J. Econ. Theory 227 (2025) 106036

Contents lists available at ScienceDirect

Journal of Economic Theory

journal homepage: www.elsevier.com/locate/jet

# Personalized pricing, network effects, and commitment ☆

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ARTICLE INFO

*JEL classification:*
D11
G32
L20
M14

*Keywords:*
Personalized pricing
Network effects
Price observability
Commitment

ABSTRACT

Big data and data technology have facilitated the widespread adoption of personalized pricing practices. While price personalization enables firms to extract greater rent from consumers, it often reduces price transparency, which can negatively impact firm profits in situations involving consumer coordination. In such contexts, a firm's commitment to pricing strategies can become essential for restoring profitability. We explore several commitment devices available to firms and discuss their implications. These devices include delegating pricing decisions to a manager who prioritizes consumer surplus, leveraging existing networks as signals for later consumers or to build reputation, and implementing uniform pricing or price caps in response to regulatory restrictions.

## 1. Introduction

Many firms today utilize various forms of consumer data and advanced algorithms to predict individual consumers' willingness to pay. This enables them to implement personalized pricing strategies, charging different prices based on consumer preferences. For example, one study found that the dating app Tinder charges older men more for its premium service.[1] Similarly, online employment marketplaces such as ZipRecruiter and LinkedIn utilize extensive customer data to set personalized prices for users, including job

☆ We thank the editor (Guillermo Ordoñez) and two anonymous referees for constructive comments that have significantly improved the paper. We also thank Pat Akey, Efstathios Avdis, Seyedehsan Azarmsa, Nina Baranchuk, Hendrik Bessembinder, Utpal Bhattacharya, Andrew Bird, Jaroslav Borovička, Martin Boyer, Zhifeng Cai, Si Cheng, Xin Chang, Carlos Esquivel, Sergei Glebkin, Itay Goldstein, Naveen Gondhi, Jakub Hajda, Guojun He, Zhiguo He, Chong Huang, Yan Ji, Rosemary Kaiser, Ron Kaniel, Todd Keister, Hao Liang, Zhi Li, Xuewen Liu, Zehao Liu, Xiaomeng Lu, Zhongjin Lu, Fangyuan Ma, Pascal Maenhout, John Nash, Piotr Orlowski, Joël Peress, Chris Reilly, Marzena Rostek, Christopher Schwarz, Jian Sun, Pascale Valery, Dimitri Vayanos, Renxuan Wang, Kelsey Wei, George Wong, Han Xia, Dingbo Xu, Haibo Xu, Yexiao Xu, Shengxing Zhang, Feng Zhao, Hongda Zhong, Bart Zhou Yueshen, and participants at 2022 Financial Markets and Corporate Governance, 2022 SFS Cavalcade Asai-Pacific, 2023 ABFER Conference, 2023 CEIBS Finance and Accounting Symposium, 2023 China Financial Research Conference (CFRC), 2023 CUFE International Summer Conference of Finance, 2023 Globalisation and Economic Policy (GEP)-China Applied Economics Workshop, 2023 Huangda-Mundell Workshops at School of Finance Renmin University of China, 2023 INSEAD Finance Symposium, 2023 MFA Conference, 2023 PKU FinTech Workshop, and seminars at Central University of Finance and Economics, Chapman University, Fordham University, HEC Montréal, HKUST Business School, INFORMS, Peking University Guanghua School of Management, Peking University HSBC Business School, Renmin University of China, Rutgers University, Southern University of Science and Technology, and University of International Business and Economics, University of California, Irvine, University of Macau, University of Texas at Dallas for helpful comments. Yan Xiong thanks the support by National Natural Science Foundation of China [NSFC 72422007] and the Research Grants Council of the Hong Kong Special Administrative Region, China [project no. 16502921]. Liyan Yang thanks the support by Bank of Canada Fellowship and Social Sciences and Humanities Research Council (SSHRC, 435-2021-0040) for the research described in this article.

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[1] See "Older men charged more for using Tinder's premium service, Choice mystery shoppers find," 12 Aug 2020, News.

https://doi.org/10.1016/j.jet.2025.106036
Received 16 May 2024; Received in revised form 22 May 2025; Accepted 23 May 2025

Available online 28 May 2025

seekers and employers.[2] In the financial technology (fintech) sector, lenders analyze consumers' digital footprints—such as the type of device used (e.g., desktop, tablet, or mobile) and the operating system (e.g., Windows, iOS, or Android)—to assess default rates and determine personalized credit terms (Berg et al., 2020).

While personalized pricing enables a firm to extract greater value by customizing prices to individual customers, it often leads to price opacity, for various reasons. For instance, the firm may lack the technology required to publicize personalized prices implemented through individual coupons. Alternatively, firms might be wary of infringing on consumer privacy, creating perceptions of unfairness, or attracting regulatory scrutiny, which can lead to reduced price transparency. Price opacity means that each price is only visible to its intended consumer. Prices, as public information, play a crucial role in coordinating economic activities in various contexts (e.g., Morris and Shin, 2002; Myatt and Wallace, 2012). The information friction associated with personalized pricing may thus alter consumers' purchasing behavior, with negative consequences for firm profit.

In this paper, we first demonstrate how the opacity inherent in personalized pricing can adversely affect firm profits. We then develop a commitment-based framework to address this challenge, analyzing several practical commitment devices that can help firms mitigate information frictions. Our analysis provides new insights into real-world phenomena ranging from corporate social responsibility (CSR) programs to observed price patterns on social media platforms.

Our model features a network product. The network effect is an important example to capture externalities and coordination in consumers' purchase decisions. It arises when the value generated by a product or service increases with the number of consumers using it. Social media platforms such as Twitter and LinkedIn, information and communication technology providers such as Huawei and AT&T, and e-commerce marketplaces such as Amazon and Alibaba all thrive on network effects. Fintech lending platforms can enhance credit-scoring models by leveraging big data collected from a large consumer base. Refining credit-scoring models ultimately benefits consumers by increasing approval rates and reducing interest rates.[3]

Our baseline model is static and lasts for one period. A monopolistic firm sells a network product to two consumers. A consumer's valuation for the product includes two components: the intrinsic value gained from consuming it and the additional value earned from network effects. Each consumer's intrinsic value follows a uniform distribution, and its realization is the consumer's private information. To capture consumer heterogeneity, we assume that the two consumers differ in distribution support and that the firm is aware of each consumer's distribution support (for instance, from the consumer's past transactions) and uses this knowledge to price discriminate against consumers to maximize profit.

To show how price opacity hurts profits, we compare two pricing regimes: transparent pricing and opaque pricing. Under transparent pricing, consumers can observe each other's prices, while under opaque pricing, each consumer can only observe her own price. As the product features network effects, each consumer bases her purchase decision on the expected purchase behavior of the other consumer. If prices are observable, a consumer can assess her peer's purchase probability and adjust her own buying decision accordingly. This price transparency enables the firm to internalize the network effects of any price changes on consumer demand when setting prices. However, when prices become unobservable under opaque pricing, the firm tends to set excessively high prices. This occurs because a price reduction for one consumer is not directly observable to the other, leaving the latter unable to respond to the price decrease.

We then extend the baseline model to a two-stage commitment game that formally connects price observability with commitment power. In the initial stage, the firm selects and publicly announces a restricted set of prices to which it commits. During the second stage, when products are sold to consumers, although neither consumer can observe the exact price offered to her peer, they both understand that all prices must fall within the firm's pre-announced set. Under this framework, different degrees of price observability correspond to different levels of commitment power. Specifically, opaque pricing represents the complete absence of commitment power, where the firm's price set equals the entire pricing space. In contrast, transparent pricing occurs when the firm can commit to distinct price intervals for different consumers. We further examine factors affecting the value of commitment, showing that commitment becomes more valuable when either: (1) network effects are stronger, or (2) consumers with a higher average intrinsic value become less likely to purchase. In these situations, the profit-reducing impact of price opacity is particularly severe.

After formalizing the commitment perspective, we examine three types of practical commitment mechanisms: formal contracts, reputation and signaling in dynamic settings, and regulatory frameworks. First, we extend the firm's objective using a delegation framework in which the firm owner writes a compensation contract for a manager, who then determines the firm's pricing strategy. We examine a compensation contract that incorporates consumer surplus, which captures CSR. Under this extended objective, the firm's pricing incentives are corrected toward lowering prices, bringing equilibrium prices closer to those that maximize firm profits. In essence, CSR serves as a commitment mechanism when personalized pricing hinders the firm's ability to commit to prices. Moreover, CSR not only enhances firm profits but also benefits consumers, reinforcing the idea of "doing good by doing well."

Second, we introduce dynamics into our model and consider the possibility that the sales history provides a signal or establishes a reputation regarding the firm's pricing strategy for future consumers. Here, we consider two settings. In the first dynamic setting, the firm sells products to the two consumers sequentially, to illustrate the signaling effect of the early price. The early consumer cannot observe the price paid by the later consumer, but the later consumer can observe the price paid by the early consumer. Consequently, the initial low price acts as a signal for the subsequent consumer, helping to alleviate her information frictions and thereby increasing firm profits. Additionally, prices are likely to increase over time, as the firm initially charges a lower price to the early consumer

[2] See "Are You Ready for Personalized Pricing?," 26 February 2018, Chicago Booth Review.

[3] According to Dave Girouard, the founder and CEO of Upstart, a prominent artificial intelligence lending platform, the company's credit model, supported by advanced technology and data science, can greatly enhance approval rates and reduce interest rates. This observation contradicts with the common belief that an improved credit model results in the rejection of more applicants. See https://www.congress.gov/event/116th-congress/house-event/LC65599/text?s=1&r=3.

to build a network. Given the low price offered to the early consumer, the firm finds it more profitable to serve those with a lower intrinsic value first. This approach allows the firm to charge low prices without sacrificing much while simultaneously establishing the network.

The second dynamic setting is an infinitely repeated game, in which each period the firm sells products to a new generation of two short-lived consumers in each period. In this setting, the early low prices help the firm build a reputation for maintaining low prices, thereby sustaining a large network. Consumers believe that if high prices are detected in the firm's history, the firm may behave opportunistically by charging high prices in the future. Thus, unlike in a static setting, low prices can be sustained in equilibrium, leading to improved firm profits within this dynamic framework.

Third, we analyze two regulatory commitment mechanisms: uniform pricing and price caps. The uniform pricing policy requires firms to charge identical prices to all consumers. For example, regulators in China have proposed rules to penalize the practice of online platforms that charge varying prices to different consumers, and the EU and the U.S. are contemplating similar regulations. This uniform pricing approach alleviates information frictions, as consumers can infer that if they observe a certain price, other consumers are receiving the same price. However, uniform pricing also limits the firm's ability to discriminate between consumers, potentially reducing its overall profits. Intuitively, as consumer homogeneity increases, the value of commitment through uniform pricing grows, resulting in higher profits for the firm.

The price cap policy — a common practice in the communications industry — requires that the firm's price cannot exceed a certain threshold. When given the option to set a price cap, the firm will typically establish a limit that particularly affects prices for consumers with a higher average intrinsic value. A price cap is beneficial as it allows the firm to commit to lower prices, thereby fostering a larger network.

Taken together, in a context characterized by personalized pricing and network value, which arguably captures several key features of the modern economy, a firm can employ various commitment devices to mitigate the information frictions associated with opaque pricing. When the network effect is stronger, or when consumers with a higher average intrinsic value are less willing to buy the product, the firm's ability to commit to its pricing strategy is more valuable. Consequently, the firm is more likely to adopt different commitment mechanisms, such as emphasizing CSR in its managerial compensation contracts, maintaining a reputation for low pricing while fostering a large network, and implementing more restrictive price caps. These considerations offer a unified perspective on various firm practices.

**Related literature.** A large body of literature examines price discrimination and personalized pricing; see the survey by Varian (1989), Armstrong (2006), Fudenberg and Villas-Boas (2006), and Stole (2007). With the rise of big data and advanced pricing algorithms, personalized pricing has become increasingly relevant, leading to continued growth in this field of study. For instance, Rhodes and Zhou (2024a) examine consumers' privacy choices when firms can use their data to make personalized offers, while Rhodes and Zhou (2024b) investigate the welfare implications of personalized pricing in an oligopolistic market. Ichihashi (2020) shows that when consumers have privacy choices, consumers benefit from revealing information to enjoy personalized recommendations, but the seller can use that same information to price discriminate. Still, with more personal data available, more consumers may be reached with less exclusion (Bergemann and Bonatti, 2019). Furthermore, Rajan and Xiong (2024) examine the strategic responses of borrowers when lenders collect individual information and offer personalized loans, while Chen et al. (2020) focus on the strategic behavior of consumers. Meanwhile, there is evidence of uniform pricing in the U.S., even when it comes at a cost relative to optimal pricing benchmarks (e.g., Cavallo, 2018; DellaVigna and Gentzkow, 2019).

We connect the personalized pricing literature with the literature on network effects (e.g., Farrell and Saloner, 1985, 1986; Katz and Shapiro, 1985, 1994; Amir and Lazzati, 2011; Hagiu and Wright, 2023). The network effect is intrinsic to the success of today's leading firms, such as Amazon, Google, and Meta, whose value increases as more users engage with their platforms. Hajihashemi et al. (2022) examine the impact of personalized pricing on consumer and producer surplus in the context of network effects and find that price personalization may actually reduce firm profits. In contrast, our paper approaches this issue from the perspective of firm commitment, examining a range of practical commitment devices.

Using models of time-inconsistent preferences, Strotz (1955) was the first to formally investigate the concept of commitment. Specifically, an agent's future behavior is likely to be inconsistent with his optimal plan in the present moment. In the presence of such inconsistency (see Rabin (1998) for a survey), a rational agent may seek to pre-commit to certain actions by eliminating future options. This hyperbolic discounting model has proven useful for examining the desirability of commitment devices (e.g., Phelps and Pollak, 1968; Laibson, 1997; Amador et al., 2006). Other models also rationalize the demand for commitment, including the temptation and self-control theory (e.g., Gul and Pesendorfer, 2001) and dual-self theories (e.g., Thaler and Shefrin, 1981; Fudenberg and Levine, 2006). See Bryan et al. (2010) for a survey on commitment devices. We contribute to this literature by concretizing the somewhat abstract notion of commitment within the framework of personalized pricing and network effects and relating this discussion to various firm practices.

By exploring various commitment devices, our paper is also connected to the literature surrounding these topics. For instance, our discussion of the extended firm incentives relates to the growing literature on CSR (e.g., Friedman, 1970; Bénabou and Tirole, 2010; Hart and Zingales, 2017; Albuquerque et al., 2019), or, more specifically, the "S" dimension of environmental, social, and governance (ESG) practices. Related to our paper, some theories rationalize firm sustainability from the perspective of profits (e.g., Baron, 2001; Stoughton et al., 2020; Albuquerque and Cabral, 2021; Bond and Levit, 2025). We add to the literature by showing that a CSR commitment can help coordinate consumers' purchase decisions, thereby addressing inefficiencies in product pricing.

In addition, our examination of the repeated selling game links our paper to the extensive literature on reputation (Klein and Leffler, 1981; Bar-Isaac and Tadelis, 2008). This body of work shows that if there are potentially infinitely many opportunities for trade and the seller values the future sufficiently, then trade may occur and efficient outcomes can be supported. We show how network effects and consumer valuation influence the reputation equilibrium within the framework of personalized pricing and network effects.

## 2. A model of personalized pricing and consumer coordination

In Subsection 2.1, we first present a simple model that lays the groundwork for our discussion. Subsections 2.2 and 2.3 characterize the equilibrium under transparent and opaque pricing, respectively. We compare these two pricing schemes in Subsection 2.4. Finally, Subsection 2.5 formalizes the commitment perspective within our framework and identifies the key determinants of commitment value.

### *2.1. Model setup*

Our model features one monopolistic firm and two consumers. There is a coordination motive across the two consumers and we model this coordination benefit as coming from a network effect. The model is static and has one date, $t = 1$. The monopolistic firm charges personalized prices to the two consumers. After observing their respective prices, the two consumers simultaneously decide whether or not to buy the firm's product. At the end of the date, the firm's payoff and consumers' utility are realized. We note that the events occurring on this date are very intense; however, this intensity provides us with the flexibility to incorporate additional dates before or afterwards, enabling a more comprehensive subsequent analysis.

**Consumer preference and network effects.** A notable characteristic of the current business landscape is the presence of externalities among consumers. For instance, a consumer's willingness to pay for being on a platform increases when other consumers also join the platform. To account for the potential externalities in consumers' purchasing behavior, we examine the network effect as an illustrative example and focus on a product that exhibits network properties. The key components in our game follow studies such as Katz and Shapiro (1985), Varian (1989), and Hajihashemi et al. (2022).

Specifically, the firm sells a network good to two consumers, consumer $H$ and consumer $L$. By consuming the product, consumer $i$ derives utility as follows:

$$\mathcal{U}_i = v_i + \lambda \cdot \mathbb{1}(\text{consumer } j \text{ makes a purchase}), \tag{1}$$

where $i, j \in \{H, L\}$ and $i \neq j$. As in Katz and Shapiro (1985), consumer $i$'s utility has two components. The first component, $v_i$, is consumer $i$'s basic willingness to pay for the product. It represents the product's intrinsic value or standalone value to the consumer, which is a random variable drawn from a distribution and can differ across the two consumers. For simplicity, we assume that the basic willingness to pay follows a uniform distribution. We consider consumers heterogeneous in that their $v_i$ follows heterogeneous uniform distributions. Without loss of generality, we normalize consumer $L$'s support as $[0, 1]$. Consumer $H$'s support is $[0, a]$, where $a \geq 1$. That is, $v_L \sim U[0, 1]$ and $v_H \sim U[0, a]$, where $a \geq 1$. While consumer heterogeneity is not required for our mechanism, we include it to enhance the model's empirical relevance. Only when $a > 1$ does the firm have an incentive to adopt personalized pricing. The realization of each $v_i$ remains the private information of consumer $i$ until the end of the date.

