by firms $A$ and $B$, respectively. Following the literature on BBP (Fudenberg and Tirole, 2000), we assume that both firms collect the consumer's purchase history data and condition their second-period prices accordingly. That is, in the second period, the firms make their price offerings to the consumer using data on her first-period purchase decisions. The reason for firms to implement BBP has been well-studied in the literature and is beyond the scope of the present paper. Li et al. (2020) show that firms cannot help but to implement BBP when the implementation cost is low.

More specifically, firm $A$ offers the consumer a price $a_{2r}$ if she purchased from firm $A$ in the first period and a price $a_{2n}$ if she purchased from firm $B$ in the first period. Similarly, firm $B$ offers the consumer a price $b_{2r}$ or $b_{2n}$ depending on whether or not she is a previous consumer.

**Price Transparency**. We consider two regimes depending on whether the firms' prices are transparent or not. Under the transparency regime, the firms' first-period prices are transparent:[6] after first-period pricing decisions are made, firm $A$ observes firm $B$'s first-period price, $b_1$, and vice versa. Under the non-transparency regime, however, a firm's first-period price remain unrevealed and unobserved by the rival firm, i.e., firm $A$ does not observe $b_1$, and firm $B$ does not observe $a_1$. The non-transparency regime captures a scenario in which, using personalization technology, a firm offers the consumer a cus-

the literature (Zhang, 2011; Li et al., 2024). It ensures that, for any location choice of the two firms, a pure-strategy equilibrium exists. A pure-strategy equilibrium may not exist when two firms are located closely enough to each other under other cost functions such as linear cost. See d'Aspremont et al. (1979) for a detailed discussion.

[6]In our model, it is not consequential whether the second-period prices are transparent or not.

tomized price that is observed by the firm but not by the rival firm (Hajihashemi et al., 2022; Allender et al., 2021). For instance, a firm may offer the consumer a coupon via its mobile app or email, which is typically not observed by rival firms. The transparency regime, by contract, captures scenarios in which firms' price data are shared through information technologies or third parties.

Under BBP, price transparency is likely to influence the firms' second-period pricing decisions: With price transparency, a firm can condition its second-period price on both the consumer's first-period purchase decision and its rival firm's first-period price. In other words, $a_{2r}$ and $a_{2n}$ can depend on the realization of $b_1$. Without price transparency, however, a firm cannot condition its second-period price on the rival firm's first-period price.

We now derive equilibrium outcomes under the two regimes and, through comparison, investigate the implications of price transparency on the two firms and the consumer.

## 3.1 The Transparency Regime

We now analyze a case in which both firms' first-period prices are transparent. Such a game has been explored in extant literature (Fudenberg and Tirole, 2000), so we describe the analysis and intuitions only briefly herein.

We use superscript $t$ to denote the transparency regime. Let $x_1^t$ be the first-period indifference location; that is, the consumer purchases from firm $A$ in the first period if her location is $x \leq x_1^t$ and purchases from firm $B$ otherwise.

We work backward to solve the game. First, consider the second period: If the consumer purchased from firm $A$ in the first period, firm $A$ offers this consumer a second-period price $a_{2r}^t$ whereas firm $B$ offers her a second-period price $b_{2n}^t$. The consumer purchases from firm $A$ if and only if $x \leq x_{2A}^t$, where the second-period indifference condition is characterized by

$$v - \theta(x_{2A}^t - y)^2 - a_{2r}^t = v - \theta(1 - y - x_{2A}^t)^2 - b_{2n}^t.$$

Solving for $x_{2A}^t$, we obtain that

$$x_{2A}^t = \frac{1}{2} - \frac{a_{2r}^t - b_{2n}^t}{2\theta(1-2y)}.$$

If the consumer purchased from firm $B$ in the first period, firm $A$ offers the consumer a second-period price, $a_{2n}^t$, whereas firm $B$ offers her a second-period price, $b_{2r}^t$. The consumer purchases from firm $A$ if and only if $x \leq x_{2B}^t$, where the indifference condition is given by

$$v - \theta(x_{2B}^t - y)^2 - a_{2n}^t = v - \theta(1 - y - x_{2B}^t)^2 - b_{2r}^t.$$

Solving for $x_{2B}^t$, we obtain that

$$x_{2B}^t = \frac{1}{2} - \frac{a_{2n}^t - b_{2r}^t}{2\theta(1-2y)}.$$

In sum, if $x \leq x_{2A}^t$, the consumer purchases from firm $A$ in both periods. If $x_{2A}^t < x \leq x_1^t$, she purchases from firm $A$ in the first period and switches to firm $B$ in the second period. If $x_1^t < x \leq x_{2B}^t$, she purchases from firm $B$ in the first period and switches to firm $A$ in the second period. Finally, if $x > x_{2B}^t$, she purchases from firm $B$ in both periods. Thus, the firms' expected second-period profits are

$$\pi_{2A}^t = x_{2A}^t a_{2r}^t + (x_{2B}^t - x_1^t) a_{2n}^t,$$

$$\pi_{2B}^t = (x_1^t - x_{2A}^t) b_{2n}^t + (1 - x_{2B}^t) b_{2r}^t.$$

Optimizing the firms' second-period profits yields the their optimal second-period prices:

$$\begin{aligned} a_{2r}^t &= \tfrac{(1-2y)(1+2x_1^t)\theta}{3}, \;\; a_{2n}^t = \tfrac{(1-2y)(3-4x_1^t)\theta}{3}, \\ b_{2r}^t &= \tfrac{(1-2y)(3-2x_1^t)\theta}{3}, \;\; b_{2n}^t = \tfrac{(1-2y)(4x_1^t-1)\theta}{3}. \end{aligned} \tag{1}$$

Now, consider the first period, in which the indifference condition is characterized by

$$v - a_1^t - \theta(x_1^t - y)^2 + \delta(v - b_{2n}^t - \theta(1 - y - x_1^t)^2) = v - b_1^t - \theta(1 - y - x_1^t)^2 + \delta(v - a_{2n}^t - \theta(x_1^t - y)^2). \tag{2}$$

On the left-hand side of Equation (2), $v - a_1^t - \theta(x_1^t - y)^2$ is the consumer's payoff when purchasing from firm $A$ in the first period, and $\delta(v - b_{2n}^t - \theta(1 - y - x_1^t)^2)$ is her discounted payoff when switching to firm $B$ in the second period. Likewise, on the right-hand side, $v - b_1^t - \theta(1 - y - x_1^t)^2$ is the consumer's payoff when purchasing from firm $B$ in the first period, and $\delta(v - a_{2n}^t - \theta(x_1^t - y)^2)$ is her discounted payoff when switching to firm $A$ in the second period.

Solving the consumer's first-period purchase decision, we obtain

$$x_1^t = \frac{1}{2} - \frac{3(a_1^t - b_1^t)}{2\theta(3 + \delta)(1 - 2y)}.$$

Plugging $x_1^t$ into the firms' second-period prices yields

$$\begin{aligned} a_{2r}^t &= \tfrac{2\theta(1-2y)}{3} - \tfrac{a_1^t - b_1^t}{3+\delta}, \quad a_{2n}^t = \tfrac{\theta(1-2y)}{3} + \tfrac{2(a_1^t - b_1^t)}{3+\delta}, \\ b_{2r}^t &= \tfrac{2\theta(1-2y)}{3} + \tfrac{a_1^t - b_1^t}{3+\delta}, \quad b_{2n}^t = \tfrac{\theta(1-2y)}{3} - \tfrac{2(a_1^t - b_1^t)}{3+\delta}. \end{aligned} \tag{3}$$

Lemma 1 follows immediately from Equation (3).

**Lemma 1** *Suppose that both firms practice BBP, and prices are transparent.*

(1) *An increase in $a_1$ intensifies the second-period price competition for firm $A$'s existing consumer but alleviates competition for firm $B$'s existing consumer, i.e.,*

$$\frac{\partial a_{2r}^t}{\partial a_1^t} < 0, \ \frac{\partial b_{2n}^t}{\partial a_1^t} < 0, \ \frac{\partial b_{2r}^t}{\partial a_1^t} > 0, \ \frac{\partial a_{2n}^t}{\partial a_1^t} > 0.$$

(2) *For the first-period demand,*

$$\left|\frac{\partial x_1^t}{\partial a_1^t}\right| = \left|\frac{\partial(1 - x_1^t)}{\partial b_1^t}\right| = \frac{3}{2\theta(3 + \delta)(1 - 2y)}.$$

Part (1) of Lemma 1 suggests that an increase in $a_1^t$ has asymmetric effects on second-period competition for an existing consumer: It reduces $a_{2r}^t$ and $b_{2n}^t$, thereby intensifying competition for firm $A$'s existing consumer. At the same time, it increases $b_{2r}^t$ and $a_{2n}^t$, thereby alleviating competition for firm $B$'s existing consumer.

The intuition is as follows. Suppose that firm $A$ increases $a_1^t$ a bit. If the consumer is still willing to purchase from firm $A$ in the first period despite the elevated $a_1^t$, she must have a strong preference for firm $A$'s product. That is, the first-period indifference location, $x_1^t$, is left-shifting. It follows that firm $A$'s first-period turf $[0, x_1^t]$ becomes less differentiated. As a result of the reduced differentiation, both firms compete more fiercely for a consumer who bought from firm $A$ in the first period, resulting in both lower $a_{2r}^t$ and $b_{2n}^t$. By contrast, firm $B$'s first-period turf $(x_1^t, 1]$ becomes more differentiated with a decrease in $x_1^t$. This slackens the second-period competition and increases both $a_{2n}^t$ and $b_{2r}^t$.