The second component in utility function (1) captures the network effect. The parameter $\lambda \in (0, 1)$ represents the magnitude of the network value inherent in the product and is common knowledge. We assume that $\lambda < 1$, such that the network value is not too large compared with the product's standalone value. The network value is achieved if and only if both consumers purchase the product. Many products feature a network effect. For instance, we can think about the product as an online video game. In this context, the first component $v_i$ in equation (1) represents the utility of user $i$ playing against her own computer while the second component in equation (1) represents the extra utility that she gains from playing with other users.

**Personalized pricing and price observability.** At the beginning of the date, the firm offers prices to consumer $H$ and consumer $L$. The prices are personalized. We use $p_i \geq 0$ to denote the price charged to consumer $i$, where $i \in \{H, L\}$. Without loss of generality, we normalize the firm's marginal cost to zero. We use $\alpha_i \in [0, 1]$ to denote the probability of consumer $i$ purchasing the product (i.e., consumer $i$'s demand). Hence, the firm's expected profit is:

$$\pi = \alpha_L p_L + \alpha_H p_H. \tag{2}$$

The firm can implement personalized pricing either by literally offering different prices to each consumer or by offering the same quoted price but different coupons to each consumer. Personalized pricing has been greatly facilitated in the era of big data and advanced artificial intelligence (AI) algorithms. Big data have lowered the costs of collecting customer-level information, making it easier for sellers to identify new customer segments to target with customized marketing and pricing plans. For instance, information such as users' locations, browser and search histories, and personal preferences can be tracked via apps and social networking sites (e.g., Twitter and LinkedIn). In addition, data brokers and information intermediaries that buy and sell customer lists enable sellers to assemble digital profiles of individual consumers. This massive volume of data, combined with the power of machine learning algorithms, has given rise to a wide and varied range of personalized services, including catered news content and advertising as well as personalized pricing.

Each consumer $i$ can observe her own price $p_i$. If consumer $i$ can also observe the other consumer's price $p_j$, the price is "transparent." In contrast, if consumer $i$ cannot observe price $p_j$, the price is "opaque." We characterize the equilibrium under transparent and opaque pricing in Sections 2.2 and 2.3, respectively. In Section 2.5, we present a framework to unify the two settings through the lens of commitment, emphasizing the significance of firm commitment in this context.

### 2.2. Transparent pricing

We first analyze transparent pricing, where consumers can observe not only their own prices, but also the prices offered to other consumers. This scenario serves as our benchmark case. We consider a perfect Bayesian equilibrium in which the players' strategies are sequentially rational given their beliefs, which are updated using the Bayes rule wherever possible. The equilibrium is characterized by consumers' purchase probabilities and offered prices. We compute the equilibrium backward. We first compute the Nash equilibrium played by both consumers when they are offered prices $p_L$ and $p_H$. The equilibrium purchase probabilities $\{\alpha_L, \alpha_H\}$ are the demand functions faced by the firm. After figuring out these demand functions, we then compute equilibrium prices that maximize the firm's expected profit.

In the main text, we focus on the interior equilibrium, where both consumers' purchase probabilities are strictly between 0 and 1. (The analysis of corner equilibria — where at least one consumer always purchases the product — is left to the appendix.) An interior equilibrium is most likely to arise when the network value is relatively low, as a higher network value tends to incentivize customers to purchase the product. Given prices $\{p_L, p_H\}$, consumer $L$ purchases the product if and only if $v_L + \lambda\alpha_H \ge p_L$, or equivalently, $v_L \ge p_L - \lambda\alpha_H$. Given that $v_L$ is uniformly distributed, consumer $L$'s purchase probability is characterized by $\alpha_L = 1 - (p_L - \lambda\alpha_H)$. Similarly, consumer $H$'s purchase probability is $\alpha_H = 1 - \frac{1}{a}(p_H - \lambda\alpha_L)$. Solving these two equations simultaneously yields the two consumers' purchase strategies, as follows:

$$\alpha_L = \frac{a(1-p_L) + \lambda(a-p_H)}{a-\lambda^2} \text{ and } \alpha_H = \frac{a - p_H + \lambda(1-p_L)}{a-\lambda^2}. \tag{3}$$

These demand functions are intuitive. Take consumer $L$ as an example: When $p_L$ is higher, consumer $L$ is less likely to purchase the product; when $p_H$ is higher, consumer $L$ understands that consumer $H$ purchases the product with a lower probability and so the expected network value decreases. This in turn discourages consumer $L$ from purchasing the product.

Equipped with the demand functions in (3), the firm chooses $p_L$ and $p_H$ to maximize the expected profit $\pi = \alpha_L p_L + \alpha_H p_H$. Taking first-order conditions, we can compute the equilibrium product prices. We find that when the network value $\lambda$ is small, the conjectured equilibrium with interior purchase probabilities is indeed be supported. When the network value $\lambda$ is large, the equilibrium will always result in at least one consumer's purchasing the product, leading to corner purchase probabilities. The following lemma summarizes the complete equilibrium under transparent pricing, where the superscript "T" indicates the case with transparent prices.

**Lemma 1** *(Transparent pricing). Under transparent pricing, there exists a unique equilibrium in which*

(1) *When $\lambda \le \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}$, the equilibrium is an interior equilibrium: the firm sets prices $(p_L^T, p_H^T) = (\frac{1}{2}, \frac{a}{2})$; consumers $L$ and $H$ purchase the product if and only if $v_L \ge \frac{a(1-\lambda)-2\lambda^2}{2(a-\lambda^2)}$ and $v_H \ge \frac{a(a-\lambda(1+2\lambda))}{2(a-\lambda^2)}$.*
(2) *When $\bar{\lambda}^T < \lambda \le \frac{a}{2}$, the equilibrium is a corner equilibrium: the firm sets prices $(p_L^T, p_H^T) = (\frac{\lambda(a+2\lambda)}{2a}, \frac{a}{2})$; consumer $L$ always buys the product whereas consumer $H$ buys if and only if $v_H \ge \frac{a}{2} - \lambda$.*
(3) *When $\lambda > \frac{a}{2}$, the equilibrium is a corner equilibrium: the firm sets prices $(p_L^T, p_H^T) = (\lambda, \lambda)$ and both consumers always buy the product.*

### 2.3. Opaque pricing

Under opaque pricing, consumers cannot observe each other's prices. We still consider a perfect Bayesian equilibrium and start with the consumers' purchase decisions. As the utility a consumer derives from consumption depends on whether the other consumer also joins the network associated with the product, the consumer bases her purchase decision on the expected purchase behavior of the other consumer. Here, we need to deal explicitly with one consumer's belief about the other consumer's purchase probability. This treatment differs from transparent pricing, under which each consumer observes both prices and so one consumer can compute the other consumer's purchase probability with equation (3).[4] In contrast, under opaque pricing, one consumer observes only her own price, but not the other consumer's.

On the equilibrium path, consumers must hold consistent beliefs, and thus, each consumer can correctly infer the price charged to the other consumer and the other consumer's resulting purchasing probability. Off the equilibrium path, a consumer receives an unexpected price and we need to specify her belief about the other consumer's price and purchasing behavior. We follow the literature (e.g., Hart and Tirole, 1990; O'Brien and Shaffer, 1992; McAfee and Schwartz, 1994; Hajihashemi et al., 2022) in adopting passive beliefs for off-equilibrium paths. Under passive beliefs, when a consumer receives an offer different from what she expects in the candidate equilibrium, she does not revise her beliefs about the price offered to the other consumer. Passive beliefs can be justified based on the notion that consumers view unexpected offers as trembles by the firm. In our context, a perfect Bayesian equilibrium with passive beliefs is similar in spirit to the concept of sequential equilibrium (Kreps and Wilson, 1982).

[4] In the language of game theory, under transparent pricing, each consumer's information set degenerates to a singleton, and thus the belief distributions assign probability one to a single node.

We use $\hat{\alpha}_H$ to denote consumer $L$'s belief about consumer $H$'s purchase probability. Consumer $L$ is willing to purchase if and only if the expected consumption utility outweighs the price, i.e., if and only if $v_L + \lambda\hat{\alpha}_H \geq p_L$, or equivalently, $v_L \geq p_L - \lambda\hat{\alpha}_H$. Note that, under passive beliefs, consumer $L$'s belief $\hat{\alpha}_H$ about consumer $H$'s purchase probability is not affected by her price $p_L$. Similarly, consumer $H$ purchases if and only if $v_H \geq p_H - \lambda\hat{\alpha}_L$, where $\hat{\alpha}_L$ denotes consumer $H$'s belief about consumer $L$'s purchase probability. As the two consumers' basic willingness to pay is assumed to be uniformly distributed, we compute their respective purchase probabilities as follows:

$$\alpha_L = 1 - (p_L - \lambda\hat{\alpha}_H) \text{ and } \alpha_H = 1 - \frac{1}{a}(p_H - \lambda\hat{\alpha}_L). \tag{4}$$

These equations are the consumers' demand functions. With these demand functions, the firm determines prices $p_L$ and $p_H$ to maximize the expected profit $\pi$, as given by equation (2). The resulting optimal pricing strategies are as follows:

$$p_L = \frac{1+\lambda\hat{\alpha}_H}{2} \text{ and } p_H = \frac{a+\lambda\hat{\alpha}_L}{2}. \tag{5}$$

Note that $\hat{\alpha}_H$ and $\hat{\alpha}_L$ are exogenous parameters in the players' optimal decisions in (4) and (5), which reflect the passive-belief specification. In equilibrium, these four equations must hold simultaneously. Additionally, consumers hold consistent beliefs in equilibrium; that is, $\hat{\alpha}_L = \alpha_L^O$ and $\hat{\alpha}_H = \alpha_H^O$, where the superscript "O" indicates the equilibrium value under opaque pricing. Thus, setting $\alpha_L = \hat{\alpha}_L = \alpha_L^O$, $\alpha_H = \hat{\alpha}_H = \alpha_H^O$, $p_L = p_L^O$, and $p_H = p_H^O$ in these four equations, we can compute the equilibrium demands and prices. We can also demonstrate that the equilibrium under opaque pricing is always interior (i.e., $\alpha_L^O \in (0,1)$ and $\alpha_H^O \in (0,1)$). This is because, as we explain in the next subsection, the firm tends to set higher prices under opaque pricing, which in turn dampens consumer demand. We characterize the equilibrium under opaque pricing in the following lemma.

**Lemma 2** *(Opaque pricing). Under opaque pricing, there exists a unique equilibrium, which is interior. In this equilibrium: (1) the firm sets prices for the two consumers at $p_L^O = \frac{a(2+\lambda)}{4a-\lambda^2}$ and $p_H^O = \frac{a(2a+\lambda)}{4a-\lambda^2}$, and (2) consumer $L$ purchases the product if and only if $v_L \geq \frac{a(2-\lambda)-\lambda^2}{4a-\lambda^2}$, while consumer $H$ purchases if and only if $v_H \geq \frac{a(2a-\lambda(1+\lambda))}{4a-\lambda^2}$.*

### 2.4. Transparent versus opaque pricing

We now compare transparent pricing with opaque pricing. Focusing again on the case in which transparent pricing yields an interior equilibrium, we find that the firm tends to charge higher prices under opaque pricing, which damages its profitability. In the next subsection, we will demonstrate that this decline in profit can be interpreted through the novel lens of firm commitment.

First, we can unify the transparent and opaque settings with the aid of beliefs. Specifically, in both transparent and opaque pricing scenarios, the firm's demand functions can be represented by equation (4) as functions of one consumer's own price and her belief about the other consumer's purchase probability, that is, $\alpha_L = \alpha_L(p_L, \hat{\alpha}_H)$ and $\alpha_H = \alpha_H(p_H, \hat{\alpha}_L)$. The difference is that, under opaque pricing, beliefs $\hat{\alpha}_H$ and $\hat{\alpha}_L$ are fixed due to price opacity, whereas under transparent pricing, beliefs $\hat{\alpha}_H$ and $\hat{\alpha}_L$ are adjusted based on the actual prices $(p_L, p_H)$ according to equation (3). This captures the coordination role of prices. We can then express the firm's profit $\pi$ as a function of $(p_L, p_H, \hat{\alpha}_L, \hat{\alpha}_H)$, that is,

$$\pi(p_L, p_H, \hat{\alpha}_L, \hat{\alpha}_H) = p_L\alpha_L(p_L, \hat{\alpha}_H) + p_H\alpha_H(p_H, \hat{\alpha}_L). \tag{6}$$

Second, equipped with the profit function $\pi(p_L, p_H, \hat{\alpha}_L, \hat{\alpha}_H)$ in equation (6), the firm chooses prices $\{p_L, p_H\}$ by computing the first-order conditions as follows:

$$\frac{\partial\pi(p_i, p_j, \hat{\alpha}_i, \hat{\alpha}_j)}{\partial p_i} = \underbrace{\alpha_i(p_i, \hat{\alpha}_j) + p_i\frac{\partial\alpha_i(p_i, \hat{\alpha}_j)}{\partial p_i}}_{\text{standard trade-off}} + \underbrace{\left(p_i\frac{\partial\alpha_i(p_i, \hat{\alpha}_j)}{\partial\hat{\alpha}_j}\frac{\partial\hat{\alpha}_j}{\partial p_i} + p_j\frac{\partial\alpha_j(p_j, \hat{\alpha}_i)}{\partial\hat{\alpha}_i}\frac{\partial\hat{\alpha}_i}{\partial p_i}\right)}_{\substack{-\text{ transparent pricing: } (<0) \\ -\text{ opaque pricing: } (=0)}}, \tag{7}$$

where $i, j \in \{L, H\}$ and $i \neq j$. When the firm raises price $p_i$, three effects correspond respectively to the three terms of equation (7). The first two terms represent a standard trade-off in the absence of network effects: raising $p_i$ enhances profits by increasing the profit margin for existing demands (i.e., the first term, $\alpha_i(p_i, \hat{\alpha}_j) > 0$) but reduces profits by depressing demands (i.e., the second term, $p_i\frac{\partial\alpha_i(p_i,\hat{\alpha}_j)}{\partial p_i} < 0$).

The third term of equation (7) captures a new effect in the presence of network effects (or, more broadly, externalities in consumer behavior), which operates through the belief variables $(\hat{\alpha}_L, \hat{\alpha}_H)$ in the two demand functions $\alpha_L(p_L, \hat{\alpha}_H)$ and $\alpha_H(p_H, \hat{\alpha}_L)$. Under transparent pricing, consumers perfectly know the actual prices $(p_L, p_H)$ and adjust their beliefs and demands accordingly. Therefore, when the firm raises price $p_i$, it fully internalizes the effect of personalized price offers on consumer demand through network effects. This captures the benefit from the coordination role of transparent pricing. Formally, the belief variables $(\hat{\alpha}_L, \hat{\alpha}_H)$ are given by the Nash equilibrium outcomes $\alpha_H(p_L, p_H)$ and $\alpha_L(p_L, p_H)$ as specified in equation (3), and we can then use the chain rule to show that the third term is negative. In contrast, under opaque pricing, each consumer may not know the actual prices offered to the other consumer. As a result, the beliefs $\hat{\alpha}_H$ and $\hat{\alpha}_L$ are fixed, which eliminates the third term.

This comparison implies that under opaque pricing, the firm cannot internalize the third effect in equation (7). As a result, the firm tends to set excessively high prices, leading to lower profits, represented as $\pi^O$. Conversely, under transparent pricing, all three effects of offering personalized prices are fully accounted for, resulting in efficient pricing levels and higher profits for the firm. The following proposition summarizes these results.

**Proposition 1** *(Transparent vs. opaque pricing). Suppose that $\lambda \le \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}$, so that the equilibrium is interior under both transparent pricing and opaque pricing. Under opaque pricing, the firm charges higher prices to consumers and makes lower profits than under transparent pricing; that is, (i) $p_L^T < p_L^O$ and $p_H^T < p_H^O$; (ii) $\pi^T > \pi^O$.*

Although the analytical results in Proposition 1 focus on interior equilibria, we conduct extensive numerical analyses to assess the robustness of these results in the context of corner equilibria. It is important to note that, in this context, the corner equilibrium specifically pertains to transparent pricing, as the equilibrium under opaque pricing is always interior. Our numerical analyses indicate that the firm consistently achieves higher profits under transparent pricing than under opaque pricing. This is intuitive, as transparent pricing allows the firm to fully internalize all three effects. Furthermore, the firm invariably charges a higher price to consumer $H$ under opaque pricing than under transparent pricing. However, in certain corner equilibria under transparent pricing, the firm may charge a higher price to consumer $L$ than under opaque pricing. This situation can occur when consumer $L$ always purchases the product while consumer $H$ purchases with some probability under transparent pricing, because consumer $L$ is less price sensitive. Going forward, to simplify our discussions while preserving the core insights, we concentrate on the region characterized by low network effects, where both consumers' purchase probabilities take interior values.

Given that the firm achieves higher profits under transparent pricing than under opaque pricing, it is beneficial to the firm to enhance its price observability. In practice, however, implementing transparent pricing typically incurs significant costs, due to various challenges. First, technology-wise, price transparency may involve high implementation costs. For the sake of simplicity, our main model assumes that there are only two consumers; however, when there are many consumers, the firm may find it cumbersome to publicize the prices being charged to each, and consumers may find it difficult to collect and analyze personalized prices. For instance, when personalized pricing is implemented through individual coupons, a consumer's personalized price is rarely observable to another consumer in a timely manner (e.g., Allender et al., 2021).

Second, as argued by Hajihashemi et al. (2022), consumer concerns surrounding privacy and fairness, both of which are challenged by personalized pricing, also discourage firms from announcing personalized prices. Charging consumers different prices for the same product may be perceived as unfair, especially when the prices are transparent and the price heterogeneity is thus blatant. Perceptions of unfairness reduce consumer satisfaction and ultimately injure firm profitability (e.g., Haws and Bearden, 2006). Revealing an anonymous distribution of the prices charged by the firm can partially alleviate these privacy and fairness concerns but not completely remove them, unlike fully transparently announcing the price charged to each consumer. In addition, blatantly advocating price discrimination can also receive unwanted regulatory attention, putting the firm at litigation risk. To avoid such obstacles, firms may refrain from using transparent pricing.

Given the challenges associated with directly enhancing price observability, we explore alternative approaches to improving firm profitability in Sections 3 through 5. To establish a theoretical foundation for these alternatives, we reinterpret transparent and opaque pricing through the lens of commitment. Drawing on this perspective, Sections 3 to 5 investigate various commitment mechanisms aimed at (partially) mitigating the profit loss resulting from price opacity.

### *2.5. The commitment perspective*

In Subsection 2.5.1, we formalize this interpretation using a commitment game framework. Next, in Subsection 2.5.2, we analyze the value of commitment in this context.

#### *2.5.1. The commitment game*

Following the literature (e.g., Amador et al., 2006; Renou, 2009; Bryan et al., 2010), we define commitment as the firm's restricting its available pricing options. In our context, a commitment game is a two stage-game: in the first stage, the firm commits to a specific subset of its price choices, and in the second stage, the firm and consumers play the game induced by the firm's commitment. Formally, we extend our baseline model outlined in Subsection 2.1 by introducing an additional date, $t = 0$. On this initial date, the firm selects and announces a subset of prices $C \subseteq \mathrm{IR}_+^2$ to which it commits. This means that the firm binds itself to charging prices only within this subset, ensuring that $(p_L, p_H) \in C$. Subsequently, at date 1, the firm and consumers play the opaque-pricing game described in Subsection 2.3. At this stage, while consumers cannot observe the exact prices, they are aware that the firm's prices are constrained to the announced subset $C$.

For tractability, we impose some restrictions on price subset $C$ by assuming that the firm can only commit to intervals. That is, the firm's commitment is limited to specified price ranges for $p_L$ and $p_H$ as follows: $C = \{(p_L, p_H) \mid \underline{p}_L \le p_L \le \bar{p}_L, \underline{p}_H \le p_H \le \bar{p}_H\}$. Consequently, its commitment is characterized by the following four variables: $\{\underline{p}_L, \bar{p}_L, \underline{p}_H, \bar{p}_H\}$. At the initial stage of our commitment game, the firm optimally chooses the following lower and upper bounds of prices: $\{\underline{p}_L, \bar{p}_L, \underline{p}_H, \bar{p}_H\} \in \mathrm{IR}_+^4$.

In the opaque-pricing equilibrium described in Lemma 2, the firm lacks the ability to choose the price subset $C$. This is conceptually equivalent to the firm's being constrained to set $\underline{p}_L = 0, \bar{p}_L = \infty, \underline{p}_H = 0$, and $\bar{p}_H = \infty$. The inability to choose these price bounds highlights the lack of commitment power in the original opaque-pricing framework outlined in Subsection 2.3.

We consider subgame perfect equilibria as our solution concept for the commitment game. Our analysis continues to focus on scenarios with relatively low network value, ensuring that the equilibrium under transparent pricing remains interior. The following proposition characterizes the equilibrium for the commitment game.

**Proposition 2** *(Commitment Equilibrium). Suppose that* $\lambda \leq \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}$. *In the commitment game, there exist subgame perfect equilibria in which*

(1) *At date* 0, *the firm sets the commitment price thresholds* $\{\underline{p}_L^*, \bar{p}_L^*, \underline{p}_H^*, \bar{p}_H^*\}$ *as follows:* $\bar{p}_L^* = \frac{1}{2}$, $\bar{p}_H^* = \frac{a}{2}$, $0 \leq \underline{p}_L^* \leq \frac{1}{2}$, *and* $0 \leq \underline{p}_H^* \leq \frac{a}{2}$.

(2) *At date* 1, *the firm sets prices* $(p_L^*, p_H^*) = (\frac{1}{2}, \frac{a}{2})$; *consumers* $L$ *and* $H$ *purchase the product if and only if* $v_L \geq \frac{a(1-\lambda)-2\lambda^2}{2(a-\lambda^2)}$ *and* $v_H \geq \frac{a(a-\lambda(1+2\lambda))}{2(a-\lambda^2)}$.

Although the commitment equilibrium in Part (1) of Proposition 2 involves a continuum of lower price bounds, the equilibrium prices and consumer behaviors outlined in Part (2) of Proposition 2 are identical across these committed price subsets. In addition, when comparing Part (2) of Proposition 2 with Part (1) of Lemma 1, we observe that the equilibrium prices and consumer demands in the augmented commitment game align precisely with those in the original transparent-pricing game. Indeed, transparent pricing represents a specific equilibrium in the commitment game, corresponding to the case in which $\underline{p}_L = \bar{p}_L = p_L^T$ and $\underline{p}_H = \bar{p}_H = p_H^T$ in Part (1) of Proposition 2. Thus, transparent pricing naturally arises as an equilibrium outcome when the firm possesses commitment power.

The intuition of Proposition 2 is as follows. As discussed in Section 2.4, under opaque pricing, the firm opportunistically raises prices compared with those in the transparent pricing scenario, ultimately undermining its profitability. Therefore, the key to restoring profitability for the firm lies in committing to lower prices. This explains why the optimal commitment outlined in Proposition 2 features a price cap, with the lower bounds of the prices being irrelevant. Additionally, as the two consumers differ in their willingness to pay, the optimal commitment establishes a distinct price cap for each consumer, aligning with their respective transparent pricing levels, i.e., $\bar{p}_L = p_L^T$ and $\bar{p}_H = p_H^T$.

### 2.5.2. The commitment value

Having formalized the concept of price observability as a form of commitment, we now explore the determinants of commitment value in our setting. We perform a comparative statics analysis focusing on two key parameters: network value, $\lambda$, and the average intrinsic value, $a$, of consumer $H$. We quantify the value of commitment using the percentage reduction in profit when shifting from transparent to opaque pricing, expressed as $(\pi^T - \pi^O)/\pi^O$. The underlying premise is that if opaque pricing results in a more significant decrease in firm profit relative to transparent pricing, then the firm's ability to commit to lower prices for consumers becomes increasingly valuable for restoring profitability.

**Proposition 3** *(The value of commitment). Suppose* $\lambda < \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}$. *The value of commitment increases in* $\lambda$, *but decreases in* $a$. *That is,* $\frac{\partial}{\partial \lambda}\frac{\pi^T-\pi^O}{\pi^T} > 0$ *and* $\frac{\partial}{\partial a}\frac{\pi^T-\pi^O}{\pi^T} < 0$.

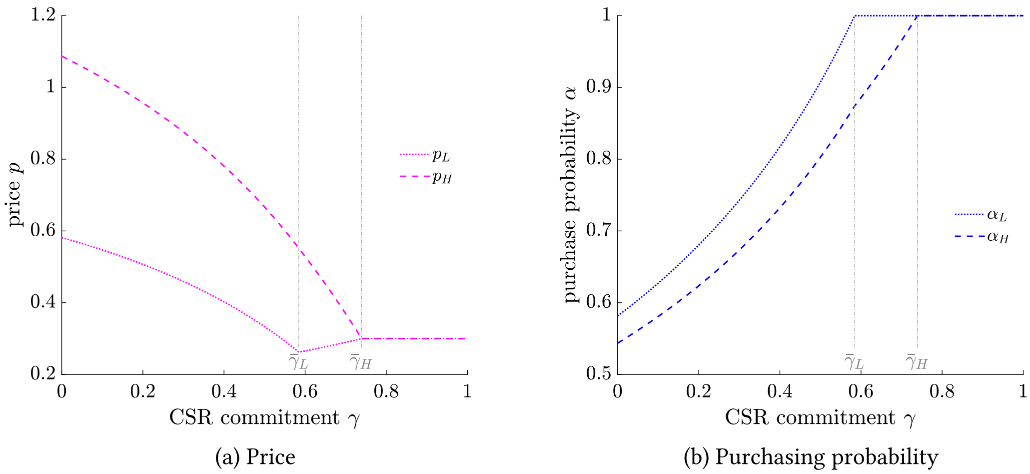
Proposition 3 shows that the value of commitment is affected by the two parameters $\lambda$ and $a$. First, a higher network effect $\lambda$ corresponds to a greater value of commitment. When the network effect is stronger, consumers have a greater need to coordinate their purchasing decisions. Consequently, the information frictions associated with opaque pricing can have a more negative impact on firm profits, making a commitment to pricing more valuable for restoring those profits.

Second, a higher value of $a$ indicates that on average, consumer $H$ can derive greater intrinsic value from consuming the product. Thus, consumer $H$ is less concerned about the potentially high price charged to consumer $L$ and has a stronger incentive to make a purchase. Meanwhile, recognizing the strong purchasing incentives of consumer $H$, consumer $L$ is also motivated to buy the network product. As a result, the firm's profit is less likely to decline significantly when moving from transparent pricing to opaque pricing.

Finally, in the commitment game analyzed here, we assume that the firm possesses an abstract commitment technology that enables distinct price caps for different investors, without detailing what the commitment technology is. While this formulation may lack direct real-world feasibility, it provides a benchmark for analyzing strategic pricing. In the following three sections, we examine concrete commitment mechanisms: formal contracts (Section 3), reputation and signaling in dynamic settings (Section 4), and regulatory frameworks (Section 5). Through these analyses, we shed light on real-world phenomena such as CSR initiatives and price discrimination patterns on social media platforms.

## 3. Extended firm incentives

In this section, we study how a firm can adopt extended incentives to commit to offering low prices to its consumers. We employ a delegation framework (e.g., Vickers, 1985; Fershtman and Judd, 1987; Sklivas, 1987; Aggarwal and Samwick, 1999; Bova and Yang, 2017; Xiong and Jiang, 2022) to illustrate the idea. Specifically, we consider a model that includes an additional date, referred to as date 0, preceding date 1. In the extended model, the firm has a risk-neutral owner and a risk-neutral manager. At date 0, the owner




This figure plots the effect of CSR commitment $\gamma$ on the firm's product prices (Panel (a)) and consumers' purchase probabilities (Panel (b)) under opaque pricing. The parameters are $a = 2$ and $\lambda = 0.3$.

**Fig. 1.** Prices and Purchase Probabilities with CSR Commitment.

first determines the manager's compensation contract, and then the manager runs the firm's operations. At date 1, the manager and the consumers play the opaque-pricing game outlined in Subsection 2.1.

**CSR commitment.** We focus on a specific form of compensation contract, which features a CSR element, although there are many other potential forms.[5] This chosen contract structure illustrates how extended firm incentives can help a firm commit to low prices and restore profits. Suppose that the manager's incentives are structured to maximize:

$$\Pi = \pi + \gamma \cdot CS, \tag{8}$$

where $CS$ represents consumer surplus and $\gamma \geq 0$ captures the importance of $CS$ relative to firm profit $\pi$. At date 0, the owner chooses the manager's contract parameter $\gamma$ to maximize expected profit $\pi$, and the value of $\gamma$ becomes common knowledge. Then, the manager takes $\gamma$ as given and chooses the pricing strategy $\{p_L, p_H\}$ to maximize $\Pi$.

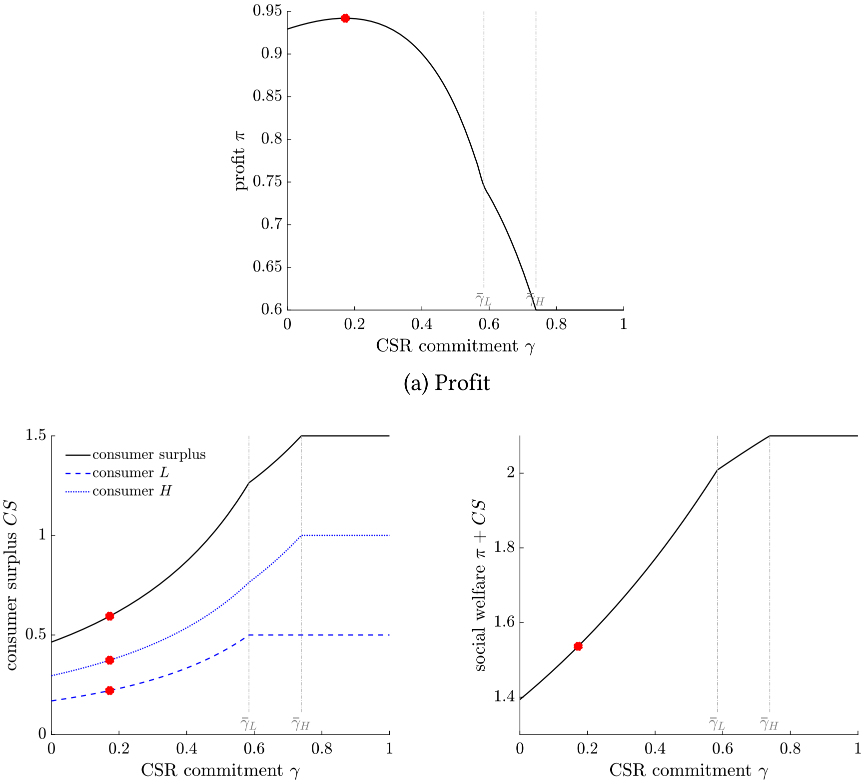
The generalized firm objective can be viewed as a particular type of CSR. Intuitively, as our economy only contains the firm and its two consumers, social welfare equals firm profits plus consumer surplus. As a result, caring about social welfare is essentially caring about consumer surplus. In this sense, we refer to parameter $\gamma$ as CSR commitment.

**Equilibrium characterization.** We compute the equilibrium backward. At date 1, for a given level of social responsibility $\gamma$, following the same procedure as in Section 2.3, we can characterize the equilibrium in the purchase subgame as given by consumers' purchase probabilities $(\alpha_H, \alpha_L)$ and offered prices $(p_H, p_L)$. Here, we use Fig. 1 to illustrate the effect of CSR commitment on the firm's pricing strategy and consumer purchase probabilities. There are three regions, depending on the value of $\gamma$. In the first region, $0 \leq \gamma < \bar{\gamma}_L$, where $\bar{\gamma}_L$ is an exogenous parameter given by (A.21) in the appendix, the two consumers' purchase probabilities take interior values (i.e., $0 < \alpha_L(\gamma) < 1$ and $0 < \alpha_H(\gamma) < 1$). In this region, as the firm commits to more CSR, it lowers its product prices and consumers become more likely to buy the product (i.e., $p_i(\gamma)$ decreases with $\gamma$ and $\alpha_i(\gamma)$ increases with $\gamma$ for $0 \leq \gamma < \bar{\gamma}_L$).

The other two regions of $\gamma$ are involved with corner equilibria. These two additional regions are divided by a threshold value $\bar{\gamma}_H$, as defined by equation (A.26) in the appendix. When $\bar{\gamma}_L < \gamma < \bar{\gamma}_H$, consumer $L$ always purchases, while consumer $H$ purchases the product with some probability (i.e., $\alpha_L(\gamma) = 1$ and $0 < \alpha_H(\gamma) < 1$). As the firm increases its CSR commitment, the price $p_H(\gamma)$ charged to consumer $H$ still decreases, but the price $p_L(\gamma)$ charged to consumer $L$ increases. When the firm finds it optimal to ensure that consumer $L$ always buys the product, the firm will optimally set the price $p_L(\gamma)$ as the consumer's expected network value. As a higher $\gamma$ implies a lower price and, thus, a higher purchase probability for consumer $H$, consumer $L$ finds the product's network value more derivable and becomes willing to accept a higher price. When $\gamma \geq \bar{\gamma}_H$, both consumers always buy the product and the firm charges a constant price at the level of the network value. This fact is reflected in the flat lines in Panels (a) and (b).

At date 1, the firm owner chooses $\gamma$ to maximize expected firm profit $\pi(\gamma) = p_H(\gamma)\alpha_H(\gamma) + p_L(\gamma)\alpha_L(\gamma)$. Given that CSR commitments help to mitigate inefficiently high prices, it immediately follows that firm profits can increase when the firm starts to commit to a positive level of CSR. Formally, under the extended firm incentive (8), the firm's profit is a function of its CSR commitment, as given

[5] Any other incentives that strengthen the firm's commitment to lowering product prices can achieve the same objective. For instance, an alternative and closely related method could involve compensating the firm's manager based on both firm profits and the size of the consumer base, such as $\pi + \gamma \cdot \alpha_i \alpha_j$. In the presence of network effects, this commitment to a large customer base can also effectively support lower prices and thereby sustain firm profits. For instance, LinkedIn's executives are compensated based on measures of member growth and engagement, which include net member signups, unique visiting members, and member page views (please refer to pages 34-35 of LinkedIn's DEF 14A for more information: https://www.sec.gov/Archives/edgar/data/1271024/000104746916012483/a2228356zdef14a.htm).




(a) Profit

(b) Consumer surplus

(c) Social welfare

This figure plots the effect of CSR commitment $\gamma$ on the firm's expected profit (Panel (a)), consumer surplus (Panel (b)), and social welfare (Panel (c)). The red dot indicates the point at which the firm profit is maximized. The parameters are $a = 2$ and $\lambda = 0.3$.

**Fig. 2.** Profit, Consumer Surplus, and Social Welfare. (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

by $\pi(\gamma)$ in equation (A.20). Taking the derivative of $\pi(\gamma)$ with respect to $\gamma$ and evaluating it at $\gamma = 0$, we obtain $\left.\frac{d\pi(\gamma)}{d\gamma}\right|_{\gamma=0} > 0$. Thus, the firm's optimal CSR engagement chosen at date 0, denoted by $\gamma^{CSR}$, must be positive.

To determine the exact value of $\gamma^{CSR}$, we plot the firm's profit $\pi(\gamma)$ against its CSR commitment $\gamma$ in Panel (a) of Fig. 2. We observe that when the firm starts committing to CSR, its profit can increase. This demonstrates the value of commitment emphasized in our paper. In addition, when the level of commitment becomes high enough, it starts to erode firm profits. This reflects the misalignment between CSR commitment as given by (8) and the traditional profit-maximization incentive. Overall, $\pi(\gamma)$ is hump-shaped. The red dot indicates the equilibrium CSR commitment $\gamma^{CSR}$, which achieves the highest firm profit.