Part (2) of Lemma 1 shows how first-period demand changes with first-period prices. Under BBP, a consumer must take her second-period payoff into account when making her first-period purchase decision. Here, second-period competition exerts two countervailing effects on the consumer's first-period purchase decision. First, if the consumer is relatively indifferent between the two products (i.e., she is located around the center of the Hotelling line), she will purchase from different firms across the two periods. That is, if she purchases product $A$ in the first period, she will switch to product $B$ in the second period, and vice versa. In this case, the consumer is less sensitive to her first-period transportation cost: If she saves in the first period, she will expend greater transportation costs in the second period, which offsets her first-period savings. In the extreme case where $\delta = 1$, the consumer's total discounted transportation cost is always $(x_1^t + 1 - x_1^t)\theta = \theta$, which is independent of her first-period purchase decision. Given that the consumer is less sensitive about her first-period transportation cost, the differentiation between the firms shrinks, and, as a result, the first-period consumer demand becomes more elastic to the firms' first-period prices. We refer to this effect as the "*differentiation-reduction effect*."

Second, under the transparency regime, the consumer's first-period purchase decision affects her second-period prices. Consider, again, the effect of an increase in $a_1^t$. If the consumer purchases from firm $A$ in the first period, according to part (1) of Lemma 1, the firms compete more fiercely for her business in the second period (i.e., $\frac{\partial a_{2r}^t}{\partial a_1^t} < 0, \frac{\partial b_{2n}^t}{\partial a_1^t} < 0$), which benefits the consumer. However, if the consumer purchases from firm $B$ in the first period, the firms compete less fiercely for her in the second period (i.e., $\frac{\partial a_{2n}^t}{\partial a_1^t} > 0, \frac{\partial b_{2r}^t}{\partial a_1^t} > 0$), which hurts the consumer. Given these strategic effects, the consumer may be willing to pay the high $a_1^t$ to purchase from firm $A$ in the first period to take advantage of fiercer price competition in the second period. As such, the first-period consumer demand is less elastic to the firms' first-period prices. We refer to this effect as the "*pricing effect*." This and the differentiation-reduction effect together determine the firms' first-period demand elasticity.

Next, we move to the first period in which the firms choose prices that maximize their total discounted profits across both periods: $\pi_A^t = a_1^t x_1^t + \delta\pi_{2A}^t, \pi_B^t = b_1^t(1 - x_1^t) + \delta\pi_{2B}^t$. Solving the firms' profit-maximization problems leads to their equilibrium strategies, as outlined in the following proposition. We use the superscript $^*$ to denote equilibrium outcomes.

**Proposition 1** *When both firms practice BBP and prices are transparent, equilibrium prices are*

$$a_1^{t*} = b_1^{t*} = \frac{(3+\delta)\theta(1-2y)}{3}, \;\; a_{2r}^{t*} = b_{2r}^{t*} = \frac{2\theta(1-2y)}{3}, \;\; a_{2n}^{t*} = b_{2n}^{t*} = \frac{\theta(1-2y)}{3}.$$

*Equilibrium profits are*

$$\pi_A^{t*} = \pi_B^{t*} = \frac{(9\theta + 8\delta\theta)(1-2y)}{18}.$$

*Equilibrium consumer surplus is*

$$CS^{t*} = (1+\delta)v - \frac{\theta(39 + 37\delta - 90y - 86\delta y + 36(1+\delta)y^2)}{36}.$$

The proof is provided in the appendix.

## 3.2 The Non-transparency Regime

In this section, we analyze a scenario in which both firms practice BBP and their first-period prices are non-transparent. We then compare the equilibrium outcomes of the transparency and non-transparency regimes to investigate their effects.

We use superscript $n$ to denote the non-transparency regime. We assume that there exists an equilibrium in which the firms charge the consumer prices $a_1^{n*}$ and $b_1^{n*}$, respectively, in the first period and that the equilibrium second-period prices are

$$a_2^{n*} = \begin{cases} a_{2r}^{n*} & \text{if the consumer purchased from firm } A \text{ in the first period;} \\ a_{2n}^{n*} & \text{if the consumer purchased from firm } B \text{ in the first period,} \end{cases}$$

$$b_2^{n*} = \begin{cases} b_{2r}^{n*} & \text{if the consumer purchased from firm } B \text{ in the first period;} \\ b_{2n}^{n*} & \text{if the consumer purchased from firm } A \text{ in the first period.} \end{cases}$$

Next, we characterize the equilibrium. Because neither firm observes its rival's first-period price, our game falls into games of imperfect information, and we resort to the solution concept of a perfect Bayesian equilibrium.

Note that, in equilibrium, the consumer may purchase from either firm in the first period, so both purchase decisions (i.e., the consumer's choice to purchase from firm $A$ or $B$ in the first period) are along the equilibrium path. In this sense, we need not be concerned about the off-equilibrium beliefs, and a firm should not update its belief regarding its rival's first-period price upon observing the consumer's first-period purchase decision. As such, firm $A$ ($B$) believes that $b_1^n = b_1^{n*}$ ($a_1^n = a_1^{n*}$) in the second period regardless of the consumer's first-period purchase.

### 3.2.1 Equilibrium Characterization

We now derive the firms' equilibrium strategies. To guarantee equilibrium, we must ensure that firm $A$ has no incentive to deviate from its equilibrium strategy, $a_1^n = a_1^{n*}$, in the first period, provided that firm $B$ follows its equilibrium strategy, $b_1^n = b_1^{n*}$. Suppose that firm $A$ charges the consumer a first-period price, $a_1^n$, and let $x_1^n$ represent the indifferent location in the first period. As discussed above, firm $B$ does not observe $a_1^n$, thus its second-period pricing strategies do not depend on it. In other words, firm $B$ charges the consumer a price $b_2^n = b_{2r}^{n*}$ if the consumer purchases from firm $B$ in the first period and a price $b_2^n = b_{2n}^{n*}$ if she purchases from firm $A$ in the first period. Meanwhile, firm $A$'s second-period price can hinge on its own first-period price, $a_1^n$.

Now consider firm $A$'s second-period pricing decision. If the consumer purchased from firm $A$ in the first period, then firm $B$ charges her price $b_2^n = b_{2n}^{n*}$ in the second period. Let $x_{2A}^n$ be the location of the second-period indifferent consumer. It follows immediately that $x_{2A}^n$ solves

$$v - \theta(x_{2A}^n - y)^2 - a_{2r} = v - \theta(1 - y - x_{2A}^n)^2 - b_{2n}^{n*}.$$

Solving for the indifference condition, we observe

$$x_{2A}^n = \frac{1}{2} - \frac{a_{2r}^n - b_{2n}^{n*}}{2\theta(1-2y)}.$$

In this case, firm $A$'s expected profit from its previous consumer is $\pi_{2Ar}^n = x_{2A}^n a_{2r}^n$. Firm $A$ chooses $a_{2r}^n$ to maximize this profit, which yields

$$a_{2r}^n = \frac{b_{2n}^{n*} + \theta(1-2y)}{2}.$$

On the other hand, if the consumer purchased from firm $B$ in the first period, then firm $B$ charges the consumer a price $b_2^n = b_{2r}^{n*}$ in the second period. Let $x_{2B}^n$ be the location of the second-period indifferent consumer. It follows immediately that $x_{2B}^n$ solves

$$v - \theta(x_{2B}^n - y)^2 - a_{2n}^n = v - \theta(1 - y - x_{2B}^n)^2 - b_{2r}^{n*}.$$

Solving for the indifference condition, we find

$$x_{2B}^{n} = \frac{1}{2} - \frac{a_{2n}^{n} - b_{2r}^{n*}}{2\theta(1-2y)}.$$

In this case, firm $A$'s expected profit from the new consumer is $\pi_{2An}^{n} = (x_{2B}^{n} - x_{1}^{n})a_{2n}^{n}$. Firm $A$ chooses $a_{2n}^{n}$ to maximize this profit, which yields

$$a_{2n}^{n} = \frac{b_{2r}^{n*} + \theta(1-2y)}{2} - \theta(1-2y)x_{1}^{n}.$$

In sum, the firm $A$'s expected second-period profit is

$$\pi_{2A}^{n} = \pi_{2Ar}^{n} + \pi_{2An}^{n} = \frac{(b_{2n}^{n*} + \theta(1-2y))^2 + (b_{2r}^{n*} + \theta(1-2y) - 2\theta(1-2y)x_{1}^{n})^2}{8\theta}.$$

Consider now the first period, the indifference condition, $x_{1}^{n}$, of which is characterized by

$$v - a_{1}^{n} - \theta(x_{1}^{n} - y)^2 + \delta(v - b_{2n}^{n*} - \theta(1-y-x_{1}^{n})^2) = v - b_{1}^{n*} - \theta(1-y-x_{1}^{n})^2 + \delta(v - a_{2n}^{n} - \theta(x_{1}^{n} - y)^2). \tag{4}$$

The left-hand side of Equation (4) denotes the consumer's total payoff when purchasing from firm $A$ in the first period. In this case, the consumer switches to firm $B$ and pays $b_{2n}^{n*}$ in the second period. Meanwhile, the right-hand side is the consumer's total payoff when purchasing from firm $B$ in the first period. In this case, the consumer switches to firm $A$ and pays $a_{2n}$ in the second period. Solving for the indifference condition yields

$$x_{1}^{n} = \frac{2(b_{1}^{n*} + \theta(1-2y)) - 2a_{1}^{n} - \delta(2b_{2n}^{n*} - b_{2r}^{n*} + \theta(1-2y))}{2\theta(2-\delta)(1-2y)}.$$

Plugging $x_1$ into the firms' second-period pricing decision, we generate

$$a_{2r}^{n} = \frac{b_{2n}^{n*} + \theta(1-2y)}{2}, \quad a_{2n}^{n} = \frac{a_{1}^{n} - b_{1}^{n*} + b_{2r}^{n*} + b_{2n}^{n*}\delta - b_{2r}^{n*}\delta}{2-\delta}.$$