**Implications and properties.** To evaluate the effects of CSR commitment, we contrast equilibrium outcomes under two scenarios: (1) the optimal CSR commitment level ($\gamma = \gamma^{CSR}$) and (2) the baseline no-commitment case ($\gamma = 0$), where equilibrium behavior is characterized by Lemma 2. Apparently, the firm earns higher expected profits under optimal CSR commitment ($\pi^{CSR} > \pi^{O}$), because $\gamma^{CSR}$ is profit-maximizing by construction. This is visually confirmed in Panel (a) of Fig. 2. In Panels (b) and (c) of Fig. 2, we also plot consumer surplus and social welfare, respectively, as functions of $\gamma$. Again, red dots marking the equilibrium under optimal CSR commitment. We find that, when the firm commits to its optimal level $\gamma^{CSR}$, compared with the situation with no such commitment, not only does the firm achieve higher profits but consumer surplus and social welfare are also higher. In other words, every player benefits from the firm's optimal CSR engagement and thus the firm does well by doing good.

Finally, we examine how exogenous parameters influence the optimal choice of CSR commitment. We find that the firm prefers a stronger CSR commitment when $\lambda$ is higher or when $a$ is lower. This intuition closely relates to Proposition 3. Specifically, as discussed in Proposition 3, the firm faces a more significant reduction in profit under opaque pricing than under transparent pricing when the network value is higher or when consumer $H$ derives a greater average intrinsic value from consumption. Consequently, in these scenarios, it becomes more valuable for the firm to leverage CSR as a means of committing to lower product prices, thereby restoring its profitability.

We summarize the section's main results in the following proposition.

**Proposition 4** *(Extended firm incentives: CSR). Suppose that the firm adopts a CSR commitment based on the extended firm objective (8). We have the following results:*

(i) *The firm's profit function $\pi(\gamma)$ increases with the CSR commitment $\gamma$ for small values of $\gamma$.*
(ii) *The firm's optimal CSR engagement benefits both the firm and consumers. That is, we have $\pi^{CSR} > \pi^O$ and $CS^{CSR} > CS^O$.*
(iii) *For a sufficiently low network value $\lambda$, the firm's optimal choice of CSR commitment $\gamma^{CSR}$ increases with $\lambda$ but decreases with $a$.*

## 4. Dynamics: signaling and reputation

Thus far, our model has been static, which limits the potential for sales history build the firm's reputation or signal its commitment to its pricing strategy. In this section, we will explore this possibility within the context of a dynamic game. In Section 4.1, we examine a sequential game in which consumers make purchases in order, with early and late consumers deriving network benefits from each another. In Section 4.2, we analyze a repeated game scenario in which the firm sells the product to consumers in each period, while later consumers can observe historical pricing information. Whereas consumers in the version of the model in Section 4.1 are long-lived, those described in Section 4.2 are short-lived, and there is no direct interaction between consumers across different periods.

### *4.1. Network as a signal in sequential purchases*

In the baseline model, the two consumers make their purchase decisions simultaneously, so they cannot observe each other's prices. In this subsection, we instead assume that consumers purchase sequentially. This change reflects the fact that later consumers, who can observe historical prices, are less affected by coordination problems. Specifically, consumers arrive and make their purchase decisions sequentially over two periods. The first consumer makes a purchase without observing the price set by the second consumer, while the second consumer can see the price established by the first. The utility for the two consumers remains as defined in equation (1), and both consumers derive their utility at the end of the game.

As later consumers can observe the prices set for earlier consumers, they are less concerned about the firm's potential opportunistic behavior and may respond more favorably to low prices, making purchases more likely. In this dynamic game, the initial low price and the established network can serve as signals to later consumers, helping to mitigate the informational frictions associated with opaque pricing. Consequently, we can expect the firm to achieve higher profits in the sequential setting than under opaque pricing, represented as $\pi^S > \pi^O$, where the superscript $S$ denotes the equilibrium in the sequential setting. The first part of Proposition 5 summarizes this finding.

**Proposition 5** *(Commitment through network: Sequential purchases). In the sequential purchase setting, we have the following findings:*

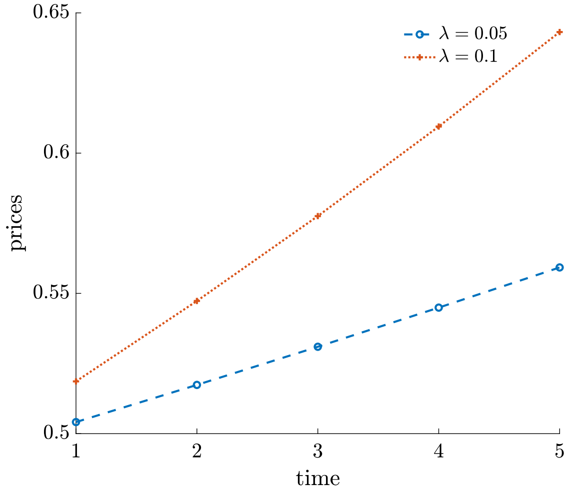
(i) *Regardless of the order in which consumers are served, the firm achieves higher profits than under opaque pricing, i.e., $\pi^S > \pi^O$.*
(ii) *If the firm can choose which consumer to serve first, it is optimal to serve consumer $L$ first and consumer $H$ second.*
(iii) *When $a = 1$, prices increase over time.*

The above profit-improvement result holds regardless of which consumer is served first. One remaining intriguing question is which consumer—$H$ or $L$—the firm should serve first when given the choice. On the one hand, consumer $H$'s greater willingness to pay translates into greater incentives to purchase at the same price, making it easier for the firm to build its initial network. Note that in a sequential setting, the initial consumer plays a crucial role in establishing a network and attracting future customers. On the other hand, to establish the initial network, the firm generally charges lower prices for the early consumer, all else being equal. Therefore, serving consumer $H$ first while charging lower prices, could lead to significant profit losses for the firm. Ultimately, we find that the latter consideration outweighs the former, making it optimal for the firm to serve consumer $L$ first. By doing so, the firm can set lower prices for consumer $L$ without incurring substantial profit losses, while simultaneously establishing its network. The second part of Proposition 5 summarizes this finding.

Finally, it is noted that the firm generally charges lower prices for the early consumer with the main intention of creating a network, as formalized in the third part of Proposition 5. To illustrate this point transparently, we eliminate consumer heterogeneity by assuming that $a = 1$. We show that prices tend to increase over time. Numerical analysis confirms that this price pattern persists with more than two consumers (Fig. 3). When late consumers observe early prices, the firm systematically raises prices while using initial discounts to establish its network. This increasing price trajectory mirrors observed practices in network-intensive industries such as social media platforms and e-commerce marketplaces.

### *4.2. Reputation in a repeated game*

In this subsection, we consider a setting in which the stage game specified in Section 2.1 is repeated indefinitely, with dates represented as $t = \{1, 2, \ldots\}$. On each date, the firm sells the network product to two consumers, $L$ and $H$, who make their purchase decisions simultaneously. The firm operates continuously, maximizing its total discounted profit over all time periods, with a discount rate of $\delta \in (0, 1)$. However, consumers can live for only one period. Each consumer can observe all historical prices for their own




This figure plots the price patterns for different values of the network effect $\lambda$ in the economy in which the firm sequentially sells the product to multiple consumers of the same type (i.e., $a = 1$).

**Fig. 3.** Sequential Purchase: Price Patterns.

type as well as for the other type. We are interested in determining whether efficient transparent prices can be sustained through reputation in a repeated game.[6]

In the repeated game setting where consumers can observe all historical prices, it is essential to specify how their beliefs about the firm's pricing strategy evolve. Let $\hat{p}_t = (\hat{p}_{L,t}, \hat{p}_{H,t})$ represent the beliefs of consumers at date $t$ regarding the firm's current pricing strategy. Here, $\hat{p}_{L,t}$ denotes consumer $H$'s belief about the price offered to consumer $L$, while $\hat{p}_{H,t}$ represents consumer $L$'s belief about the price offered to consumer $H$.

We construct a "trigger strategy" or "bootstrap" equilibrium (e.g., Klein and Leffler, 1981; Bar-Isaac and Tadelis, 2008). The evolution of consumers' belief is specified as follows:

$$(\hat{p}_{L,t}, \hat{p}_{H,t}) = \begin{cases} \left(p_L^T, p_H^T\right) & \text{if } p_{L,t-i} \le p_L^T \text{ and } p_{H,t-i} \le p_H^T \text{ for } i \in \{1, 2, \ldots\}, \\ \left(p_L^O, p_H^O\right) & \text{otherwise,} \end{cases} \tag{9}$$

where $\left(p_L^T, p_H^T\right)$ represents the equilibrium prices under transparent pricing, while $\left(p_L^O, p_H^O\right)$ denotes the equilibrium prices under opaque pricing, as discussed in Sections 2.2 and 2.3.

The belief specification in (9) indicates that consumers believe that the firm charges the low prices under transparent pricing as long as all prices up to that date have fallen below the transparent prices. Once a high price is detected, consumers will believe that the firm is behaving opportunistically by charging high prices as under opaque pricing. Specifically, for consumer $L$, she will only believe that the firm continues to charge $H$ low efficient prices if all historical prices for consumer $H$ are below $p_H^O$. Conversely, consumer $H$ will believe that the firm remains trustworthy only if all historical prices for $L$ are below $p_L^O$. If these conditions are not met, consumers will punish the firm by assuming that it will charge high prices.

Given consumers' belief $\hat{p}$ about the firm's pricing strategy, the firm will choose prices in the current period to maximize the total profit:

$$\Pi(\hat{p}) = \max_p \{p_L \alpha_L + p_H \alpha_H + \delta \Pi(\hat{p}')\}, \tag{10}$$

where the future evolution of beliefs $\hat{p}'$ is governed by equation (9). The following proposition summarizes the conditions under which the reputation equilibrium, characterized by efficient transparent prices in each period, can be sustained.

**Proposition 6** *(Commitment through reputation: Repeated game). Suppose that $\lambda \le \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}$. In a repeated game, the reputation equilibrium where the firm sets prices $(p_L^T, p_H^T) = (\frac{1}{2}, \frac{a}{2})$ in each period can be sustained when parameter conditions permit. Specifically:*

(i) *The reputation equilibrium is more likely to be sustained when the firm's discount factor $\delta$ is close to 1.*

[6] As in the literature on repeated game models (e.g., Bar-Isaac and Tadelis, 2008), there may be other equilibria that support similar outcomes through different strategies, and other equilibria altogether. For instance, there is an equilibrium in which consumers anticipate that the firm will charge inefficiently high prices, as seen under opaque pricing, and the firm indeed sets these prices.

(ii) *Assuming that $\delta > \frac{1}{2}$. A marginal increase in the network value from zero to a positive value will incentivize the firm to maintain the reputation equilibrium.*
(iii) *Suppose that $\lambda$ is sufficiently small and $\delta > \frac{1}{2}$. The reputation equilibrium is more likely to be sustained when $a$ is lower.*

First, when the firm's discount factor $\delta$ approaches 1 (indicating that the firm strongly values its reputation), efficient low prices can be sustained. This equilibrium is maintained through consumers' belief-based punishment: any price deviation will cause consumers to perceive the firm as opportunistic, triggering future punishment. Second, when the network value is zero, the information frictions associated with opaque pricing are muted, rendering a reputation for charging low, efficient prices irrelevant. However, a slight increase in the network value makes a commitment to maintaining low prices valuable, encouraging the firm to uphold its good reputation.

Third, our numerical analysis indicates that for high values of the discount factor $\delta$ and a given network value $\lambda$, the firm has a stronger incentive to maintain the reputation equilibrium when $a$ is lower. This result can be proven analytically when $\lambda$ is sufficiently low, as demonstrated in Part (iii) of Proposition 6. The intuition behind this finding aligns with the insights from Proposition 3. Specifically, a lower $a$ corresponds to a higher value of commitment, meaning that the firm's profit under opaque pricing is significantly lower than under transparent pricing. Consequently, in this scenario, it is more beneficial for the firm to maintain a good reputation.

## 5. Commitment through regulation

This section analyzes two regulatory approaches to firm commitment: uniform pricing and price caps. Their effectiveness hinges on credible enforcement through regulatory frameworks.

### 5.1. Uniform pricing

While a firm may face challenges in committing to individualized pricing (as discussed in Section 2.5.1), it may maintain a commitment to uniform pricing across consumers. Indeed, regulations across China, the EU, and the U.S. tend to push toward uniform pricing, thereby empowering firms with the commitment necessary to adopt this pricing strategy.[7] In this section, we examine whether uniform pricing—with its regulatory-guaranteed commitment power—can enable a firm to regain profitability.

Under uniform pricing, both consumers are charged the same price $p$. By observing the price $p$, each consumer knows that the other consumer is also receiving the same price. Similar to the transparent pricing setting discussed in Section 2.2, the consumers' beliefs $\hat{\alpha}_H$ and $\hat{\alpha}_L$ are adjusted according to the actual price $p$. The equilibrium derivations under uniform pricing parallel those from the transparent pricing model in Section 2.2, except that now the firm's action space is smaller. The following lemma summarizes the equilibrium under uniform pricing, where the superscript "U" indicates the equilibrium under this pricing strategy.

**Lemma 3** *(Uniform pricing). Under uniform pricing, there exists a unique equilibrium in which*

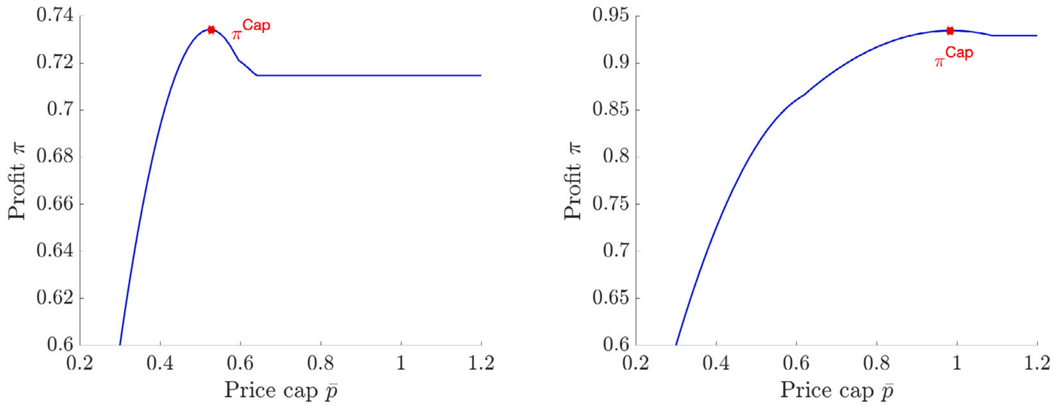
(i) *When $\lambda \le \bar{\lambda}^U \equiv \frac{\sqrt{a^2+34a+1}-a-1}{8}$, the firm sets the uniform price $p^U = \frac{1}{2}\frac{2a+\lambda+a\lambda}{1+a+2\lambda}$. Consumers $L$ and $H$ will make their respective purchases if and only if $v_L \ge \frac{(p^U-\lambda)(a+\lambda)}{a-\lambda^2}$ and $v_H \ge \frac{a(p^U-\lambda)(1+\lambda)}{a-\lambda^2}$.*
(ii) *When $\lambda > \bar{\lambda}^U$, the firm sets the uniform price $p^U = \frac{\lambda}{2}$, and both consumers will always purchase the product.*

By comparing the profit $\pi^U$ under uniform pricing with the profit $\pi^O$ under opaque pricing we show that the uniform pricing strategy is more likely to restore firm profitability when consumers are more homogeneous. In this scenario, the firm can avoid significant price discrimination, making it efficient to set similar prices for different consumers. The following proposition summarizes this result.

**Proposition 7** *(Commitment through uniform pricing). The firm achieves higher profit under uniform pricing than under opaque pricing when consumers are more homogeneous. Specifically, as $a$ is sufficiently close to one, we have $\pi^U > \pi^O$.*

In addition, our numerical analysis indicates that for moderate values of $a$, the firm achieves higher profits under uniform pricing when the network effect $\lambda$ is strong. For example, when $a = 1.2$ and $\lambda > 0.16$, uniform pricing results in greater profits for the firm. A stronger network effect implies a higher cost associated with consumer coordination failures, leading to lower profits under opaque pricing. In this context, it is more profitable for the firm to adopt a uniform pricing strategy.

[7] For instance, China's market regulator, the State Administration for Market Regulation, issued draft rules aimed at punishing illegal pricing activities, including the practice of online platforms charging different prices based on customers' purchasing behavior ("China proposes rules to punish illegal e-commerce pricing," Reuters, July 2, 2021). In the EU and the US, as in China, personalized prices based on a customer's digital footprint on the platform may also violate the rules. Recent antitrust reforms, such as the Digital Markets Act (DMA), American Innovation and Choice Online Act (AICOA), and the Open App Markets Act, focus on regulating technology platforms, with an emphasis on regulating the information derived from these platforms. According to the Robinson-Patman Violations, personalized pricing may become unlawful if it does not reflect the different costs of dealing with different buyers or is not the result of a seller's attempts to meet a competitor's offering. See Gilbert (2023) for a survey article on related discussions in the EU and the US.




(a) $p_H^* = p_L^* = \bar{p}$ (b) $p_H^* = \bar{p}$ and $p_L^* < \bar{p}$

This figure plots the effect of the price cap on firm profits. The red dot represents the equilibrium price cap that maximizes the firm's expected profit, resulting in an optimal profit denoted as $\pi^{Cap}$. In Panel (a), with $a = 1.1$ and $\lambda = 0.3$, the optimal price cap leads to both consumers' prices being capped. In Panel (b), with parameters set at $a = 2$ and $\lambda = 0.3$, the optimal price cap means that consumer $H$'s price is capped while consumer $L$'s price is not, i.e., $p_H^* = \bar{p}$ and $p_L^* < \bar{p}$.

**Fig. 4.** Price Cap and Profit.

### *5.2. Price cap*

The firm may choose to implement a price cap, which represents the maximum price it charges all consumers. Similar to uniform pricing, the regulatory framework might give firms the ability to commit to such price limits. For example, the Federal Communications Commission (FCC) in the U.S. has established various price caps on fees charged by telecommunications providers to ensure that rates are fair, non-discriminatory, and conducive to a competitive market environment.[8]

When the firm commits to a price cap, denoted as $\bar{p}$, the firm's prices must satisfy $p_L \leq \bar{p}$ and $p_H \leq \bar{p}$. Note that the optimal commitment discussed in Proposition 2 also features price caps, but in this case different price caps are set for different consumers. The implementation and commitment requirements are thus significantly stronger, if not impossible to meet, especially in markets with a large number of consumers.

We analyze the implications of a price cap using the same two-stage commitment framework described in Subsection 2.5.1. Whereas the firm previously selected price intervals at the initial stage, it now chooses a single price cap. This restricted choice set reflects weaker commitment power compared with the abstract technology in 2.5.1. However, the price cap commitment is credible. Regulatory enforcement ensures compliance once the cap is set. We still adopt the solution of a subgame perfect equilibrium and compute the equilibrium backward. First, for any given price cap $\bar{p}$, we characterize the date-1 equilibrium pricing and purchase decisions. We then solve for the optimal price cap $\bar{p}^*$ at date 0.

At date 1, when the price cap $\bar{p}$ is sufficiently high, the firm's pricing strategy faces virtually no constraints. Consequently, the equilibrium aligns with that of the baseline model without any commitment. However, a low price cap alters the firm's pricing strategy. As consumer $H$ consistently pays a higher price than consumer $L$ due to her greater willingness to pay, the firm's pricing for consumer $H$ is impacted first when the price cap is binding. Specifically, under a moderate price cap, the firm charges the maximum price to consumer $H$: $p_H^* = \bar{p}$. When the price cap becomes sufficiently low, the prices for both consumers are capped: $p_L^* = p_H^* = \bar{p}$.

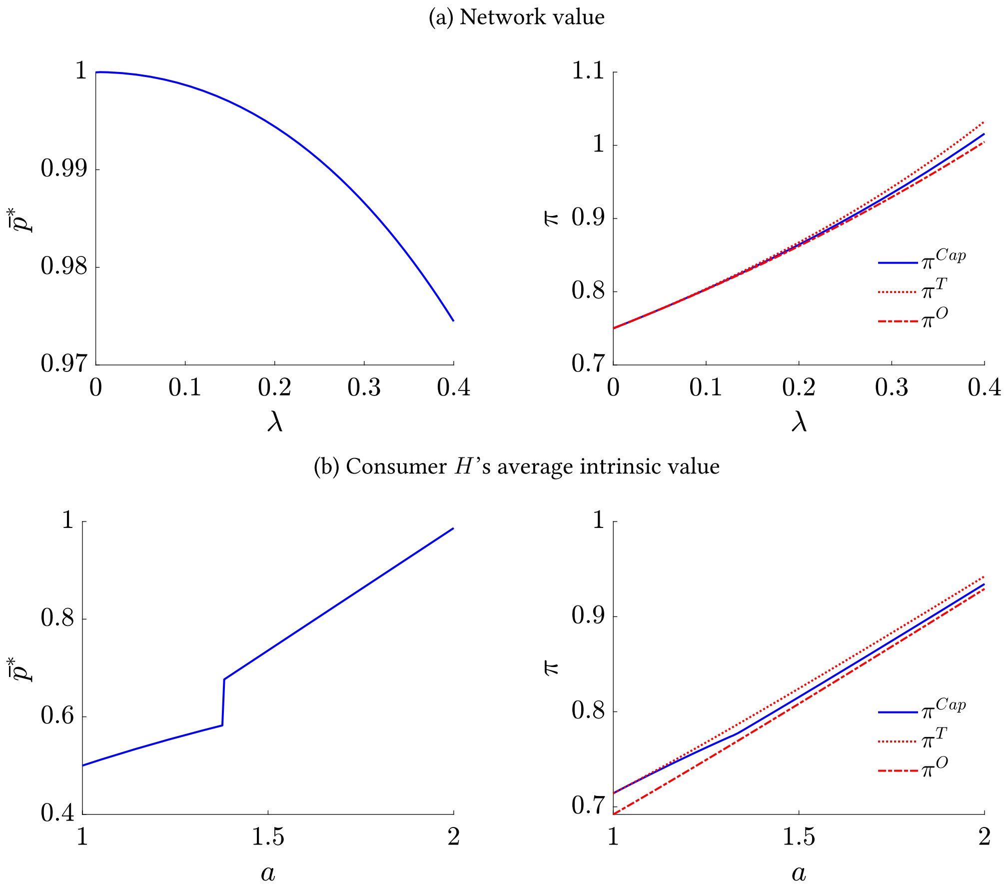
For a given price cap $\bar{p}$, we compute the firm's expected profit in the date-1 equilibrium, denoted as $\pi(\bar{p})$. At date 0, the firm selects $\bar{p}$ to maximize $\pi(\bar{p})$, yielding the equilibrium price cap $\bar{p}^*$. Similar to the optimal CSR commitment in Section 3 (see Panel (a) of Fig. 2), Fig. 4 plots the firm's expected profit $\pi(\bar{p})$ against the price cap $\bar{p}$. The function $\pi(\bar{p})$ becomes flat at the right end, reflecting the non-binding nature of the firm's pricing strategy when the price cap is sufficiently high. In equilibrium, the firm always chooses a price cap such that consumer $H$'s price is binding (i.e., $p_H^* = \bar{p}$). Nonetheless, consumer $L$'s price can be either binding (i.e., $p_L^* = \bar{p}$, Panel (a) of Fig. 4) or non-binding (i.e., $p_L^* < \bar{p}$, Panel (b) of Fig. 4). Intuitively, when $a$ is small, the two consumers are similar and so the prices for both consumers are capped.

We summarize the equilibrium price cap in the following lemma.

**Lemma 4** *(Price cap). In the commitment game in which the firm commits to a price cap, the equilibrium cap $\bar{p}^*$ is always binding for consumer $H$ (i.e., $p_H = \bar{p}^*$) but may not be binding for $L$ (i.e., $p_L \leq \bar{p}^*$).*

Fig. 5 examines how the firm's optimal price cap $\bar{p}^*$ and the resulting firm profit $\pi^{Cap}$ depend on the network value $\lambda$ and consumer $H$'s average intrinsic value $a$. In the top left panel, the equilibrium price cap $\bar{p}^*$ decreases as the network value $\lambda$ increases. As stated in Proposition 3, the commitment becomes more valuable when the network effect is stronger. Consequently, the firm is

[8] See "Regulating Telecommunications Lessons from U.S. price cap experience," World Bank (1996).




This figure illustrates how the network value $\lambda$ and consumer $H$'s average intrinsic value $a$ influence the firm's optimal price cap and the firm's profit. In Panel (a), the parameter is set at $a = 2$, while in Panel (b), it is set at $\lambda = 0.3$.

**Fig. 5.** Effects of $\lambda$ and $a$.

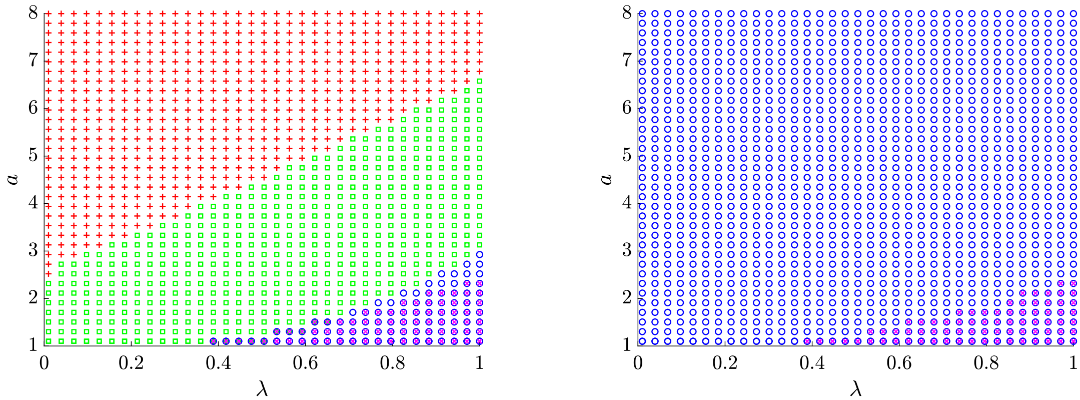
inclined to impose greater constraints on its pricing strategy by setting a lower price cap, thereby committing to lower prices for consumers. The top right panel demonstrates how network effects and commitment power jointly shape profits: (1) $\pi^{Cap}$ rises with $\lambda$, as stronger network effects boost consumer valuations, and (2) the ordering $\pi^O \leq \pi^{Cap} \leq \pi^T$ emerges because price capping offers intermediate commitment power between opaque pricing's no commitment($\pi^O$) and transparent pricing's stronger commitment ($\pi^T$). In the bottom left panel, the optimal price cap increases with $a$, because Proposition 1 indicates that a higher $a$ implies a lower value of commitment. Therefore, the firm does not need to restrict its pricing strategy as much, leading to a higher price cap. Here, we also observe a discrete increase in the price cap around $a = 1.4$, which results from an equilibrium shift. Specifically, at low values of $a$, where commitment is valuable, the firm must impose a restrictive price cap, leading to both consumer $L$'s and consumer $H$'s prices being capped. However, as $a$ continues to rise and the firm relaxes this constraint, the equilibrium transitions to a scenario in which consumer $L$'s price is no longer capped. Nevertheless, within each type of equilibrium, the optimal price cap increases with $a$. The bottom right panel reveals that the valuation parameter $a$ produces analogous effects to the network parameter $\lambda$: (1) $\pi^{Cap}$ increases with $a$ as higher consumer valuations directly raise profits; and (2) the consistent ordering $\pi^O \leq \pi^{Cap} \leq \pi^T$ again demonstrates how commitment power governs profit outcomes.

## 6. Discussion

In this section, we first discuss real-life scenarios that correspond to different values of $\lambda$ and $a$, the two key parameters in our model. We then explore the commitment mechanisms that are more socially or privately preferable for different combinations of $\lambda$ and $a$.

**Parameters $\lambda$ and $a$ in practice.** Our economy is characterized by two key parameters: $\lambda$, representing network value, and $a$, the intrinsic value of high-valuation consumers, which also reflects consumer heterogeneity. These parameters provide a valuable perspective on the economy and strengthen the connection between our model and practical applications.

For example, both the telecommunications industry and social media platforms exhibit a high network value $\lambda$. Software platforms such as Overleaf experience network effects, but to a lesser extent due to their unique features and smaller user base. Similarly, the online lending sector displays weaker network effects. In terms of consumer valuation, users of social media platforms demonstrate




(a) Preference by the Firm (b) Preference by the Social Planner

This figure illustrates the preferred commitment device for the firm (Panel (a)) and the social planner (Panel (b)) across different values of $\lambda$ and $a$. A red plus sign indicates that the firm favors sequential purchases, a green square represents a preference for CSR commitment, a blue circle denotes a preference for uniform pricing, and a magenta cross denotes a preference for price cap.

**Fig. 6.** Commitment Devices That Is Preferred by Firm and Social Planner.

greater heterogeneity than telecommunications consumers, resulting in a higher $a$. Conversely, the preferences of Overleaf users are likely to be more aligned than those of users in the online lending space, leading to a lower $a$.

Proposition 3 indicates that the value of commitment increases with $\lambda$ but decreases with $a$. Consequently, among the industries sampled, the telecommunications sector exhibits the highest value of commitment, while the online lending sector shows the lowest.

**Choices across various commitment devices.** Although the commitment devices explored in our paper are only a few examples and do not cover the full range of potential strategies, an intriguing question remains: In economies characterized by varying values of $\lambda$ and $a$, which commitment device prevails? In Fig. 6, we numerically compare four commitment devices: CSR, sequential purchases (serving low-valuation consumers first), uniform pricing, and price caps. We analyze which device is preferred by the firm in Panel (a) and by the social planner in Panel (b). In the figure, a red plus sign indicates a preference for sequential purchases, a green square represents a preference for CSR, a blue circle denotes a preference for uniform pricing, and a magenta cross is a preference for price caps.

We begin with the social planner's preferences, as illustrated in Panel (b) of Fig. 6. The social planner consistently favors uniform pricing over other options, supporting the current regulatory policy that promotes uniform pricing, as discussed in Section 5.1. Moreover, in regions characterized by a high $\lambda$ and low $a$, the firm optimally sets very low price caps; as a result, the two consumers are charged the same price. In this context, uniform pricing and price caps become equivalent, both serving as preferred commitment strategies for the social planner. Notably, as mentioned earlier, this scenario—marked by consumer homogeneity and strong network effects—frequently occurs in industries such as telecommunications. Indeed, we observe that regulations in this sector encourage the adoption of price caps.

Compared with the social planner's preference, the commitment device favored by the firm shows greater variety. When consumer preferences are heterogeneous (i.e., high $a$), sequential purchases are the most effective strategy for enhancing firm profit, as establishing an initial network is crucial for attracting future high-valuation consumers. Conversely, in scenarios where consumers are more homogeneous (i.e., low $a$), the optimal commitment device depends on the network effect. If the network effect is weak (i.e., low $\lambda$), CSR commitment becomes the best choice for the firm. However, if the network effect is strong, uniform pricing emerges as the optimal strategy. In this context, consumer homogeneity enables the firm to avoid price discrimination, making uniform pricing the preferred approach. As previously discussed, price caps can achieve similar outcomes and are also optimal. Notably, in this situation, the preferences of the firm and the social planner align.

## 7. Conclusion

The rise of big data and data technology has increased the prevalence of personalized pricing practices. We illustrate that when externalities exist in consumer purchase decisions, the price opacity associated with personalized pricing can result in coordination failures among consumers, ultimately injuring firm profits. In such scenarios, a firm's commitment to lowering prices becomes valuable in restoring profitability.

We explore several practical concrete commitment devices that firms may utilize to overcome the information frictions associated with personalized pricing. First, the firm may delegate pricing decisions to a manager who also cares about consumer surplus. This delegation helps the firm commit to setting lower prices and partially addresses the coordination problem. Importantly, this approach not only enhances firm profits but also boosts consumer surplus and social welfare, thereby providing justification for the principle of "doing well by doing good."

Second, the firm can leverage dynamics to mitigate information frictions. For example, instead of selling products to consumers simultaneously, the firm can adopt a sequential selling approach. This allows the firm to establish a network that signals a probable high network value to later consumers. Moreover, in a repeated game context, consumers can punish the firm for opportunistically charging high prices by assuming that such behavior will persist. This belief can discipline the firm and encourage it to maintain a good reputation for charging low prices.

Third, several regulations that promote fair, non-discriminatory pricing enhance the firm's commitment power, helping to alleviate information frictions. For instance, when a firm commits to charging the same price for all consumers, its profits are likely to improve when there is mild heterogeneity among consumers. Additionally, some regulations impose price caps, which also benefit the firm by enabling it to commit to lower prices, thereby enhancing profitability.

## CRediT authorship contribution statement

**Yan Xiong:** Writing – review & editing, Writing – original draft, Visualization, Validation, Funding acquisition, Formal analysis, Conceptualization. **Liyan Yang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

## Declaration of competing interest

Yan Xiong has received financial support from National Natural Science Foundation of China [NSFC 72422007] and the Research Grants Council of the Hong Kong Special Administrative Region, China [project no. 16502921] for the research described in this article. There are no other conflicts of interest to disclose.

Liyan Yang has received financial support from Bank of Canada Fellowship and Social Sciences and Humanities Research Council (SSHRC, 435-2021-0040) for the research described in this article. There are no other conflicts of interest to disclose.

## Appendix A. Proofs

**Proof of Lemma 1. Case 1:** $\alpha_L, \alpha_H < 1$ We begin by examining the case where both consumers' purchase probabilities take interior values, i.e., $\alpha_L, \alpha_H < 1$. We insert equations (3) into $\pi = p_L\alpha_L + p_H\alpha_H$ and express $\pi$ as a function of $p_L$ and $p_H$ as following:

$$\pi(p_L, p_H) = \frac{p_H\left(a + \lambda - 2\lambda p_L\right) + ap_L\left(\lambda - p_L + 1\right) - p_H^2}{a - \lambda^2}. \tag{A.1}$$

Taking the derivative of $\pi(p_L, p_H)$ with respect to $p_L$ and setting it to zero, we obtain $p_L(p_H) = \frac{a(1+\lambda)-2\lambda p_H}{2a}$. The second-order condition is $\frac{\partial\pi(p_L,p_H)}{\partial p_L^2} = -\frac{2a}{a-\lambda^2} < 0$. Similarly, maximizing $\pi(p_L, p_H)$ with respect to $p_H$ generates $p_H(p_L) = \frac{a+\lambda-2\lambda p_L}{2}$. The second-order condition is $\frac{\partial\pi(p_L,p_H)}{\partial p_H^2} = -\frac{2}{a-\lambda^2} < 0$. The interaction of the two best response functions yields the unique optimal prices

$$p_L^T = \frac{1}{2} \text{ and } p_H^T = \frac{a}{2}. \tag{A.2}$$

Inserting (A.2) into consumers' purchase strategies (3) yields their equilibrium purchase probabilities as follows:

$$\alpha_L^T = \frac{a(1+\lambda)}{2(a-\lambda^2)} \text{ and } \alpha_H^T = \frac{a+\lambda}{2(a-\lambda^2)}. \tag{A.3}$$

It is important to ensure that consumers' purchase probabilities take interior values. Since $\alpha_L^T > \alpha_H^T$, it suffices to verify that $\alpha_L^T < 1$, which requires that $\lambda < \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}$. Furthermore, under the optimal prices $(p_L^T, p_H^T)$, the resultant maximum profit is

$$\pi_{Case1}^T = \frac{a(a+2\lambda+1)}{4\left(a-\lambda^2\right)}. \tag{A.4}$$

**Case 2:** $\alpha_L = 1$ **and** $\alpha_H < 1$**.** Since consumer $L$ will make the purchase if and only if $v_L + \lambda\alpha_H \geq p_L$, $\alpha_L = 1$ implies that the consumer with the lowest standalone value ($v_L = 0$) will also buy the product, which implies that $p_L \leq \lambda\alpha_H$. The profit-maximizing firm must choose the highest possible price:

$$p_L = \lambda\alpha_H. \tag{A.5}$$

Further, consumer $H$ will buy if and only if $v_H + \lambda\alpha_L \geq p_H$, which happens with probability

$$\alpha_H = 1 - \frac{1}{a}(p_H - \lambda). \tag{A.6}$$

Inserting equations (A.5) and (A.6) into firm profit function $\pi = p_L + p_H\alpha_H$ and maximizing, we obtain the optimal prices as follows:

$$p_L^T = \frac{\lambda(a+2\lambda)}{2a} \text{ and } p_H^T = \frac{a}{2}. \tag{A.7}$$

Inserting (A.7) into equation (A.6) yields consumer $H$'s equilibrium purchase probability:

$$\alpha_H^T = \frac{1}{2} + \frac{\lambda}{a}. \tag{A.8}$$

Replacing (A.7) and (A.8) into the profit function we obtain the equilibrium profit as

$$\pi_{Case2}^T = \frac{(a+2\lambda)^2}{4a}. \tag{A.9}$$

Finally, to ensure that $\alpha_H^T < 1$ we need $\lambda < \frac{a}{2}$. Since $\frac{a}{2} > \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}$, when $\lambda < \bar{\lambda}^T$, both the interior solutions (Case 1) and corner solutions (Case 2) can be sustained. However, a comparison of equations (A.4) and (A.9) shows that $\pi_{Case1}^T > \pi_{Case2}^T$. Thus, the firm finds it optimal to induce the case with interior purchase probabilities.