Lemma 2 follows immediately:

**Lemma 2** *Suppose that both firms practice BBP, and prices are non-transparent.*

(1) *An increase in $a_1^n$ raises $a_{2n}^n$ but has no effect on $a_{2r}^n$, i.e.,*

$$\frac{\partial a_{2r}^n}{\partial a_1^n} = 0, \ \frac{\partial a_{2n}^n}{\partial a_1^n} > 0.$$

(2) *Compared to the transparency regime, first-period demand is more elastic to first-period prices, i.e.,*

$$\left|\frac{\partial x_1^n}{\partial a_1^n}\right| = \frac{1}{\theta(2-\delta)(1-2y)} > \left|\frac{\partial x_1^t}{\partial a_1^t}\right| = \frac{3}{2\theta(3+\delta)(1-2y)}.$$

Consider part (1) first. With an increase in $a_1^n$, the consumer may purchase product $B$ in the first period for two possible reasons: (1) she prefers product $B$, or (2) she prefers product $A$ but is deterred by the elevated price, $a_1^n$. Given that the consumer may still prefer product $A$, firm $A$ need not cut its second-period price, $a_{2n}^n$, too aggressively to poach this consumer in the second period. As a result, $a_{2n}^n$ increases with $a_1^n$. And, because firm $B$ does not observe or respond to $a_1^n$, it always charges the equilibrium poaching price, $b_{2n}^n = b_{2n}^{n*}$, if the consumer purchases from firm $A$ in the first period. Because $b_{2n}^n$ does not change, firm $A$ need not adjust $a_{2r}^n$ to retain its consumer either. As a result, $a_{2r}^n$ is constant with $a_1^n$.

Now, consider part (2). As described earlier, under BBP, the consumer takes her second-period payoff into account when making her first-period purchase decision. Again, the second-period game affects the consumer's first-period purchase decision through two countervailing forces: the differentiation-reduction effect, which makes the first-period demand more elastic, and the pricing effect, which makes the first-period demand less elastic.

Under both regimes, the consumer purchases from different firms and travels to different locations over two periods if she is located around the center of the Hotelling line. Therefore, the differentiation-reduction effect remains the same under both regimes.

As for the pricing effect, under transparent prices, $x_1^t$ decreases accordingly when $a_1^t$

increases. Two forces drive the consumer to be less sensitive to changes in the first-period price $a_1^t$. First, firm $A$'s turf $[0, x_1^t]$ becomes less differentiated as $a_1^t$ increases. As a result, both firms compete more fiercely in the second period, thereby decreasing $a_{2r}^t$ and $b_{2n}^t$. Anticipating this, the consumer is willing to tolerate an increased $a_1^t$ in exchange for a lower second-period price $b_{2n}^t$. Mathematically, this is represented as

$$\frac{\partial b_{2n}^t}{\partial a_1^t} = -\frac{2}{3+\delta}, \ \frac{\partial a_{2r}^t}{\partial a_1^t} = -\frac{1}{3+\delta}.$$

Second, firm $B$'s turf $[x_1^t, 1]$ becomes more differentiated when $a_1^t$ increases, which slackens the second-period competition and increases $a_{2n}^t$ and $b_{2r}^t$. As a result, the consumer is less willing to purchase from firm $B$ in the first period, because otherwise she must pay higher prices in the second period. Mathematically, this is represented as

$$\frac{\partial a_{2n}^t}{\partial a_1^t} = \frac{2}{3+\delta}, \ \frac{\partial b_{2r}^t}{\partial a_1^t} = \frac{1}{3+\delta}.$$

As an increased $a_{2n}^t$ and decreased $b_{2n}^t$ reduce the consumer's demand elasticity, the total pricing effect under the transparency regime is

$$\left|\frac{\partial a_{2n}^t}{\partial a_1^t}\right| + \left|\frac{\partial b_{2n}^t}{\partial a_1^t}\right| = \frac{4}{3+\delta}.$$

When prices are non-transparent, however, firm $B$ does not respond to an increase in $a_1^n$ when offering prices to a new customer. Given that $b_{2n}^n$ does not respond to $a_1^n$, firm $A$ need not update its $a_{2r}^n$ either. As such, the pricing effect under the non-transparency regime only results from a change in $a_{2n}^n$. Therefore, the pricing effect under the non-transparency regime is minimized:

$$\frac{\partial a_{2n}^n}{\partial a_1^n} = \frac{1}{2-\delta} < \frac{4}{3+\delta}.$$

Thus, the consumer is more tolerant of a higher $a_1^t$ when prices are transparent because

(1) by purchasing from $A$ at $t = 1$, she secures a lower price from firm $B$ at $t = 2$; and (2) by purchasing from $B$ at $t = 1$, she suffers a higher price from firm $A$ at $t = 2$. When prices are non-transparent, however, only the second force remains, and the first force vanishes. As a result, the magnitude of the pricing effect is minimized under the non-transparency regime, making the first-period demand more elastic to the first-period prices.

Next, we solve for the equilibrium outcome. In the first period, firm $A$ chooses $a_1^n$ to maximize its total profit across both periods, i.e., $\pi_A^n = a_1^n x_1^n + \delta \pi_{2A}^n$. To ensure equilibrium, firm $A$'s profit must be maximized at $a_1^n = a_1^{n*}$, i.e., $a_1^{n*} = \arg\max_{a_1^n} \pi_A^n$. Applying the first-order conditions yields

$$a_1^{n*} = \frac{4(b_1^{n*} + \theta(1-2y)) - 4(b_1^{n*} + b_{2n}^{n*} - b_{2r}^{n*} + \theta(1-2y))\delta + (4b_{2n}^{n*} - 3b_{2r}^{n*} + \theta(1-2y))\delta^2}{8 - 6\delta}.$$

Similarly, for firm $B$, we have

$$b_1^{n*} = \frac{4(a_1^{n*} + \theta(1-2y)) - 4(a_1^{n*} + a_{2n}^{n*} - a_{2r}^{n*} + \theta(1-2y))\delta + (4a_{2n}^{n*} - 3a_{2r}^{n*} + \theta(1-2y))\delta^2}{8 - 6\delta}.$$

Solving firms' profit-maximization problems yields their equilibrium strategies, as outlined in the following proposition.

**Proposition 2** *When both firms practice BBP, and prices are not-transparent, equilibrium prices are*

$$a_{2r}^{n*} = b_{2r}^{n*} = \frac{2\theta(1-2y)}{3}, \quad a_{2n}^{n*} = b_{2n}^{n*} = \frac{\theta(1-2y)}{3}, \quad a_1^{n*} = b_1^{n*} = \frac{(6-\delta)\theta(1-2y)}{6}.$$

*Equilibrium profits are*

$$\pi_A^{n*} = \pi_B^{n*} = \frac{(18\theta + 7\delta\theta)(1-2y)}{36}.$$

*Equilibrium consumer surplus is*

$$CS^{n*} = (1+\delta)v - \frac{\theta(39 + 19\delta - 90y - 50\delta y + 36(1+\delta)y^2)}{36}.$$

The proof is provided in the appendix. Table 1 summarizes the equilibrium strategies and outcomes under different regimes.

| | Transparency | Non-transparency |
|---|---|---|
| $a_1, b_1$ | $\frac{(3+\delta)\theta(1-2y)}{3}$ | $\frac{(6-\delta)\theta(1-2y)}{6}$ |
| $a_{2r}, b_{2r}$ | $\frac{2\theta(1-2y)}{3}$ | $\frac{2\theta(1-2y)}{3}$ |
| $a_{2n}, b_{2n}$ | $\frac{\theta(1-2y)}{3}$ | $\frac{\theta(1-2y)}{3}$ |
| $(x_1, x_{2A}, x_{2B})$ | $(\frac{1}{2}, \frac{1}{3}, \frac{2}{3})$ | $(\frac{1}{2}, \frac{1}{3}, \frac{2}{3})$ |
| $\pi_A, \pi_B$ | $\frac{(9+8\delta)\theta(1-2y)}{18}$ | $\frac{(18+7\delta)\theta(1-2y)}{36}$ |
| CS | $\frac{36(1+\delta)v-\theta(39+37\delta-90y-86\delta y+36(1+\delta)y^2)}{36}$ | $\frac{36(1+\delta)v-\theta(39+19\delta-90y-50\delta y+36(1+\delta)y^2)}{36}$ |

Table 1: Equilibrium strategies and outcomes under different regimes

## 3.3 The Effect of Price Transparency

So far, we have analyzed equilibrium outcomes under BBP when prices are transparent and non-transparent. We now compare these equilibrium outcomes to investigate how price transparency affects prices, firm profits, and consumer surplus. The following proposition summarizes our results:

**Proposition 3** *Under BBP, price transparency alleviates the first-period price competition, benefiting firm profits at the expense of the consumer.*

Figure 1 illustrates the firms' equilibrium first-period prices under the opposing regimes. As can be seen, equilibrium first-period price is higher when prices are transparent. This finding suggests that price transparency significantly alleviates price competition and increases equilibrium first-period prices.