**Case 3: $\alpha_L < 1$ and $\alpha_H = 1$.** The derivation is similar to Case 2. We can characterize that the firm's optimal prices are $p_L^T = \frac{1}{2}$ and $p_H^T = \frac{\lambda(1+2\lambda)}{2}$. The two consumers' equilibrium purchase probabilities are respectively $\alpha_L^T = \frac{1}{2} + \lambda$ and $\alpha_H^T = 1$. To ensure that $\alpha_L^T < 1$, we need $\lambda < \frac{1}{2}$. The resultant firm profit is $\pi_{Case3}^T = \frac{1}{4} + \lambda + \lambda^2$. By comparing the firm profit in Cases 2 and 3, we find that when $\lambda < \frac{1}{2}$, $\pi_{Case2}^T > \pi_{Case3}^T$. This indicates that Case 3 is less profitable for the firm than Case 2.

**Case 4: $\alpha_L = \alpha_H = 1$.** When $\alpha_L = \alpha_H = 1$, we must have $p_L \le \lambda$ and $p_H \le \lambda$. Again, the firm must choose the highest possible prices: $p_L = p_H = \lambda$. Thus, the firm profit is $\pi_{Case3}^T = 2\lambda$. It is easy to show that $\pi_{Case4}^T < \pi_{Case2}^T$ and thus this case is dominated by Case 2. In other words, Case 4 will be selected by the firm only when $\lambda$ is very large, i.e., $\lambda > \frac{a}{2}$, rendering neither Case 1 nor Case 2 viable.

In summary, the equilibrium purchase probabilities under transparent pricing are as follows:

$$\begin{cases} \alpha_L^T, \alpha_H^T < 1 & \text{when } \lambda < \bar{\lambda}^T \equiv \frac{\sqrt{a(a+8)}-a}{4}, \\ \alpha_L^T = 1, \alpha_H^T < 1 & \text{when } \bar{\lambda}^T < \lambda < \frac{a}{2}, \\ \alpha_L^T = \alpha_H^T = 1 & \text{otherwise.} \end{cases}$$

**Proof of Lemma 2.** Inserting the demand functions (4) into the firm profit function (2) and maximizing, we obtain the firm's optimal pricing strategies as given by equations (5). Replacing $p_L$ and $p_H$ in equations (4) by equations (5) and imposing belief consistency in equilibrium $\hat{\alpha}_H = \alpha_H^O$ and $\hat{\alpha}_L = \alpha_L^O$, we obtain the equilibrium purchase probabilities as follows:

$$\alpha_L^O = \frac{a(2+\lambda)}{4a-\lambda^2} \text{ and } \alpha_H^O = \frac{2a+\lambda}{4a-\lambda^2}. \tag{A.10}$$

Inserting $(\alpha_L^O, \alpha_H^O)$ into (5) yields the equilibrium prices:

$$p_L^O = \frac{a(2+\lambda)}{4a-\lambda^2} \text{ and } p_H^O = \frac{a(2a+\lambda)}{4a-\lambda^2}. \tag{A.11}$$

It is immediate that $\alpha_L^O - \alpha_H^O = \frac{(a-1)\lambda}{4a-\lambda^2} > 0$. Since $1 - \alpha_L^O = \frac{a(2-\lambda)-\lambda^2}{4a-\lambda^2} > \frac{2-\lambda-\lambda^2}{4a-\lambda^2} > 0$, where the first inequality follows from $a > 1$ and the second from $\lambda < 1$, both $\alpha_L^O$ and $\alpha_H^O$ are less than 1. Finally, the firm's equilibrium profit is

$$\pi^O = \frac{a\left(4a^2 + \lambda^2 + a(4 + 8\lambda + \lambda^2)\right)}{(4a-\lambda^2)^2}. \tag{A.12}$$

**Proof of Proposition 1.** Suppose that $\lambda < \frac{\sqrt{a(a+8)}-a}{4}$. Based on Lemmas 1 and 2, when $\lambda < \frac{\sqrt{a(a+8)}-a}{4}$, the comparison of equations (A.4) and (A.12) yields

$$\pi_{Case1}^T - \pi^O = \frac{a\lambda^2\left(4a^2 + a\left(5\lambda^2 + 16\lambda + 4\right) + \lambda^2(2\lambda+5)\right)}{4\left(a-\lambda^2\right)\left(4a-\lambda^2\right)^2} > 0.$$

Furthermore, $p_L^O - p_L^T = \frac{\lambda(2a+\lambda)}{2(4a-\lambda^2)} > 0$ and $p_H^O - p_H^T = \frac{a\lambda(2+\lambda)}{2(4a-\lambda^2)} > 0$.

**Proof of Proposition 2.** In this proof, we will first establish that the firm maximizes its profit through transparent pricing. Subsequently, we will show that if a commitment made at date 0 can induce the same pricing strategy as that achieved under transparent pricing, it is an optimal commitment for the firm, thereby constituting a subgame perfect equilibrium.

To begin, we demonstrate that the firm attains its highest profit with transparent pricing. Let $(p_L^*, p_H^*)$ denote the prices that maximize the firm's profit. Such a pricing strategy can always be implemented under transparent pricing, wherein the firm charges prices $(p_L^*, p_H^*)$ and consumers believe that these are the prices being charged. Thus, transparent pricing can lead to the firm achieving its maximum profit.

Therefore, if a commitment made at date 0 can lead to the same prices and consumer purchasing behavior as those observed under transparent pricing at date 1, it should be the optimal commitment for the firm. We now confirm that the commitment $\{\underline{p}_L, \bar{p}_L, \underline{p}_H, \bar{p}_H\}$, which satisfies $\bar{p}_L = p_L^T = \frac{1}{2}$, $\bar{p}_H = p_H^T = \frac{a}{2}$, $0 \le p_L \le p_L^T$, and $0 \le p_H \le p_H^T$, represents optimal commitments for the firm. Once again, we focus on the case where $\lambda < \bar{\lambda}^T$, ensuring that consumers' purchase probabilities under transparent pricing take interior values.

We conjecture that under this commitment, at date 1, the firm's optimal prices $(p_L^*, p_H^*)$ are given by equations (A.2), and the two consumers' purchase probabilities $(\alpha_L^*, \alpha_H^*)$ are given by equations (A.3). We will show that at date 1, the firm has no incentives to deviate from the conjectured pricing strategy. Consider the off-equilibrium prices $(p_L, p_H)$, where $p_L < p_L^T$ or $p_H < p_H^T$. After receiving $p_L$, consumer $L$ still believes that consumer $H$'s price stays at the equilibrium $p_H^T$ and the resulting purchase probability is at the equilibrium level given by (A.3). Thus, consumer $L$ computes her purchase probability as follows:

$$\alpha_L = 1 - \left(p_L - \lambda\alpha_H^T\right) = 1 - \left(p_L - \lambda\frac{a+\lambda}{2(a-\lambda^2)}\right).$$

Similarly, after observing the off-equilibrium price $p_H$, consumer $H$'s purchase probability becomes:

$$\alpha_H = 1 - \frac{1}{a}\left(p_H - \lambda\alpha_L^T\right) = 1 - \frac{1}{a}\left(p_H - \lambda\frac{a(1+\lambda)}{2(a-\lambda^2)}\right).$$

Thus, after offering the prices $(p_L, p_H)$, the firm makes profits $\pi = p_L\alpha_L + p_H\alpha_H$, which can be simplified to the following:

$$\pi(p_L, p_H) = p_L\left(1 - \left(p_L - \lambda\frac{a+\lambda}{2(a-\lambda^2)}\right)\right) + p_H\left(1 - \frac{1}{a}\left(p_H - \lambda\frac{a(1+\lambda)}{2(a-\lambda^2)}\right)\right).$$

Taking partial derivatives yield $\frac{\partial\pi(p_L,p_H)}{\partial p_L} = 1 - 2p_L + \frac{\lambda(a+\lambda)}{2(a-\lambda^2)}$ and $\frac{\partial\pi(p_L,p_H)}{\partial p_H} = 1 - \frac{2}{a}p_H + \frac{\lambda(1+\lambda)}{2(a-\lambda^2)}$. It is clear that for $p_L < p_L^T = \frac{1}{2}$, we have $\frac{\partial\pi(p_L,p_H)}{\partial p_L} > 0$. Thus, within the committed range $p_L \in [\underline{p}_L, p_L^T]$, the firm has no incentive to lower the price for consumer $L$. Similarly, for $p_H < p_H^T = \frac{a}{2}$, it follows that $\frac{\partial\pi(p_L,p_H)}{\partial p_H} > 0$. So, again, within the committed range $p_H \in [\underline{p}_H, p_H^T]$, the firm also has no incentive to reduce the price for consumer $H$.

In summary, given the commitments $\{\underline{p}_L, \bar{p}_L, \underline{p}_H, \bar{p}_H\}$, where $\bar{p}_L = p_L^T = \frac{1}{2}$, $\bar{p}_H = p_H^T = \frac{a}{2}$, $0 \le p_L \le p_L^T$, and $0 \le p_H \le p_H^T$, the firm's prices (A.2) and the two consumers' purchase probabilities (A.3) can be sustained in the subgame. This results in the same level of firm profit as achieved under transparent pricing. Therefore, these commitments constitute subgame perfect equilibria.

**Proof of Proposition 3.** Based on Lemmas 1 and 2, we obtain that, when $\lambda < \bar{\lambda}^T$,

$$\frac{\pi^T - \pi^O}{\pi^T} = \frac{\lambda^2\left(4a^2 + a\left(5\lambda^2 + 16\lambda + 4\right) + \lambda^2(2\lambda+5)\right)}{(a+2\lambda+1)\left(4a-\lambda^2\right)^2}.$$

Taking derivative with respect to $a$ and $\lambda$ respectively yields $\partial\left(\frac{\pi^T-\pi^O}{\pi^T}\right)/\partial a = -\frac{4\lambda^2\left(4a^3+a^2\left(11\lambda^2+32\lambda+8\right)+a\left(20\lambda^3+54\lambda^2+24\lambda+4\right)+\lambda^2\left(2\lambda^3+16\lambda^2+30\lambda+11\right)\right)}{(a+2\lambda+1)^2\left(4a-\lambda^2\right)^3} < 0$ and $\partial\left(\frac{\pi^T-\pi^O}{\pi^T}\right)/\partial\lambda = \frac{8\lambda\left(4a^4+a^3\left(11\lambda^2+28\lambda+8\right)+a^2\left(25\lambda^3+54\lambda^2+28\lambda+4\right)+a\left(\lambda^3+16\lambda^2+25\lambda+11\right)\lambda^2+\lambda^5\right)}{(a+2\lambda+1)^2\left(4a-\lambda^2\right)^3} > 0.$

**Proof of Proposition 4. Part (i) of Proposition 4**

We first characterize the equilibrium for a given value of $\gamma$, and then proceed to explore the properties of the firm's profit function $\pi(\gamma)$. Throughout the appendices, we focus on the relevant cases in which $\gamma \le 1$. This is because if $\gamma > 1$, it is possible that the firm sets infinitely low prices in equilibrium, i.e., $p_L, p_H \to -\infty$. We will discuss the following four cases, depending on whether the purchase probabilities of the two consumers take interior values or not.

**Case 1:** $\alpha_L, \alpha_H < 1$. Given the beliefs about the two consumers' purchase probabilities $\hat{\alpha}_L$ and $\hat{\alpha}_H$, following similar analysis in Section 2.3, we compute the two consumers' respective purchase probabilities as in equations (4). Then, equipped with these demand functions (4), the firm determines prices $p_L$ and $p_H$ to maximize the general firm incentive (8), $\Pi = \pi + \gamma \cdot CS$, where the firm's expected profit $\pi$ is given by equation (2), and consumer surplus $CS$ is the sum of the two consumers' ex ante utility from consumption:

$$CS = \underbrace{\int_{p_L-\lambda\hat{\alpha}_H}^{1} (v - p_L)dv + \alpha_L\alpha_H\lambda}_{\text{consumer } L\text{'s utility}} + \underbrace{\int_{p_H-\lambda\hat{\alpha}_L}^{a} \frac{1}{a}(v - p_H)dv + \alpha_L\alpha_H\lambda}_{\text{consumer } H\text{'s utility}}. \tag{A.13}$$

Maximizing $\Pi$ yields the optimal pricing strategy as follows:

$$p_L = \frac{a\left(\gamma\left(-\left(\hat{\alpha}_H+2\right)\lambda + \gamma - 3\right) + 2\hat{\alpha}_H\lambda + 2\right) - 2\gamma\lambda^2\left(2\left(\hat{\alpha}_H\gamma\lambda + \gamma\right) + \hat{\alpha}_L(1-\gamma)\right)}{a(2-\gamma)^2 - 4\gamma^2\lambda^2}, \tag{A.14}$$

$$p_H = \frac{a^2(2-\gamma)(1-\gamma) + a\lambda\left(2\gamma\left(\hat{\alpha}_H(\gamma-1)\lambda - 2\gamma\lambda - 1\right) - \hat{\alpha}_L(\gamma-2)\right) - 4\hat{\alpha}_L\gamma^2\lambda^3}{a(2-\gamma)^2 - 4\gamma^2\lambda^2}. \tag{A.15}$$

Note that $\hat{\alpha}_H$ and $\hat{\alpha}_L$ are exogenous parameters in the players' optimal decisions in equations (4), (A.14), and (A.15), which reflect the passive belief specification. In equilibrium, these four equations must hold simultaneously. Additionally, consumers hold consistent beliefs in equilibrium; that is, $\hat{\alpha}_L = \alpha_L^{CSR}$ and $\hat{\alpha}_H = \alpha_H^{CSR}$. Thus, setting $\hat{\alpha}_L = \alpha_L^{CSR}$, $\hat{\alpha}_H = \alpha_H^{CSR}$, $p_L = p_L^{CSR}$, and $p_H = p_H^{CSR}$ in these four equations, we compute the equilibrium demands and prices as follows:

$$\alpha_L^{CSR} = \frac{a(2+\lambda-\gamma(1-\lambda))}{a(2-\gamma)^2-\lambda^2(1+\gamma)^2}, \tag{A.16}$$

$$\alpha_H^{CSR} = \frac{a(2-\gamma)+\lambda(1+\gamma)}{a(2-\gamma)^2-\lambda^2(1+\gamma)^2}, \tag{A.17}$$

$$p_L^{CSR} = \frac{a\left(2+\gamma^2+\lambda-\gamma(3+2\lambda)\right)-\gamma(1+\gamma)\lambda^2}{a(2-\gamma)^2-\lambda^2(1+\gamma)^2}, \tag{A.18}$$

$$p_H^{CSR} = a\frac{a(\gamma^2-3\gamma+2)-\lambda\left(\gamma^2\lambda+\gamma(2+\lambda)-1\right)}{a(2-\gamma)^2-\lambda^2(1+\gamma)^2}. \tag{A.19}$$

Equipped with these equations, we express the firm's profit function as follows:

$$\pi(\gamma) = \frac{a\begin{pmatrix} a\left(\gamma^3\left(\lambda^2+2\lambda-1\right)+\gamma^2\left(5-3\lambda^2\right)-\gamma\left(3\lambda^2+12\lambda+8\right)+\lambda^2+8\lambda+4\right) \\ -a^2(\gamma-1)(\gamma-2)^2-(\gamma+1)\lambda^2\left(\gamma^2(2\lambda-1)+2\gamma(\lambda+2)-1\right)\end{pmatrix}}{\left(a(2-\gamma)^2-\lambda^2(\gamma+1)^2\right)^2}. \tag{A.20}$$

Let's denote the equilibrium profit function in (A.20) as $\pi^{\text{Case 1}}(\gamma)$.