Meanwhile, price transparency has no effect on second-period prices. This is because, regardless of whether prices are transparent or not, in equilibrium, the firms' first-period

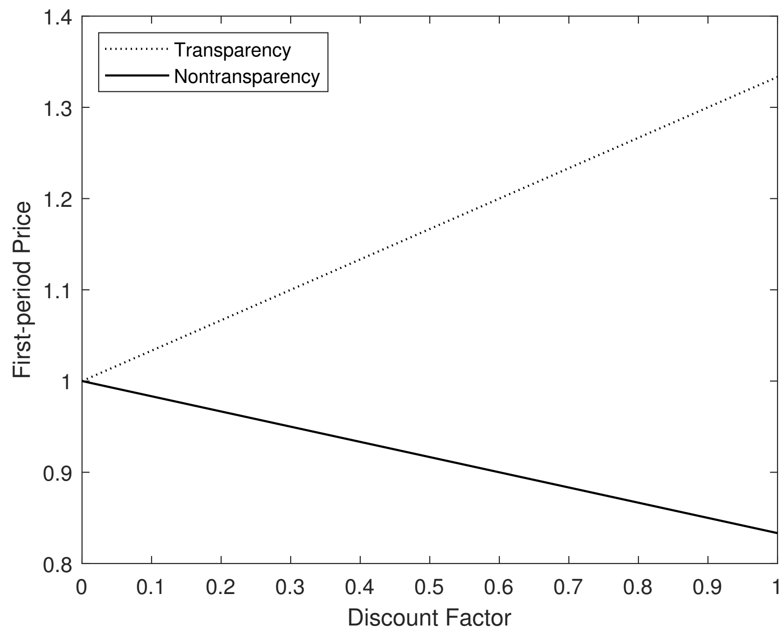


Figure 1: Equilibrium first-period prices ($\theta = 1, y = 0$)

prices are equal, and the indifference location in equilibrium is always $x_1^{n*} = x_1^{t*} = \frac{1}{2}$. As a result, the firms always start with the same market partition in the second period, leading to the same second-period equilibrium prices.

Figure 2 illustrates equilibrium firm profits. In our model, while price transparency does not affect firm profits when firms and consumer are impatient ($\delta = 0$), it leads to substantial profit improvements when market participants are patient. For instance, in our model, when market participants are patient (i.e., $\delta = 1$), price transparency leads to a 36.0% profit improvement for firms who enjoy the significantly reduced first-period price competition. The consumer, on the other hand, suffers from this alleviated competition and the resulting elevated prices.

## 3.4 Endogenous Transparency

Firms often have the power to decide whether or not to share price data with their rivals. For example, the "TrueCar Certified Dealer" program allows car dealers to share their

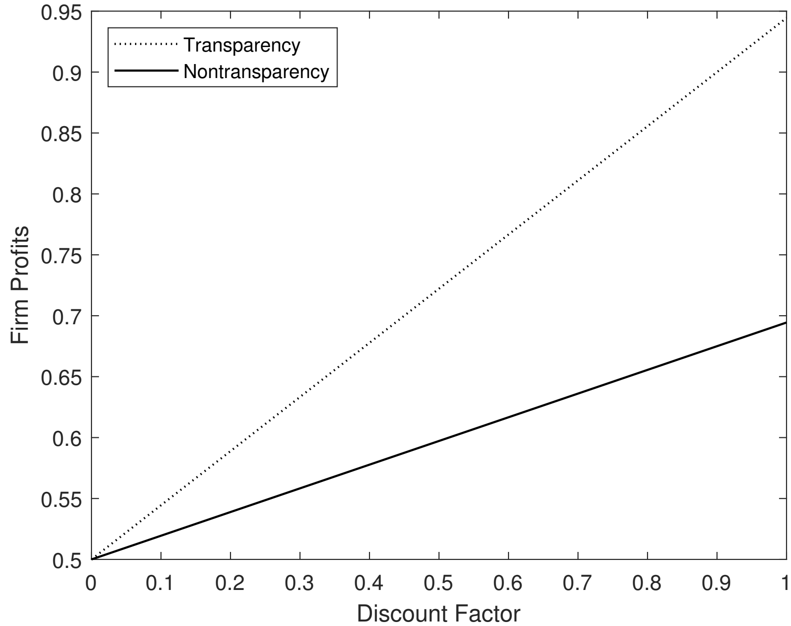


Figure 2: Equilibrium firm profits ($\theta = 1, y = 0$)

transaction data with others (a car dealer can, of course, choose not to participate in the program but still observe their competitors' prices via the platform). One app can also its data with other apps through tools such as the Android Developers Tools.

So, when firms have the discretion to share their data, will they do so? In this section, we answer this question by allowing both firms to choose whether to make their prices transparent to their rivals before engaging in market competition.

In the previous analyses, we examined subgames under which both firms share or withhold their price data, and it suffices to consider the remaining subgame under which firms adopt asymmetric sharing decisions. We use superscript $s$ to denote this subgame, where $s$ stands for "semi-transparent". Without loss of generality, we assume that firm $A$ shares its first-period price, $a_1^s$, with firm $B$, whereas firm $B$ conceals its first-period price $b_1^s$.

Because firm $B$ observes both $a_1^s$ and $b_1^s$, its second-period prices $b_{2r}^s$ and $b_{2n}^s$ can depend on $a_1^s$ and $b_1^s$. As such, we denote its second-period prices to be $b_{2r}^s(a_1^s, b_1^s)$ and $b_{2n}^s(a_1^s, b_1^s)$.

Firm $A$, by contrast, only observes its own first-period price when making its second-period pricing decisions. Because firm $A$ does not observe $b_1^s$, it rationally expects firm $B$'s second-period prices to be $b_{2r}^s(a_1^s, b_1^{s*})$ and $b_{2n}(a_1^s, b_1^{s*})$, where $b_1^{s*}$ is firm $B$'s equilibrium first-period price.

Consider firm $A$'s second-period pricing decision. Let $x_{2A}^s(a_1^s, b_1^{s*})$ be firm $A$'s belief regarding its previous consumer's the second-period indifferent location. Straightforward calculations show that

$$x_{2A}^s(a_1^s, b_1^{s*}) = \frac{1}{2} - \frac{a_{2r}^s(a_1^s, b_1^{s*}) - b_{2n}^s(a_1^s, b_1^{s*})}{2\theta(1-2y)}.$$

If the consumer purchases from firm $A$ at $t = 1$, it chooses $a_{2r}^s(a_1^s, b_1^{s*})$ to maximize its second-period profit. Solving its profit-maximization problem yields

$$a_{2r}^s(a_1^s, b_1^{s*}) = \frac{b_{2n}^s(a_1^s, b_1^{s*}) + \theta(1-2y)}{2}.$$

Similarly, if the consumer buys from firm $B$ in the first period, both firms compete for its purchase at $t = 2$. We have

$$x_{2B}^s(a_1^s, b_1^{s*}) = \frac{1}{2} - \frac{a_{2n}^s(a_1^s, b_1^{s*}) - b_{2r}^s(a_1^s, b_1^{s*})}{2\theta(1-2y)},$$

and firm $A$'s optimal pricing decision is

$$a_{2n}^s(a_1^s, b_1^{s*}) = \frac{b_{2r}^s(a_1^s, b_1^{s*}) + \theta(1-2y)}{2} - \theta(1-2y)x_1^s(a_1^s, b_1^{s*}).$$

Next, we investigate firm $A$'s incentive to deviate in the first period. If firm $A$ charges a price $a_1^s$ in the first period, then the first-period indifference condition, $x_1^s$, will be

$$\begin{aligned} v - a_1^s - \theta(x_1^s(a_1^s, b_1^{s*}) - y)^2 + \delta(v - b_{2n}^s(a_1^s, b_1^{s*}) - \theta(1-y-x_1^s(a_1^s, b_1^{s*}))^2) = \\ v - b_1^{s*} - \theta(1-y-x_1^s(a_1^s, b_1^{s*}))^2 + \delta(v - a_{2n}^s(a_1^s, b_1^{s*}) - \theta(x_1^s(a_1^s, b_1^{s*}) - y)^2). \end{aligned} \tag{5}$$

The left-hand side of Equation (5) denotes the consumer's surplus when buying from $A$ in the first period. In this case, the consumer switches to firm $B$ and pays $b^s_{2n}(a^s_1, b^{s*}_1)$ in the second period. Meanwhile, the right-hand side is the consumer's surplus when buying from firm $B$ in the first period, in which the consumer switches to firm $A$ and pays $a^s_{2n}(a^s_1, b^{s*}_1)$ in the second period. Solving for the indifference condition, we obtain

$$x^s_1(a^s_1, b^{s*}_1) = \frac{2(b^{s*}_1 + \theta(1-2y)) - 2a^s_1 - \delta(2b^s_{2n}(a^s_1, b^{s*}_1) - b^s_{2r}(a^s_1, b^{s*}_1) + \theta(1-2y))}{2\theta(1-2y)(2-\delta)}. \quad (6)$$

Plugging (6) into the second-period pricing decision, we obtain firm $A$'s second-period prices as follows:

$$a^s_{2r}(a^s_1, b^{s*}_1) = \frac{b^s_{2n}(a^s_1, b^{s*}_1) + \theta(1-2y)}{2}, \quad (7)$$

and

$$a^s_{2n}(a^s_1, b^{s*}_1) = \frac{a^s_1 - b^{s*}_1 + b^s_{2r}(a^s_1, b^{s*}_1) + b^s_{2n}(a^s_1, b^{s*}_1)\delta - b^s_{2r}(a^s_1, b^{s*}_1)\delta}{2-\delta}, \quad (8)$$

which depend on $b^s_{2r}(a^s_1, b^{s*}_1)$ and $b^n_{2r}(a^s_1, b^{s*}_1)$.

We now derive firm $B$'s second-period prices. Because firm $B$ observes $a^s_1$, it need not form beliefs regarding it. The second-period indifference condition of its previous consumer is

$$x^s_{2B}(a^s_1, b^s_1) = \frac{1}{2} - \frac{a^s_{2n}(a^s_1, b^{s*}_1) - b^s_{2r}(a^s_1, b^s_1)}{2\theta(1-2y)}.$$

Firm $B$ chooses $b^s_{2r}$ to maximize its profit from the previous consumer, $\pi^s_{2Br} = (1 - x^s_{2B})b^s_{2r}$, which yields

$$b^s_{2r}(a^s_1, b^s_1) = \frac{a^s_{2n}(a^s_1, b^{s*}_1) + \theta(1-2y)}{2}. \quad (9)$$

For its new consumer, the indifference condition is

$$x^s_{2A}(a^s_1, b^s_1) = \frac{1}{2} - \frac{a^s_{2r}(a^s_1, b^{s*}_1) - b^s_{2n}(a^s_1, b^s_1)}{2\theta(1-2y)}.$$

Firm $B$ chooses $b^s_{2n}$ to maximize its profit from the new consumer, $\pi^s_{2Bn} = b^s_{2n}(x^s_1 - x^s_{2A})$, which yields

$$b^s_{2n}(a^s_1, b^s_1) = \frac{a^s_{2r}(a^s_1, b^{s*}_1) - \theta(1-2y)}{2} + \theta(1-2y)x^s_1(a^s_1, b^s_1). \tag{10}$$

Consider firm $B$'s incentive to deviate in the first period. When firm $B$ chooses a first-period price $b^s_1$, the first-period indifference condition is given by

$$v - a^s_1 - \theta(x^s_1(a^s_1, b^s_1) - y)^2 + \delta(v - b^s_{2n}(a^s_1, b^s_1) - \theta(1 - y - x^s_1(a^s_1, b^s_1))^2) =$$
$$v - b^s_1 - \theta(1 - y - x^s_1(a^s_1, b^s_1))^2 + \delta(v - a^s_{2n}(a^s_1, b^{s*}_1) - \theta(x^s_1(a^s_1, b^s_1) - y)^2),$$

It follows immediately that

$$x^s_1(a^s_1, b^s_1) = \frac{2(b^s_1 + \theta(1-2y)) - 2a^s_1 + \delta(2a^s_{2n}(a^s_1, b^{s*}_1) - a^s_{2r}(a^s_1, b^{s*}_1) - \theta(1-2y))}{2\theta(1-2y)(2-\delta)}. \tag{11}$$

Plugging (11) into (10), we rewrite $b^s_{2r}$ and $b^s_{2n}$ as functions of $a^s_{2r}$ and $a^s_{2n}$. Substituting them into Equations (7) and (8), we solve for firm $A$'s optimal second-period prices:

$$a^s_{2n}(a^s_1, b^{s*}_1) = \frac{\theta(1-2y)}{3} + \frac{2(a^s_1 - b^{s*}_1)}{3+\delta}, \;\; a^s_{2r}(a^s_1, b^{s*}_1) = \frac{2\theta(1-2y)}{3} - \frac{a^s_1 - b^{s*}_1}{3+\delta}. \tag{12}$$

Maximizing firm $A$'s total profits with respect to $a^s_1$, we obtain firm $A$'s optimal first-period price:

$$a^{s*}_1(b^{s*}_1) = \frac{b^{s*}_1(9-7\delta) + (3+\delta)^2\theta(1-2y)}{18-4\delta}. \tag{13}$$

Lastly, we solve for the firm $B$'s first-period pricing. If firm $B$ deviates from its equilibrium first-period price and charges $b^s_1$, firm $A$ does not observe this deviation, leaving its second-period pricing strategy unaffected (which is characterized in (12)). Firm $B$'s second-period prices, however, can depend on $b^s_1$. Straightforward calculations show that

$$b^s_{2r}(a^s_1, b^s_1) = \frac{a^s_1 - b^{s*}_1}{3+\delta} + \frac{2\theta(1-2y)}{3}$$

and

$$b_{2n}^s(a_1^s, b_1^s) = \frac{b_1^{s*} - b_1^s}{2-\delta} - \frac{2(a_1^s - b_1^{s*})}{3+\delta} + \frac{\theta(1-2y)}{3}.$$

Maximizing firm $B$'s total profit leads to

$$b_1^s(a_1^s, b_1^{s*}) = \frac{3b_1^{s*}(12-11\delta)\delta + 3a_1^s(2-\delta)(6-7\delta) + (6-\delta)(2-\delta)(3+\delta)\theta(1-2y)}{6(3+\delta)(4-3\delta)}.$$

A perfect Bayesian equilibrium requires beliefs to be rational, i.e., $b_1^s(a_1^{s*}, b_1^{s*}) = b_1^{s*}$. We solve for $b_1^{s*}$ and obtain

$$b_1^{s*}(a_1^{s*}) = \frac{3a_1^{s*}(6-7\delta) + (6-\delta)(3+\delta)\theta(1-2y)}{36-15\delta}. \tag{14}$$

Using Equations (13) and (14), we solve for equilibrium prices $(a_1^{s*}, b_1^{s*})$:

$$a_1^{s*} = \frac{2(81-30\delta-4\delta^2)\theta(1-2y)}{162-87\delta}, \;\; b_1^{s*} = \frac{(162-87\delta-17\delta^2)\theta(1-2y)}{162-87\delta}.$$

And equilibrium firm profits are:

$$\pi_A^s = \frac{(13122-6804\delta-5058\delta^2+2761\delta^3)\theta(1-2y)}{9(54-29\delta)^2},$$

$$\pi_B^s = \frac{(13122-4617\delta-6597\delta^2+2815\delta^3)\theta(1-2y)}{9(54-29\delta)^2}.$$

Now, we have obtained the firms' profits under all subgames. Comparing firm profits across different regimes, we obtain the following proposition.

**Proposition 4** *When faced with whether or not to share their price data, firms always share.*

Proposition 4 uncovers that, when firms can choose whether to share their price data with their rivals, they will always share to benefit from alleviated market competition and higher profits. The consumer, on the other hand, suffers from the alleviated competition and the resulting elevated prices.

Our research offers important implications for public policymakers concerned with information transparency and data sharing. Crémer et al. (2019) of the EC argues that "data sharing and data pooling arrangements will frequently be pro-competitive" but "can become anti-competitive in some situations." They further suggest that more analyses of these practices' pro- and anti-competitive aspects are required to provide policy guidance. Also in the U.S., a debate continues on whether more price information is always a good thing for consumers and competition in markets such as healthcare (Koslov and Jex, 2015). Koslov and Jex of The Federal Trade Commission (FTC) states that, while some state and federal policymakers have promoted price transparency initiatives, too much transparency can harm competition in any market. Likewise, the National Development and Reform Commission (NDRC) of China has expressed concerns regarding the transfer of price information (e.g., through industrial associations) among firms in certain industries. Our study suggests that data sharing and price transparency can raise equilibrium prices, which benefits firms but at the expense of consumer surplus. As such, public policymakers must avoid singularly promoting transparency and instead take a staunch stance against the sharing of price data among firms to promote healthy competition and protect consumer surplus.

Lastly, it is worth mentioning that blockchain technology can facilitate the exchange and validation of information between different market participants and, accordingly, improve price transparency. As noted by Guo (2024), with blockchains, complete transaction records are not only inherently accessible but can also be verified easily and at low costs. As such, this modern technology increases the transparency of transaction attributes among all participants. Our analysis reveals that, despite their various benefits including enhancing product safety and combating counterfeits, blockchains may make prices too transparent, thereby softening market competition and ultimately hurting consumers. Policymakers must take this effect into consideration when designing regulations for blockchain technology.

# 4 Product Positioning

While our basic model assumes that the locations of their products are exogenously fixed at $(y, 1-y)$, firms in practice often strategize their product positioning before engaging in price competition. This positioning decision is not only relevant to competition and pricing but, more importantly, directly affects social welfare. In this section, we extend our model by allowing firms to endogenously position their products before engaging in market competition and examine how price transparency affects the firms' positioning decisions.

We add a period $t = 0$ to the basic model in which firms $A$ and $B$ simultaneously choose their locations, $x_A, x_B \in \mathbb{R}$, on the Hotelling line. Although the consumer is located within the closed interval $[0, 1]$, we allow the firms to position their products outside that interval (Tyagi, 2000; Zhang, 2011; Liu and Tyagi, 2011; Li et al., 2024). For instance, firms may locate their malls outside the city in which consumers reside or offer products that contain nuisance features (Zhang, 2011). We assume without loss of generality that firm $A$ is positioned to the left of firm $B$, i.e., $x_A \leq x_B$.

We continue to use $t$ to denote the transparency regime, $n$ to denote the non-transparency regime, and $^*$ to denote equilibrium outcomes. We compare the equilibrium outcome under the transparency and non-transparency regimes when product positions are endogenized. For brevity, we relegate the analysis to the appendix and summarize the results in the following proposition.

**Proposition 5** *When firms can endogenously position their products,*

1. *Compared to the non-transparency regime, products are more differentiated under the transparency regime. That is,* $|x_A^t - x_B^t| > |x_A^n - x_B^n|$.