To complete the analysis of this interior equilibrium, we must ensure that both consumers' purchase probabilities indeed lie between 0 and 1, i.e., $\alpha_L^{CSR}, \alpha_H^{CSR} \in (0,1)$. We now solve conditions that sustain the interior purchase probability $\alpha_L, \alpha_H < 1$. Using equations (A.16) and (A.17), we know that $\alpha_L^{CSR} - \alpha_H^{CSR} = \frac{(a-1)(1+\gamma)\lambda}{a(2-\gamma)^2-\lambda^2(1+\gamma)^2} > 0$. That is, consumer $L$ is more likely to make the purchase than consumer $H$. Furthermore, equations (A.16) and (A.17) imply that to ensure $\alpha_L^{CSR} > 0$ and $\alpha_H^{CSR} > 0$ we need $\gamma < \frac{2\sqrt{a}-\lambda}{\sqrt{a}+\lambda}$. Taking the derivative of $\alpha_L^{CSR}$ in equation (A.16) with respect to $\gamma$ yields

$$\begin{aligned}
\frac{\partial \alpha_L^{CSR}}{\partial \gamma} &= \frac{a\left((\gamma+1)\lambda^2(\lambda+5-\gamma(1-\lambda))+a(2-\gamma)(-\gamma(1-\lambda)+4\lambda+2)\right)}{\left(a(2-\gamma)^2-(\gamma+1)^2\lambda^2\right)^2} \\
&> \frac{a\left((\gamma+1)\lambda^2(\lambda+5-\frac{2+\lambda}{1-\lambda}(1-\lambda))+a(2-\gamma)(-\frac{2+\lambda}{1-\lambda}(1-\lambda)+4\lambda+2)\right)}{\left(a(2-\gamma)^2-(\gamma+1)^2\lambda^2\right)^2} \\
&= \frac{3a\lambda(a(2-\gamma)+\lambda(1+\gamma))}{\left(a(2-\gamma)^2-(\gamma+1)^2\lambda^2\right)^2} > 0,
\end{aligned}$$

where the first inequality follows because $\gamma < \frac{2+\lambda}{1-\lambda}$ (noting that $\gamma < \frac{2\sqrt{a}-\lambda}{\sqrt{a}+\lambda} < \frac{2+\lambda}{1-\lambda}$). Therefore, $\alpha_L^{CSR}$ is an increasing function of $\gamma$. Solving $\alpha_L^{CSR} < 1$ yields

$$\gamma < \bar{\gamma}_L \equiv \frac{-\sqrt{a}\sqrt{a\lambda^2+10a\lambda+a+24\lambda^2}+a\lambda+3a+2\lambda^2}{2(a-\lambda^2)}. \tag{A.21}$$

Therefore, when $\gamma < \bar{\gamma}_L$, we have $\alpha_L^{CSR} < 1$ and $\alpha_H^{CSR} < 1$.

**Case 2:** $\alpha_L = 1, \alpha_H < 1$. $\alpha_L = 1$ implies that even the consumer $L$ with the lowest willingness to pay ($v_L = 0$) wants to buy the product, and thus the price charged to consumer $L$ cannot exceed the expected network value; that is, $p_L \le \lambda\hat{\alpha}_H$. Given this, the firm must choose the highest possible price to consumer $L$, namely, $p_L = \lambda\hat{\alpha}_H$. Inserting $p_L = \lambda\hat{\alpha}_H$ into consumers' purchase strategies (4) and the firm's objective function $\Pi = \pi + \gamma \cdot CS$, where $\pi$ and $CS$ are given by (2) and (A.13), we obtain the following price $p_H$ that maximizes $\Pi$:

$$p_H = \frac{a(1-\gamma)-\lambda\hat{\alpha}_L+2\gamma\lambda}{2-\gamma}. \tag{A.22}$$

Setting $\alpha_L = \hat{\alpha}_L = 1$ and $\alpha_H = \hat{\alpha}_H$ in equations (4), (A.22), and $p_L = \lambda\hat{\alpha}_H$, we can compute the equilibrium demands and prices as follows:

$$\alpha_L^{CSR} = 1, \alpha_H^{CSR} = \frac{a+\lambda+\gamma\lambda}{a(2-\gamma)}, \tag{A.23}$$

$$p_L^{CSR} = \frac{\lambda(a+\lambda+\gamma\lambda)}{a(2-\gamma)}, p_H^{CSR} = \frac{a(1-\gamma)+\lambda(1-2\gamma)}{2-\gamma}. \tag{A.24}$$

The resulting firm profit is

$$\pi^{\text{Case 2}}(\gamma) = \frac{(1-\gamma)(a+3\lambda)(a+\gamma\lambda+\lambda)}{a(2-\gamma)^2}. \tag{A.25}$$

Since $\frac{\partial \pi^{\text{Case 2}}(\gamma)}{\partial \gamma} = -\frac{(a+3\lambda)(a\gamma+4\gamma\lambda-2\lambda)}{a(2-\gamma)^3} < 0$, in this region the firm profit decreases in $\gamma$.

To ensure that $\alpha_H^{CSR} < 1$, we need

$$\gamma < \bar{\gamma}_H \equiv \frac{a-\lambda}{a+\lambda}. \tag{A.26}$$

Simple comparison yields $\bar{\gamma}_L < \bar{\gamma}_H$, where $\bar{\gamma}_L$ is given by (A.21). We further prove that $\alpha_L = 1$ and $\alpha_H < 1$ cannot be sustained when $\gamma < \bar{\gamma}_L$. We will examine the unconstrained problem as in Case 1 and show that when $\gamma < \bar{\gamma}_L$, the objective function is marginally increasing at $p_L = \lambda\hat{\alpha}_H$ so that the firm always has incentives to deviate from $\alpha_L = 1$ and $\alpha_H < 1$. Specifically, inserting the consumer purchase strategies (4) into the firm's objective function $\Pi = \pi + \gamma \cdot CS$ and taking the derivative of $\Pi$ with respect to $p_H$, we obtain the optimal price $p_H(p_L) = \frac{a(\gamma-1)-\hat{\alpha}_L\lambda+2\gamma\lambda(\hat{\alpha}_H\lambda-p_L+1)}{\gamma-2}$. Inserting $p_H(p_L)$ into $\Pi$, taking the derivative of $\Pi$ with respect to $p_L$, replacing $p_L = \lambda\hat{\alpha}_H$, and replacing the purchase beliefs $\hat{\alpha}_L$ and $\hat{\alpha}_H$ with the equilibrium levels (A.23), we obtain

$$\frac{\partial \Pi}{\partial p_L}\Big|_{p_L=\lambda\hat{\alpha}_H} = \frac{(a-\lambda^2)\gamma^2 - \gamma(2\lambda^2 + a(3+\lambda)) + a(2-\lambda) - \lambda^2}{2(2-\gamma)}.$$

We can compute that when $\gamma < \bar{\gamma}_L$, $\frac{\partial \Pi}{\partial p_L}\big|_{p_L=\lambda\hat{\alpha}_H} > 0$; that is, to set the price $p_L = \lambda\hat{\alpha}_H$ and induce $\alpha_L = 1$ and $\alpha_H < 1$ is suboptimal for the firm. Therefore, the corner case with $\alpha_L < 1$ and $\alpha_H = 1$ can only be sustained when $\bar{\gamma}_L < \gamma < \bar{\gamma}_H$.

**Case 3:** $\alpha_L < 1, \alpha_H = 1$**.** Similar to Case 2, $\alpha_H = 1$ implies that even the consumer $H$ with the lowest willingness to pay ($v_H = 0$) wants to buy the product, and thus the price charged to consumer $H$ cannot exceed the expected network value; that is, $p_H \le \lambda\hat{\alpha}_L$. Given this, the firm must choose the highest possible price to consumer $H$, namely, $p_H = \lambda\hat{\alpha}_L$. Inserting $p_H = \lambda\hat{\alpha}_L$ into consumers' purchase strategies (4) and the firm's objective function $\Pi = \pi + \gamma \cdot CS$, where $\pi$ and $CS$ are given by (2) and (A.13), we obtain the following optimal price $p_L$:

$$p_L = \frac{1-\gamma-\lambda\hat{\alpha}_H + 2\gamma\lambda}{2-\gamma}. \tag{A.27}$$

Setting $\alpha_L = \hat{\alpha}_L$ and $\alpha_H = \hat{\alpha}_H = 1$ in equations (4), (A.27), and $p_H = \lambda\hat{\alpha}_L$, we can compute the equilibrium demands and prices as follows:

$$\alpha_L^{CSR} = \frac{1+\gamma+\gamma\lambda}{2-\gamma}, \alpha_H^{CSR} = 1, \tag{A.28}$$

$$p_L^{CSR} = \frac{1-\gamma+\lambda-2\gamma\lambda}{2-\gamma}, p_H^{CSR} = \frac{\lambda(1+\lambda+\gamma\lambda)}{2-\gamma}. \tag{A.29}$$

To ensure that $\alpha_L^{CSR} < 1$, we need $\gamma < \bar{\gamma}_H' \equiv \frac{1-\lambda}{1+\lambda}$. Simple comparison yields $\bar{\gamma}_L > \bar{\gamma}_H'$, where $\bar{\gamma}_L$ is given by (A.21).

Similar to Case 2, we can show that when $\gamma < \bar{\gamma}_H'$, the firm always has incentives to raise the price charged to consumer $H$, thereby violating $p_H \le \lambda\hat{\alpha}_L$. Therefore, the conjectured equilibrium in which $\alpha_L = 1$ and $\alpha_H < 1$ cannot be sustained.

**Case 4:** $\alpha_L = \alpha_H = 1$**.** When $\alpha_L = \alpha_H = 1$, as analyzed before, the firm's prices must not exceed the expected network value: $p_H \le \lambda\hat{\alpha}_L$ and $p_L \le \lambda\hat{\alpha}_H$, and the firm will choose the highest possible price: $p_H = \lambda\hat{\alpha}_L$ and $p_L = \lambda\hat{\alpha}_H$. Since in equilibrium $\alpha_L^{CSR} = \hat{\alpha}_L = 1$ and $\alpha_H^{CSR} = \hat{\alpha}_H = 1$, we obtain $p_H^{CSR} = p_L^{CSR} = \lambda$. And the firm profit is $\pi^{\text{Case 4}} = 2\lambda$.

We then characterize the parameter region that can sustain the conjectured equilibrium. As in Cases 2 and 3, we will show that when $\gamma < \bar{\gamma}_H$, the firm has incentives to raise prices $p_L$ and $p_H$ at the level $p_L = \lambda\hat{\alpha}_H$ and $p_H = \lambda\hat{\alpha}_L$. Thus, the conjectured corner case $\alpha_L = \alpha_H = 1$ can be sustained only when $\gamma > \bar{\gamma}_H$. Specifically, inserting the consumer purchase strategies (4) into the firm's objective function $\Pi = \pi + \gamma \cdot CS$, taking the derivative of $\Pi$ with respect to $p_L$ and $p_H$, and evaluating the derivatives at $p_L = p_H = \lambda$, we obtain: $\frac{\partial \Pi}{\partial p_L}\big|_{p_L=p_H=\lambda} = 1-\lambda-\gamma(1+\lambda)$ and $\frac{\partial \Pi}{\partial p_H}\big|_{p_L=p_H=\lambda} = 1-\gamma-\frac{(1+\gamma)\lambda}{a}$. When $\gamma < \bar{\gamma}_H$, we can compute that $\frac{\partial \Pi}{\partial p_L}\big|_{p_L=p_H=\lambda} > 0$ and $\frac{\partial \Pi}{\partial p_H}\big|_{p_L=p_H=\lambda} > 0$ so that the firm has incentives to raise prices. Therefore, only when $\gamma > \bar{\gamma}_H$ can the conjectured corner case $\alpha_L = \alpha_H = 1$ be sustained.

To summarize, given $\gamma$, the firm's profit function is as follows:

$$\pi(\gamma) = \begin{cases} \pi^{\text{Case 1}}, & \gamma < \bar{\gamma}_L \\ \pi^{\text{Case 2}}, & \bar{\gamma}_L < \gamma < \bar{\gamma}_H \\ 2\lambda, & \gamma > \bar{\gamma}_H \end{cases} \tag{A.30}$$

where $\pi^{\text{Case 1}}$ and $\pi^{\text{Case 2}}$ are given by (A.20) and (A.25), respectively. Overall, since $\pi(\gamma)$ monotonically decreases in $\gamma$ when $\bar{\gamma}_L < \gamma < \bar{\gamma}_H$ and is independent of $\gamma$ when $\gamma > \bar{\gamma}_H$, the level of social responsibility that maximizes the firm profit must lie within $[0, \bar{\gamma}_L]$. So, it suffices to focus on the interior case.

When $\gamma < \bar{\gamma}_L$, the first-order derivative of $\pi(\gamma)$ with respect to $\gamma$ can be expressed as:

$$\frac{d\pi}{d\gamma} = \frac{a\left(\begin{array}{c} a^2(2-\gamma)\left(\begin{array}{c} \gamma^3\left(2\lambda^2+2\lambda-1\right)+\gamma^2\left(-10\lambda^2+12\lambda+4\right) \\ -4\gamma\left(5\lambda^2+9\lambda+1\right)+2\lambda(5\lambda+4) \end{array}\right) \\ +a\lambda^2\left(\begin{array}{c} \gamma^4\left(\lambda^2+4\lambda-2\right)+\gamma^3\left(-8\lambda^2+12\lambda+14\right) \\ -12\gamma^2\lambda(\lambda+5)+\gamma\left(4\lambda^2-32\lambda-50\right)+7\lambda^2+36\lambda+20 \end{array}\right) \\ -a^3(2-\gamma)^3\gamma-(\gamma+1)^2\lambda^4\left(\gamma^2(2\lambda-1)+10\gamma-2\lambda-7\right) \end{array}\right)}{\left(a(2-\gamma)^2-\lambda^2(1+\gamma)^2\right)^3}. \tag{A.31}$$

Setting $\gamma \to 0$ yields $\frac{d\pi}{d\gamma}\mid_{\gamma\to 0}= \frac{a\lambda\left(4a^2(5\lambda+4)+a\left(7\lambda^2+36\lambda+20\right)\lambda+(2\lambda+7)\lambda^3\right)}{\left(4a-\lambda^2\right)^3} > 0$. This proves Part (i) of the proposition.

**Part (ii) of Proposition 4**

As discussed in the proof of Part (i), the optimal level of CSR commitment $\gamma^{CSR}$ lies within $(0, \bar{\gamma}_L]$. When $\gamma < \bar{\gamma}_L$, consumer $L$'s surplus is $CS_L(\gamma) = \int_{p_L-\lambda\hat{\alpha}_H}^1 (v-p_L)dv + \alpha_L\alpha_H\lambda$, which can be simplified to $CS_L(\gamma) = \frac{a^2(\lambda+2-\gamma(1-\lambda))^2}{2\left(a(2-\gamma)^2-(\gamma+1)^2\lambda^2\right)^2}$. Denote $cs_L = \frac{\lambda+2-\gamma(1-\lambda)}{a(2-\gamma)^2-(\gamma+1)^2\lambda^2} > 0$ so that $CS_L(\gamma) = \frac{a^2}{2}cs_L^2$. We next prove that $cs_L(\gamma)$ increases in $\gamma$ and thus $CS_L(\gamma)$ increases in $\gamma$. $\frac{\partial cs_L}{\partial\gamma} = \frac{\gamma^2(1-\lambda)\left(a-\lambda^2\right)-2\gamma(\lambda+2)\left(a-\lambda^2\right)+a(8\lambda+4)+\lambda^2(\lambda+5)}{(a(2-\gamma)^2-(\gamma+1)^2\lambda^2)^2} > 0$, where the inequality holds because the numerator $\gamma^2(1-\lambda)\left(a-\lambda^2\right)-2\gamma(\lambda+2)\left(a-\lambda^2\right)+a(8\lambda+4)+\lambda^2(\lambda+5)$, having an axis of symmetry at $\gamma=\frac{2+\lambda}{1-\lambda}$ and opening upward, is positive when $\gamma < \bar{\gamma}_L$. So, $CS_L(\gamma)$ increases in $\gamma$ when $0<\gamma<\bar{\gamma}_L$. That is, $CS_L(\gamma^{CSR}) > CS_L(0)$, or $CS_L^{CSR} > CS_L^O$.

Similarly, consumer $H$'s surplus is $CS_H(\gamma) = \int_{p_H-\lambda\hat{\alpha}_L}^a \frac{1}{a}(v-p_H)dv + \alpha_L\alpha_H\lambda$, which can be simplified to $CS_H(\gamma) = \frac{a(a(2-\gamma)+(\gamma+1)\lambda)^2}{2\left(a(2-\gamma)^2-(\gamma+1)^2\lambda^2\right)^2}$. Denote $cs_H = \frac{a(2-\gamma)+(\gamma+1)\lambda}{a(2-\gamma)^2-(\gamma+1)^2\lambda^2} > 0$ so that $CS_H(\gamma) = \frac{a^2}{2}cs_H^2$. We show that $cs_H(\gamma)$ increases in $\gamma$ because $\frac{\partial cs_H}{\partial\gamma} = \frac{\gamma^2\left(a^2-a(\lambda+1)\lambda+\lambda^3\right)+2\gamma\left(-2a^2+a(2\lambda-1)\lambda+\lambda^3\right)+4a^2+a(5\lambda+8)\lambda+\lambda^3}{(2\left(a(2-\gamma)^2-(\gamma+1)^2\lambda^2\right)^2)^2} > 0$, where the inequality holds because the numerator, having an axis of symmetry at $\gamma = \frac{2a+\lambda}{a-\lambda}$ and opening upward, is positive when $\gamma < \bar{\gamma}_L$. So, $CS_H(\gamma)$ increases in $\gamma$ when $0<\gamma<\bar{\gamma}_L$. That is, $CS_H(\gamma^{CSR}) > CS_H(0)$, or $CS_H^{CSR} > CS_H^O$.

Taken together, both consumers are better off at $\gamma=\gamma^{CSR}$ than at $\gamma=0$, the total consumer surplus must be higher at $\gamma=\gamma^{CSR}$, i.e., $CS^{CSR} > CS^O$.

**Part (iii) of Proposition 4**

As shown in the proof of Part (i), the equation (A.31) determines the implicit relationship between the optimal CSR commitment $\gamma^{CSR}$ and the two parameters $a$ and $\lambda$. The implicit differentiation suggests that $\lim_{\lambda\to 0}\frac{\partial\gamma^{CSR}}{\partial a} = -\frac{\gamma(2-\gamma)}{2(1+a)(1+\gamma)} < 0$. Furthermore, when $\lambda\to 0$, $\frac{d\pi}{d\gamma} = -\frac{\gamma(1+a)}{(2-\gamma)^3} < 0$, and thus $\gamma^{CSR}\to 0$. Therefore, $\lim_{\lambda\to 0}\frac{\partial\gamma^{CSR}}{\partial\lambda} = \frac{2-8\gamma-\gamma^2}{1+a+\gamma+a\gamma} > 0$.