2. *Compared to the non-transparency regime, social welfare is lower, firms' profits are higher, and consumer surplus is lower under the transparency regime.*

Table 2 summarizes the equilibrium strategies and profits under different regimes.

| | Non-transparency | Transparency |
|---|---|---|
| $(x_A, x_B)$ | $\left(\frac{-6-\delta}{12(2+\delta)}, \frac{30+13\delta}{12(2+\delta)}\right)$ | $\left(\frac{-81-63\delta+28\delta^2}{324+108\delta-120\delta^2}, \frac{405+171\delta-148\delta^2}{324+108\delta-120\delta^2}\right)$ |
| $a_1, b_1$ | $\frac{\theta(6-\delta)(18+7\delta)}{36(2+\delta)}$ | $\frac{\theta(9+8\delta)(81-6\delta-11\delta^2)}{18(27+9\delta^2-10\delta^2)}$ |
| $a_{2r}, b_{2r}$ | $\frac{\theta(18+7\delta)}{9(2+\delta)}$ | $\frac{\theta(243+117\delta-88\delta^2)}{9(27+9\delta^2-10\delta^2)}$ |
| $a_{2n}, b_{2n}$ | $\frac{\theta(18+7\delta)}{18(2+\delta)}$ | $\frac{\theta(243+117\delta-88\delta^2)}{18(27+9\delta^2-10\delta^2)}$ |
| $\pi_A, \pi_B$ | $\frac{\theta(18+7\delta)^2}{216(2+\delta)}$ | $\frac{\theta(9+8\delta)^2(27-11\delta)}{108(27+9\delta-10\delta^2)}$ |

Table 2: Equilibrium strategies under endogenous location

Why do firms offer more differentiated products when prices are transparent? A firm takes two effects into consideration when positioning its product: On one hand, when firm $A$ positions its product further away from the center of the Hotelling line (i.e., when $x_A$ decreases), the consumer, on average, must expend higher transportation costs to purchase its product. This *distance-increasing effect* hurts the firm. On the other hand, when firm $A$ moves to the left, it also goes further away from firm $B$'s location, and the two products become more differentiated, thereby dampening market competition. This *competition-reduction effect* benefits the firm. The same logic also applies to firm $B$. When positioning their products, firms must carefully balance these two effects.

We now compare these two effects under the two regimes. First, the distance-increasing effect remains unchanged across the regimes, given that the consumer always expends the same unit transportation cost when making a purchase. Second, as discussed earlier, compared to the transparency regime, the firms compete more fiercely under the non-transparency regime, which significantly erodes firm profits. As such, even with the competition-reduction effect growing profits under both regimes, this growth is suppressed under the non-transparency regime, i.e., the competition-reduction effect is weakened under the non-transparency regime (the growth of a smaller pie is less than the growth of a bigger pie). Combining the above two effects, the firms are willing to offer more differentiated products under the transparency regime to take advantage of a more effective competition-reduction effect.

Our result uncovers another benefit of price transparency for firms: In addition to alleviating price competition, price transparency further increases the horizontal differentiation of the firms' products, which again softens price competition and leaves the firms better off. As for the consumer, she must manage higher prices and transportation costs and is unambiguously worse off.

In addition to harming the consumer, price transparency's overall impact on social welfare is negative because it leads to inefficiently high levels of product differentiation. For example, in our model, when $\delta = 1$, the products are positioned at $(x_A^n, x_B^n) \approx (-0.194, 1.194)$ under the non-transparency regime but $(x_A^t, x_B^t) \approx (-0.372, 1.372)$ under the transparency regime. This excessive product differentiation significantly raises the consumer's transportation costs, creating a deadweight loss that ultimately lowers social welfare.

Our findings on product design offer insights for both managers and public policymakers. We suggest firm managers to take price (non)transparency into consideration when designing their products: in a market where prices are transparent (non-transparent), they should design more (less) differentiated products. Our results also recommend public policymakers to pay extra attention to markets in which product designs are relatively flexible and form transparency laws and regulations that encourage healthy competition and improve consumer surplus and social welfare.

Lastly, note that our results continue to hold when the firms endogenously make their data-sharing decisions. That is, when the two firms decide on both production positioning and data sharing, they always share their price data and offer more differentiated products, thereby hurting consumer surplus and social welfare. This result, again, cautions public policymakers to take measures to regulate the sharing of price data.

# 5 Concluding Remarks

With advancements in information technologies and big data analytics, firms can now offer personalized prices to individual consumers, e.g., through mobile apps. These prices target individual consumers and typically are not observed by other firms. Nonetheless, firms may voluntarily share their pricing data with other firms, thereby making the prices transparent.

This paper studies the effect of price transparency on market competition when firms practice BBP. Our analysis suggests that price transparency has significant implications for equilibrium outcomes, alleviating market competition to improve firm profits but harming consumers in the process.

Under BBP, when a consumer purchases from a particular firm at a high (low) price in the first period, the firms compete more (less) fiercely for that same consumer in the second period. This pricing effect is more salient when prices are transparent and a firm can respond to its rival's first-period price deviation and less salient when prices are non-transparent and a firm does not observe or respond to its rival's price deviation. As a result, price transparency alleviates market competition, thereby improving firm profits at the expense of consumers.

We further find that, when firms can endogenously choose their positioning of products before engaging in price competition, price transparency increases the horizontal differentiation between the firms' products, which improves firm profits but decreases consumer surplus. This result highlights another peril of price transparency. Our findings indicate that increased price transparency can negatively impact consumer surplus and social welfare. Additionally, we find that firms tend to voluntarily share price data of existing transactions with competitors (e.g., through blockchain technology), which can undermine competitive practices. Therefore, regulatory policies such as the Data Governance Act should not only restrict the sharing of future prices but also address the competitive risks associated with sharing past prices. We also advise firms to consider the competitive implications of price transparency in their pricing strategies and overall decision-making.

Our work can be extended in a number of directions. For instance, our paper focuses on the effects of price transparency under BBP, and future research may investigate these effects on other scenarios. In addition, while we study firms' marketing decisions such as pricing and product positioning, researchers can extend this work to explore how price transparency affects other decisions such as advertising and product quality. Lastly, in our paper, consumers are rational and maximize their expected payoff; it would be of interest to consider scenarios in which consumers are subject to behavioral biases such as price fairness.

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# A Technical Details

## A.1 Proof of Proposition 1

In the first period, firm $A$ chooses $a_1^t$ to maximize $\pi_A^t = a_1^t x_1^t + \delta \pi_{2A}^t$. The first-order condition yields that

$$\frac{b_1^t(9-7\delta) - 2a_1^t(9-2\delta) + \theta(1-2y)(3+\delta)^2}{2\theta(1-2y)(3+\delta)^2} = 0. \tag{15}$$

Similarly, the first-order condition for firm $B$ is

$$\frac{a_1^t(9-7\delta) - 2b_1^t(9-2\delta) + \theta(1-2y)(3+\delta)^2}{2\theta(1-2y)(3+\delta)^2} = 0. \tag{16}$$

Solving Equations (15) and (16), we obtain that $a_1^{t*} = b_1^{t*} = \frac{(3+\delta)\theta(1-2y)}{3}$. Plugging them into Equation (3) yields that

$$a_{2r}^{t*} = b_{2r}^{t*} = \frac{2\theta(1-2y)}{3}, \;\; a_{2n}^{t*} = b_{2n}^{t*} = \frac{\theta(1-2y)}{3},$$

and the corresponding firm profits are $\pi_A^{t*} = \pi_B^{t*} = \frac{(9\theta+8\delta\theta)(1-2y)}{18}$. Consumer surplus is

$$CS^{t*} = (1+\delta)v - \frac{\theta(39+37\delta-90y-86\delta y+36(1+\delta)y^2)}{36}.$$

This completes the proof. □

## A.2 Proof of Proposition 2

As discussed in the paper, firms $A$ and $B$ solve a system of six equations:

$$\begin{cases} a_1^{n*} &= \frac{4(b_1^{n*}+\theta(1-2y))-4(b_1^{n*}+b_{2n}^{n*}-b_{2r}^{n*}+\theta(1-2y))\delta+(4b_{2n}^{n*}-3b_{2r}^{n*}+\theta(1-2y))\delta^2}{8-6\delta}, \\ b_1^{n*} &= \frac{4(a_1^{n*}+\theta(1-2y))-4(a_1^{n*}+a_{2n}^{n*}-a_{2r}^{n*}+\theta(1-2y))\delta+(4a_{2n}^{n*}-3a_{2r}^{n*}+\theta(1-2y))\delta^2}{8-6\delta}, \\ a_{2r}^{n*} &= \frac{b_{2n}^{n*}+\theta(1-2y)}{2}, \\ a_{2n}^{n*} &= \frac{a_1^{n*}-b_1^{n*}+b_{2r}^{n*}+\delta(b_{2n}^{n*}-b_{2r}^{n*})}{2-\delta}, \\ b_{2r}^{n*} &= \frac{a_{2n}^{n*}+\theta(1-2y)}{2}, \\ b_{2n}^{n*} &= \frac{b_1^{n*}-a_1^{n*}+a_{2r}^{n*}+\delta(a_{2n}^{n*}-a_{2r}^{n*})}{2-\delta}. \end{cases} \tag{17}$$

Solving Equation (17), we find

$$a_{2r}^{n*} = b_{2r}^{n*} = \frac{2\theta(1-2y)}{3}, \;\; a_{2n}^{n*} = b_{2n}^{n*} = \frac{\theta(1-2y)}{3}, \;\; a_1^{n*} = b_1^{n*} = \frac{(6-\delta)\theta(1-2y)}{6},$$

and the corresponding firm profits are $\pi_A^{n*} = \pi_B^{n*} = \frac{9\theta+8\delta\theta}{18}$. Consumer surplus is

$$CS^{n*} = (1+\delta)v - \frac{\theta(39+19\delta-90y-50\delta y+36(1+\delta)y^2)}{36}.$$

This completes the proof. □

## A.3 Proof of Proposition 3

Firm profits are

$$\pi_A^{n*} - \pi_A^{t*} = \frac{18\theta+7\delta\theta}{36}(1-2y) - \frac{9\theta+8\delta\theta}{18}(1-2y) = -\frac{\delta\theta}{4}(1-2y) \leq 0.$$

Consumer surplus is

$$CS^{n*} - CS^{t*} = \frac{\delta\theta(1-2y)}{2} \geq 0.$$

This completes the proof. □

## A.4 Analysis of BBP with Endogenous Product Positioning

### A.4.1 Transparency Regime

Let $x_1^t$ be the first-period indifference location and $x_{2A}^t$ and $x_{2B}^t$ be the second-period indifference locations, where $x_{2A}^t < x_1^t < x_{2B}^t$. The first-period prices are denoted by $(a_1^t, b_1^t)$ whereas the second-period prices are denoted by $(a_{2r}^t, a_{2n}^t, b_{2r}^t, b_{2n}^t)$. We solve the game using backward induction.

First, consider the second period. Given the firms' locations, $x_A^t$ and $x_B^t$, $x_{2A}^t$ is determined by

$$v - \theta(x_{2A}^t - x_A^t)^2 - a_{2r}^t = v - \theta(x_B^t - x_{2A}^t)^2 - b_{2n}^t,$$

which yields

$$x_{2A}^t = \frac{x_A^t + x_B^t}{2} - \frac{a_{2r}^t - b_{2n}^t}{2\theta(x_B^t - x_A^t)}.$$

Similarly, for $x_{2B}^t$, we have

$$v - \theta(x_{2B}^t - x_A^t)^2 - a_{2n}^t = v - \theta(x_B^t - x_{2B}^t)^2 - b_{2r}^t,$$

which leads to

$$x_{2B}^t = \frac{x_A^t + x_B^t}{2} - \frac{a_{2n}^t - b_{2r}^t}{2\theta(x_B^t - x_A^t)}.$$

Consider the firms' second-period profit-maximization problem. Firm $A$ chooses $a_{2r}^t$ and $a_{2r}^n$ to maximize $\pi_{2A}^t = x_{2A}^t a_{2r}^t + (x_{2B}^t - x_1^t)a_{2n}^t$, whereas firm $B$ chooses $b_{2r}^t$ and $b_{2n}^t$ to maximize $\pi_{2B}^t =$

$(x_1^t - x_{2A}^t)b_{2n}^t + (1 - x_{2B}^t)b_{2r}^t$. Solving the firms' profit-maximization problem, we find

$$\begin{cases} a_{2r}^t &= \frac{(x_B^t - x_A^t)(x_A^t + x_B^t + 2x_1^t)\theta}{3}, \\ a_{2n}^t &= \frac{(x_B^t - x_A^t)(2 + x_A^t + x_B^t - 4x_1^t)\theta}{3}, \\ b_{2r}^t &= \frac{(x_B^t - x_A^t)(4 - x_A^t - x_B^t - 2x_1^t)\theta}{3}, \\ b_{2n}^t &= \frac{(x_B^t - x_A^t)(4x_1^t - x_A^t - x_B^t)\theta}{3}, \end{cases} \tag{18}$$

Now, consider the first period. The indifference condition is characterized by

$$v - a_1^t - \theta(x_1^t - x_A^t)^2 + \delta(v - b_{2n}^t - \theta(x_B^t - x_1^t)^2) = v - b_1^t - \theta(x_B^t - x_1^t)^2 + \delta(v - a_{2n}^t - \theta(x_1^t - x_A^t)^2). \tag{19}$$

Plugging $a_{2n}^t$ and $b_{2n}^t$ from (18) into Equation (19), we obtain

$$x_1^t = \frac{3(x_A^t + x_B^t) + \delta(2 - x_A - x_B)}{2(3+\delta)} - \frac{3(a_1^t - b_1^t)}{2\theta(3+\delta)(x_B^t - x_A^t)}. \tag{20}$$

Plugging (20) into (18), we can write $a_{2r}^t, a_{2n}^t, b_{2r}^t$, and $b_{2n}^t$ as functions of $a_1^t$ and $b_1^t$. Now consider the firms' first-period optimization problem. Firm $A$'s total profit over two periods is $\pi_A^t = a_1^t x_1^t + \delta\pi_{2A}^t$ while firm $B$'s is $\pi_B^t = b_1^t(1 - x_1^t) + \delta\pi_{2B}^t$. The first-order condition dictates that

$$\begin{cases} \frac{\partial \pi_A^t}{\partial a_1^t} &= \frac{9(x_A^t + x_B^t) + 2\delta(7 - 4x_A^t - 4x_B^t) + \delta^2(3x_A^t + 3x_B^t - 2)}{2(3+\delta)^2} - \frac{a_1^t(18 - 4\delta) + b_1^t(9 - 7\delta)}{2\theta(3+\delta)^2(x_B^t - x_A^t)} = 0, \\ \frac{\partial \pi_B^t}{\partial b_1^t} &= \frac{9(2 - x_A^t - x_B^t) + 2\delta(4x_A^t + 4x_B^t - 1) + \delta^2(4 - 3x_A^t + 3x_B^t)}{2(3+\delta)^2} - \frac{b_1^t(18 - 4\delta) + a_1^t(9 - 7\delta)}{2\theta(3+\delta)^2(x_B^t - x_A^t)} = 0. \end{cases} \tag{21}$$

Solving Equation (21), we obtain

$$\begin{cases} a_1^t &= \frac{\theta(x_B^t - x_A^t)(27(2 + x_A^t + x_B^t) - 6\delta(4x_A^t + 4x_B^t - 3) + \delta^2(9x_A^t + 9x_B^t - 20))}{81 - 33\delta}, \\ b_1^t &= \frac{\theta(x_B^t - x_A^t)(27(4 - x_A^t - x_B^t) - 6\delta(5 - 4x_A^t - 4x_B^t) - \delta^2(9x_A^t + 9x_B^t + 2))}{81 - 33\delta}. \end{cases} \tag{22}$$

Last, we consider the firms' positioning decisions. Substituting (22) into (19), we obtain

$$x_1^t = \frac{9(2 + x_A^t + x_B^t) - \delta(4 + 7x_A^t + 7x_B^t)}{54 - 22\delta}. \tag{23}$$

Then, substituting (23) back into (18), we derive the second-period equilibrium prices. Now, we use the first-order condition to find the firms' optimal positioning decision. Since we focus on symmetric equilibrium, it suffices to check firm $B$'s first-order condition, which is given by

$$\begin{aligned} \frac{\partial \pi_B^t}{\partial x_B^t} &= -\frac{\theta}{18(27 - 11\delta)^2}[729({x_A^t}^2 + 16x_B^t - 2x_A^t x_B^t - 3{x_B^t}^2 - 16) + 162\delta({x_A^t}^2 - 2x_A^t x_B^t - 3{x_B^t}^2 - 2) \\ &\quad -9\delta^2(55{x_A^t}^2 + 712x_B^t - 110x_A^t x_B^t - 165{x_B^t}^2 - 708) + 4\delta^3(36{x_A^t}^2 + 474x_B^t - 72x_A^t x_B^t - 108{x_B^t}^2 - 443)]. \end{aligned} \tag{24}$$

Using $\frac{\partial \pi_B^t}{\partial x_B^t} = 0$ and the symmetry between the two firms, we find

$$x_A^{t*} = \frac{-81 - 63\delta + 28\delta^2}{324 + 108\delta - 120\delta^2}, \quad x_B^{t*} = \frac{405 + 171\delta - 148\delta^2}{324 + 108\delta - 120\delta^2}. \tag{25}$$

We can then summarize the equilibrium outcomes as follows.

$$a_1^{t*} = b_1^{t*} = \frac{\theta(9 + 8\delta)(81 - 6\delta - 11\delta^2)}{18(27 + 9\delta^2 - 10\delta^2)},$$

$$a_{2r}^{t*} = b_{2r}^{t*} = \frac{\theta(243 + 117\delta - 88\delta^2)}{9(27 + 9\delta^2 - 10\delta^2)}, \quad a_{2n}^{t*} = b_{2n}^{t*} = \frac{\theta(243 + 117\delta - 88\delta^2)}{18(27 + 9\delta^2 - 10\delta^2)}.$$

### A.4.2 Non-transparency Regime

We begin with the second period. Consider first firm $A$'s second-period pricing decision. If the consumer purchased from firm $A$ at $t = 1$, firm $A$ believes that firm $B$ will charge her a price $b_{2n}^{n*}$. Let $x_{2A}^n$ be the indifferent consumer, which solves

$$v - \theta(x_{2A}^n - x_A^n)^2 - a_{2r}^n = v - \theta(x_B^n - x_{2A}^n)^2 - b_{2n}^{n*}.$$

Solving the indifference condition, we have

$$x_{2A}^n = \frac{x_B^n + x_A^n}{2} - \frac{a_{2r}^n - b_{2n}^{n*}}{2\theta(x_B^n - x_A^n)}.$$

Firm $A$'s expected profit from its previous consumer is $\pi_{2Ar}^n = x_{2A}^n a_{2r}^n$. Firm $A$ chooses $a_{2r}^n$ to maximize this profit, which yields

$$a_{2r}^n = \frac{b_{2n}^{n*} + \theta({x_B^n}^2 - {x_A^n}^2)}{2}. \tag{26}$$

Similarly, for the consumer who bought from $B$ at $t = 1$, firm $A$ believes that firm $B$ will charge a price $b_{2r}^{n*}$. The indifferent condition $x_{2B}^n$ is characterized by

$$x_{2B}^n = \frac{x_A^n + x_B^n}{2} - \frac{a_{2n}^n - b_{2r}^{n*}}{2\theta(x_B^n - x_A^n)}.$$

Maximizing firm $A$'s profit, we get

$$a_{2n}^n = \frac{b_{2r}^{n*} + \theta({x_B^n}^2 - {x_A^n}^2)}{2} - \theta(x_B^n - x_A^n)x_1^n. \tag{27}$$

Firm $A$'s expected second-period profit is

$$\pi_{2A}^n = \pi_{2Ar}^n + \pi_{2An}^n = \frac{[\theta({x_B^n}^2 - {x_A^n}^2) + b_{2n}^{n*}]^2 + [b_{2r}^{n*} + \theta({x_B^n}^2 - {x_A^n}^2) - 2\theta(x_B^n - x_A^n)x_1^n]^2}{8\theta(x_B^n - x_A^n)}$$

Now, consider the first period. The indifference condition $x_1$ is determined by

$$v - a_1^n - \theta(x_1^n - x_A^n)^2 + \delta(v - b_{2n}^{n*} - \theta(x_B^n - x_1^n)^2) = v - b_1^{n*} - \theta(x_B^n - x_1^n)^2 + \delta(v - a_{2n}^n - \theta(x_1^n - x_A^n)^2),$$

which leads to

$$x_1^n = \frac{1}{2}\left[x_A^n + x_B^n + \frac{2b_1^{n*} - 2a_1^n - \delta(2b_{2n}^{n*} - b_{2r}^{n*})}{(2-\delta)\theta(x_B^n - x_A^n)}\right]. \tag{28}$$

Plugging (28) into (27), we have

$$a_{2n}^n = \frac{a_1^n - b_1^{n*} + b_{2r}^{n*} + \delta(b_{2n}^{n*} - b_{2r}^{n*})}{2-\delta}. \tag{29}$$

In the first period, firm $A$ chooses $a_1^n$ to maximize its total profit across both periods, $\pi_A^n = a_1^n x_1^n + \delta \pi_{2A}^n$. In equilibrium, firm $A$'s profit must be maximized at $a_1^n = a_1^{n*}$. Applying the first-order condition, we have

$$a_1^{n*} = \frac{4(b_1^{n*} + \theta({x_B^n}^2 - {x_A^n}^2)) - 4(b_1^{n*} + b_{2n}^{n*} - b_{2r}^{n*} + \theta({x_B^n}^2 - {x_A^n}^2))\delta + (4b_{2n}^{n*} - 3b_{2r}^{n*} + \theta({x_B^n}^2 - {x_A^n}^2))\delta^2}{8 - 6\delta}, \tag{30}$$

For firm $B$, we can similarly find its optimal second-period prices, $b_{2r}^n$ and $b_{2n}^n$, given firm $A$'s equilibrium strategy $(a_{2r}^{n*}, a_{2n}^{n*})$. We have

$$b_{2r}^n = \frac{a_{2n}^{n*} - \theta({x_B^n}^2 - {x_A^n}^2)}{2} + \theta(x_B^n - x_A^n), \tag{31}$$

and

$$b_{2n}^n = \frac{a_{2r}^{n*} - \theta({x_B^n}^2 - {x_A^n}^2)}{2} + \theta(x_B^n - x_A^n)x_1^n. \tag{32}$$

In the first period, the indifference condition $x_1^n$ from firm $B$'s perspective is determined by

$$v - a_1^{n*} - \theta(x_1^n - x_A^n)^2 + \delta(v - b_{2n}^n - \theta(x_B^n - x_1^n)^2) = v - b_1^n - \theta(x_B^n - x_1^n)^2 + \delta(v - a_{2n}^{n*} - \theta(x_1^n - x_A^n)^2),$$

which leads to

$$x_1^n = \frac{1}{2}\left[x_A^n + x_B^n - \frac{2a_1^{n*} - 2b_1^n - \delta(2a_{2n}^{n*} - a_{2r}^{n*})}{(2-\delta)\theta(x_B^n - x_A^n)}\right]. \tag{33}$$

Plugging (33) into (32), we have

$$b_{2n}^n = \frac{b_1^n - a_1^{n*} + a_{2r}^{n*} + \delta(a_{2n}^{n*} - a_{2r}^{n*})}{2-\delta}. \tag{34}$$

In the first period, firm $B$ chooses $b_1^n$ to maximize its total profit across both periods, $\pi_B^n = b_1^n(1-x_1^n)+\delta\pi_{2B}^n$. In equilibrium, firm $B$'s profit must be maximized at $b_1^n = b_1^{n*}$. Using the first-order condition, we have

$$b_1^{n*} = \frac{4(a_1^{n*}+\theta({x_B^n}^2-{x_A^n}^2)) - 4(a_1^{n*}+a_{2n}^{n*}-a_{2r}^{n*}+\theta({x_B^n}^2-{x_A^n}^2))\delta + (4a_{2n}^{n*}-3a_{2r}^{n*}+\theta({x_B^n}^2-{x_A^n}^2))\delta^2}{8-6\delta}. \tag{35}$$

In equilibrium, beliefs must be rational, i.e., the beliefs must be equal to their equilibrium values. Therefore, the six equations (26), (29), (30), (31), (34), and (35) form a linear system of $(a_1^{n*}, b_1^{n*}, a_{2r}^{n*}, a_{2n}^{n*}, b_{2r}^{n*}, b_{2n}^{n*})$. Solving this equation system, we have

$$\begin{cases} a_1^{n*} &= \theta(x_B^n - x_A^n)\frac{6(x_A^n+x_B^n+2)-\delta(7x_A^n+7x_B^n+8)+\delta^2(3x_A^n+3x_B^n-1)}{6(3-2\delta)}, \\ b_1^{n*} &= \theta(x_B^n - x_A^n)\frac{-6(x_A^n+x_B^n-4)+\delta(7x_A^n+7x_B^n-22)-\delta^2(3x_A^n+3x_B^n-5)}{6(3-2\delta)}, \\ a_{2r}^{n*} &= \theta(x_B^n - x_A^n)\frac{2+4x_A^n+4x_B^n-\delta-3\delta(x_A^n+x_B^n)}{9-6\delta}, \\ a_{2n}^{n*} &= \theta(x_B^n - x_A^n)\frac{2+x_A^n+x_B^n-2\delta}{9-6\delta}, \\ b_{2r}^{n*} &= \theta(x_B^n - x_A^n)\frac{10-4x_A^n-4x_B^n-7\delta+3\delta(x_A^n+x_B^n)}{9-6\delta}, \\ b_{2n}^{n*} &= \theta(x_B^n - x_A^n)\frac{4-x_A^n-x_B^n+2\delta}{9-6\delta}. \end{cases} \tag{36}$$

Lastly, we analyze the firms' optimal positioning decisions. We can write $\pi_A^n$ and $\pi_B^n$ as functions of $(x_A^n, x_B^n)$. Again, since we are looking for symmetric equilibrium, it suffices to consider the first-order condition for firm $B$, which is

$$\begin{aligned} \frac{\partial \pi_B^n(x_A^n,x_B^n)}{x_B^n} &= \frac{-\theta}{36(3-2\delta)^2}(18({x_A^n}^2-2x_A^n x_B^n+16x_B^n-3{x_B^n}^2-16)+\delta(248-5{x_A^n}^2+15{x_B^n}^2+10x_A^n x_B^n-200x_B^n) \\ &\quad -6\delta^2(-9+3{x_A^n}^2+20x_B^n-6x_A^n x_B^n-9{x_B^n}^2)+\delta^3(-61+9{x_A^n}^2+84x_B^n-18x_A^n x_B^n-27{x_B^n}^2)). \end{aligned} \tag{37}$$

Then, using $\frac{\partial \pi_B^n(x_A^n,x_B^n)}{x_B^n} = 0$ and the symmetry between the two firms, we have

$$x_A^{n*} = \frac{-6-\delta}{12(2+\delta)}, \quad x_B^{n*} = \frac{30+13\delta}{12(2+\delta)}. \tag{38}$$

The corresponding equilibrium prices are

$$a_1^{n*} = b_1^{n*} = \frac{\theta(6-\delta)(18+7\delta)}{36(2+\delta)}, \quad a_{2r}^{n*} = b_{2r}^{n*} = \frac{\theta(18+7\delta)}{9(2+\delta)}, \quad a_{2n}^{n*} = b_{2n}^{n*} = \frac{\theta(18+7\delta)}{18(2+\delta)}.$$

### A.4.3 Comparing the Transparency and Non-transparency Regimes

First, we compare the equilibrium product positions across the two regimes:

$$x_B^{t*} - x_B^{n*} = \frac{\delta(63+29\delta-9\delta^2)}{6(2+\delta)(27+9\delta-10\delta^2)} > 0.$$

We always have $x_B^{t*} > x_B^{n*} > 1$ and $x_A^{t*} < x_A^{n*} < 0$. That is, firms offer more differentiated products when prices are transparent.

For any symmetric firm locations $(y, 1-y)$, social welfare over the two periods is

$$SW(y) = v - 2\int_0^{\frac{1}{2}} \theta(x-y)^2 dx + \delta v - 2\delta \int_0^{\frac{1}{3}} \theta(x-y)^2 dx - 2\delta \int_{\frac{1}{2}}^{\frac{2}{3}} \theta(x-y)^2 dx.$$

When $y < 0$, total social welfare always increases with $y$. Since $x_A^{t*} < x_A^{n*} < 0$, social welfare is higher under the non-transparency regime.

To compare profits, note that $a_1^{t*} - a_1^{n*} = \frac{\delta(-2214+\delta(-1653+\delta(343+246\delta)))}{36(2+\delta)(-27-9\delta+10\delta^2)} > 0$, and $a_{2r}^{t*} - a_{2r}^{n*} = 2(a_{2n}^{t*} - a_{2n}^{n*}) = \frac{2\delta(-63+\delta(-29+9\delta))}{9(2+\delta)(-27-9\delta+10\delta^2)} > 0$. This implies that, in both periods, both firms under the transparency regime charge strictly higher prices than if they were under the non-transparency regime. Meanwhile, the firms' market shares are the same under the two regimes. Therefore, firms make higher profits under the transparency regime.

Since social welfare is lower and firms' profits are higher under the transparency regime, the consumer must be worse off under the transparency regime.