**Proof of Proposition 5.** For illustration, we will analyze the scenario in which the firm serves consumer $L$ first, noting that the analysis for serving consumer $H$ first follows a similar approach.

We solve the sequential game using backward induction. Given consumer $L$'s price $p_L$, the later consumer $H$ will assess $L$'s purchase probability $\alpha_L$ and makes the purchase if and only if $v_H + \lambda\alpha_L \geq p_H$, which happens with probability

$$\alpha_H = 1 - \frac{1}{a}\left(p_H - \lambda\alpha_L\right). \tag{A.32}$$

By contrast, consumer $L$ cannot observe $H$'s price and can only form belief about $H$'s purchase probability $\hat{\alpha}_H$. Consumer $L$ will make the purchase if and only if $v_L + \lambda\hat{\alpha}_H \geq p_L$, which happens with probability

$$\alpha_L = 1 - (p_L - \lambda\hat{\alpha}_H) \tag{A.33}$$

Inserting the two demand functions (A.32) and (A.33) into the firm's profit function $p_L\alpha_L + p_H\alpha_H$ and maximizing, we obtain the optimal pricing strategy:

$$p_L = \frac{a(2-\lambda+2\lambda\hat{\alpha}_H)-\lambda^2(1+\lambda\hat{\alpha}_H)}{4a-\lambda^2} \text{ and } p_H = \frac{a(2a+\lambda+\lambda^2\hat{\alpha}_H)}{4a-\lambda^2}. \tag{A.34}$$

Then, inserting the price function (A.34) into the demands (A.32) and (A.33) and imposing consistency $\alpha_H = \hat{\alpha}_H$, we obtain the equilibrium purchase probabilities, where the superscript $S$ indicates the equilibrium in the sequential purchase setting:

$$\alpha_L^S = \frac{a(1+\lambda)}{2a-\lambda^2} \text{ and } \alpha_H^S = \frac{2a+\lambda}{2(2a-\lambda^2)}. \tag{A.35}$$

Inserting the equilibrium purchase probabilities (A.35) into price functions (A.34) yields the equilibrium prices:

$$p_L^S = \frac{1}{2} \text{ and } p_H^S = \frac{a(2a+\lambda)}{2(2a-\lambda^2)}. \tag{A.36}$$

When $a = 1$, (A.36) shows that $p_L^S = \frac{1}{2}$ and $p_H^S = \frac{2+\lambda}{2(1-\lambda^2)}$. A straightforward comparison reveals that $p_L^S < p_H^S$, which proves the third part of the Proposition.

We next compare the profits. Inserting the equilibrium purchase probabilities (A.35) and prices (A.36) into firm profit function yields the optimal profit when it serves consumer $L$ first:

$$\pi^S_{Lfirst} = \frac{a\left(4a^2 - \lambda^2(1+2\lambda) + 4a(1+2\lambda)\right)}{4(2a-\lambda^2)^2}. \tag{A.37}$$

Following similar approach, we can characterize the firm's optimal profit when it serves consumer $H$ first:

$$\pi^S_{Hfirst} = \frac{a\left(4a^2 - 2\lambda^3 + a(4+8\lambda-\lambda^2)\right)}{4(2a-\lambda^2)^2}. \tag{A.38}$$

It follows that $\pi^S_{Lfirst} - \pi^S_{Hfirst} = \frac{(a-1)a\lambda^2}{4(2a-\lambda^2)^2} > 0$. Thus, it is optimal for the firm to serve consumer $L$ first. This proves the second part of Proposition 5.

Finally, to show that the firm's profit improves in the sequential setting compared to the simultaneous setting, it suffices to compare $\pi^S_{Hfirst}$ with $\pi^O$. Define $G(a,\lambda) \equiv \pi^S_{Hfirst} - \pi^O = \frac{a\lambda^2(2+\lambda)}{4(8a^2-6a\lambda^2+\lambda^4)^2} g(a,\lambda)$, where

$$g(a,\lambda) \equiv 4a^2(2+3\lambda) - a\lambda^2(5\lambda-2) - 2\lambda^4. \tag{A.39}$$

Since $\frac{\partial g(a,\lambda)}{\partial a} = 8a(2+3\lambda) - \lambda^2(5\lambda-2) > 16 + 24\lambda + 2\lambda^2 - 5\lambda^3 > 0$, where the first inequality holds because $a > 1$ and the second holds because $\lambda < 1$, $g(a,\lambda) > g(1,\lambda) = -2\lambda^4 - 5\lambda^3 + 2\lambda^2 + 12\lambda + 8 > 0$, where the inequality holds because $\lambda < 1$. Therefore, $\pi^S_{Hfirst} > \pi^O$. This proves the first part of Proposition 5.

**Proof of Proposition 6.** The firm's optimal pricing strategy – and consequently its total profit – depends on the beliefs of current consumers. We will explore the following two scenarios.

First, suppose that the firm has a bad reputation in that current consumers believe it will charge high prices to others. According to the belief specification (9), the firm remains trapped in this negative reputation, regardless of how low it sets its prices in the current period. As a result, the firm has no incentive to deviate and continues to maintain its bad reputation.

Second, suppose that the firm has a good reputation in that it consistently charged low prices to its consumers and thus current consumers believe it will continue this practice. Given this favorable consumer belief, we examine whether the firm will choose to deviate in order to prioritize immediate profit or maintain its good reputation.

- Suppose that the firm aims to maintain the good reputation by charging low prices in the current period: $p_L \le \frac{1}{2}$ and $p_H \le \frac{a}{2}$. We can verify that within this price region the firm must set the highest possible prices: $p_L = \frac{1}{2}$ and $p_H = \frac{a}{2}$. Thus, the firm's total profit is

$$\Pi = \sum_{t=0}^{\infty} \pi_t^T = \frac{1}{1-\delta}\frac{a(1+a+2\lambda)}{4(a-\lambda^2)}. \tag{A.40}$$

- Suppose that the firm deviates and charges high prices to exploit consumers in the current period. It is important to note that, during this period, consumers still maintain a favorable belief about the firm, leading them to believe that the probabilities of consumer purchases are $(\hat{\alpha}_L, \hat{\alpha}_H) = (\alpha_L^T, \alpha_H^T) = \left(\frac{a(1+\lambda)}{2(a-\lambda^2)}, \frac{a+\lambda}{2(a-\lambda^2)}\right)$. Thus, the firm must choose prices to maximize the immediate profit: $\max_{p_L, p_H} p_L\left(1 - (p_L - \lambda\alpha_H^T)\right) + p_H\left(1 - \frac{p_H - \lambda\alpha_L^T}{a}\right)$, which yields the optimal current prices $(p_L, p_H) = \left(\frac{2a+a\lambda-\lambda^2}{4(a-\lambda^2)}, \frac{a(2a+\lambda-\lambda^2)}{4(a-\lambda^2)}\right)$. We can verify that indeed $p_L > \frac{1}{2}$ and $p_H > \frac{a}{2}$. Inserting these optimal prices into the profit function yields the optimal immediate profit: $\frac{4a^3+a^2\left(-3\lambda^2+8\lambda+4\right)+a\left(\lambda^2-4\lambda-3\right)\lambda^2+\lambda^4}{16\left(a-\lambda^2\right)^2}$. After the deviation, the firm only repeats the inefficient opaque prices $p^O$ and make the profit $\pi^O$ accordingly. Thus, the total profit from deviation from the good reputation is

$$\Pi' = \frac{4a^3 + a^2\left(-3\lambda^2+8\lambda+4\right) + a\left(\lambda^2-4\lambda-3\right)\lambda^2 + \lambda^4}{16\left(a-\lambda^2\right)^2} + \frac{\delta}{1-\delta} a \frac{4a^2+\lambda^2+a(4+8\lambda+\lambda^2)}{(4a-\lambda^2)^2}. \tag{A.41}$$

Taken together, the firm will not deviate from the high reputation when $\Pi \ge \Pi'$. We examine the following cases.

(1) Suppose that the discount factor is approaching 1. When the firm is sufficiently patient, its total profit is dominated by the future profit. Since $\pi^T > \pi^O$, it is optimal to maintain the good reputation, i.e., $\Pi > \Pi'$.

(2) Suppose that the network effect $\lambda$ is sufficiently low, specifically as $\lambda$ approaches 0. Then, $\lim_{\lambda\to 0}(\Pi-\Pi') \approx \frac{\lambda^2 a^3(a+1)(2\delta-1)}{(1-\delta)(4a^2-5a\lambda^2+\lambda^4)^2} > 0$ given that $\delta > \frac{1}{2}$. By contrast, when $\lambda = 0$, $\Pi = \Pi'$, which means the firm is indifferent regarding the maintenance of a good reputation. Therefore, as the network effect transitions from $\lambda = 0$ to $\lambda > 0$, the firm is incentivized to set low prices and maintain its good reputation.

(3) Consider the case when $\lambda \to 0$ and $\delta > \frac{1}{2}$. Then, $\partial\left(\lim_{\lambda\to 0}(\Pi-\Pi')\right)/\partial a = \frac{\lambda^2 a^2(2\delta-1)\left(3\lambda^4-2a^2\left(5\lambda^2+2\right)-a\left(5\lambda^2-4\lambda^4\right)\right)}{(1-\delta)\left(4a^2-5a\lambda^2+\lambda^4\right)^3} \approx -\frac{4\lambda^2 a^4(2\delta-1)}{(1-\delta)\left(4a^2-5a\lambda^2+\lambda^4\right)^3} < 0$, where the approximation follows because $\lambda \to 0$. Thus, for sufficiently low $\lambda$, $\Pi - \Pi'$ decreases in $a$, and the condition $\Pi > \Pi'$ is more likely to hold when $a$ is lower.

**Proof of Lemma 3.** The uniform pricing scenario represents a specific case of transparent pricing, where $p_L = p_H = p$. Similar to the transparent pricing context, we will explore the following cases based on whether the purchase probabilities take extreme values.

**Case 1:** $\alpha_L, \alpha_H < 1$**.** By substituting $p_L = p_H = p$ into the profit function (A.1), we derive the profit function for uniform pricing:

$$\pi(p) = \frac{\lambda + a(2-2p+\lambda) - 2(1+2\lambda)p}{a-\lambda^2}. \tag{A.42}$$

Taking the first-order derivative of $\pi(p)$ with respect to $p$ and setting it to zero, we obtain the optimal price as given by

$$p^U = \frac{2a+\lambda+a\lambda}{2(1+a+2\lambda)}. \tag{A.43}$$

Since $\pi(p)$ is a concave function, i.e., $\frac{\partial^2\pi}{\partial p^2} = -\frac{2(1+a+2\lambda)}{1-\lambda^2} < 0$, $p^U$ is the unique price that maximizes the firm's profit function. Inserting (A.43) into consumers' purchase strategies (3) yields their equilibrium purchase probabilities as follows:

$$\alpha_L^U = \frac{\lambda(a^2-\lambda) + a(2+3\lambda+3\lambda^2)}{2(1+a+2\lambda)(a-\lambda^2)} \text{ and } \alpha_H^U = \frac{2a^2 + a\lambda(3-\lambda) + \lambda(1+3\lambda)}{2(1+a+2\lambda)(a-\lambda^2)}. \tag{A.44}$$

We then characterize the conditions for $\alpha_L < 1$ and $\alpha_H < 1$ when $p = p^U$. We obtain that when $\lambda < \bar{\lambda}^U \equiv \frac{\sqrt{a^2+34a+1}-a-1}{8}$, $\alpha_L < \alpha_H < 1$. The resultant optimal profit is

$$\pi^U_{Case1} = \frac{(\lambda + a(2+\lambda))^2}{4(1+a+2\lambda)(a-\lambda^2)}. \tag{A.45}$$

**Case 2:** $\alpha_L = \alpha_H = 1$**.** We first prove that under uniform pricing, if one consumer buys the product with certainty, the other one must buy with certainty as well. Suppose not but $\alpha_L < 1$ and $\alpha_H = 1$. In this conjectured case, consumer $L$ will buy the product if and only if $v_L + \lambda\alpha_H \geq p$. Since $\alpha_H = 1$ and $v_L$ is uniformly distributed, consumer $L$'s purchase probability can be expressed as $\alpha_L = 1 - p + \lambda$. Furthermore, for consumer $H$ to buy the product with certainty, it must hold that $p \leq \lambda\alpha_L = \lambda(1-p+\lambda)$, which is equivalent to $p \leq \lambda$. However, given $p \leq \lambda$, consumer $L$'s purchase probability must be $\alpha_L = 1$. Thus, the conjectured case cannot hold. Similarly, we can show that the case $\alpha_L = 1$ and $\alpha_H < 1$ cannot hold.

Now, we consider the case in which $\alpha_L = \alpha_H = 1$. As previously discussed, for both consumers to purchase the product with certainty, the condition $p \leq \lambda$ must be satisfied. To maximize profit, the firm should charge the highest feasible price, which leads to $p = \lambda$. The firm profit is $\pi^U_{Case2} = 2\lambda$. A simple comparison of the two profit scenarios reveals that $\pi^U_{Case1} > \pi^U_{Case2}$. Therefore, if Case 1 can be sustained, which occurs when $\lambda < \bar{\lambda}^U$, the firm will not induce $\alpha_L = \alpha_H = 1$. It is important to note that $\bar{\lambda}^U < 1$ occurs only when $a < 5$; otherwise, when $a > 5$, the region where $\lambda < \bar{\lambda}^U$ becomes empty.

To summarize, the equilibrium purchase probabilities under uniform pricing are as follows:

$$\begin{cases} \alpha_L^U, \alpha_H^U < 1 & \text{when } \lambda < \bar{\lambda}^U \equiv \frac{\sqrt{a^2+34a+1}-a-1}{8}, \\ \alpha_L^U = \alpha_H^U = 1 & \text{otherwise.} \end{cases}$$

**Proof of Proposition 7.** Consider the case in which $\alpha \to 1$. When $\lambda < \lim_{a\to 1}\bar{\lambda}^U = \frac{1}{2}$, we find that $\lim_{a\to 1}(\pi^U_{Case1} - \pi^O) = \frac{\lambda^2}{2(2-\lambda)^2(1-\lambda)} > 0$. In contrast, when $\lambda > \frac{1}{2}$, we have $\lim_{a\to 1}(\pi^U_{Case2} - \pi^O) = 2\lambda - \frac{2}{(2-\lambda)^2} > 0$. This inequality holds because $2\lambda - \frac{2}{(2-\lambda)^2}$ starts at $\frac{1}{9}$ when $\lambda = \frac{1}{2}$, reaches its maximum at $\lambda = 2 - 2^{1/3}$, and then decreases to zero as $\lambda$ approaches 1. Taken together, when $\alpha$ approaches 1, $\pi^U > \pi^O$.

**Proof of Lemma 4.** We first characterize the equilibrium in the subgame for a given price cap $\bar{p}$.

**Case 1:** $\bar{p} > p_H^O$**.** In Section 2.3, we've characterized the equilibrium in the absence of a price cap constraint, which is equivalent to $\bar{p} \to \infty$. As shown in Lemma 2, the firm charges prices $p_L^O = \frac{a(2+\lambda)}{4a-\lambda^2}$ and $p_H^O = \frac{a(2a+\lambda)}{4a-\lambda^2}$. It is evident that the price charged to consumer $H$ is higher than that charged to consumer $L$, i.e., $p_H^O > p_L^O$. Thus, when the price cap is sufficiently high, i.e., $\bar{p} > p_H^O$, the price cap constraint does not bind the firm. In other words, $p_H^{Cap} = p_H^O$ and $p_L^{Cap} = p_L^O$. This indicates that the equilibrium established in the baseline model remains intact. The resulting profit can be calculated as outlined in equation (A.12).

**Case 2:** $\frac{a(1+\lambda)}{2a+\lambda-\lambda^2} < \bar{p} < p_H^O$**.** We next consider the case in which $\bar{p} < p_H^O = \frac{a(2a+\lambda)}{4a-\lambda^2}$. Since the firm typically charges a higher price to consumer $H$ due to her greater willingness to pay, we anticipate that the price cap constraint will first impact $H$. Therefore, we conjecture that the equilibrium price charged to consumer $H$ will be $p_H^{Cap} = \bar{p}$. Given this price, consumer $H$ will buy the product if and only if $v_H + \lambda\hat{\alpha}_L \geq \bar{p}$, which happens with probability

$$\alpha_H = 1 - \frac{1}{a}\left(\bar{p} - \lambda\hat{\alpha}_L\right), \tag{A.46}$$

where $\hat{\alpha}_L$ is consumer $H$'s belief about consumer $L$'s purchase probability. For consumer $L$, she knows that $H$ gets charged the price $\bar{p}$ and thus she can infer the purchase probability $\alpha_H$ perfectly. She will buy the product if and only if $v_L + \lambda\alpha_H \geq p_L$, which happens with probability:

$$\alpha_L = 1 - (p_L - \lambda\alpha_H). \tag{A.47}$$

Now, for the firm, the problem is to choose $p_L$ to maximize the following profit, $\pi = p_L\alpha_L + \bar{p}\alpha_H$, where $\alpha_L$ and $\alpha_H$ are given by equations (A.46) and (A.47) respectively. The optimization problem yields $p_L = \frac{a(1+\lambda)-\lambda\bar{p}+\lambda^2\hat{\alpha}_L}{2a}$. Inserting this $p_L$ into equation (A.47) and setting consistent beliefs $\alpha_L = \hat{\alpha}_L$ yields $\alpha_L^{Cap} = \frac{a(1+\lambda)-\lambda\bar{p}}{2a-\lambda^2}$. Thus, the equilibrium price charged to consumer $L$ is $p_L^{Cap} = \frac{a(1+\lambda)-\lambda\bar{p}}{2a-\lambda^2}$. The resulting profit is: $\pi_{Case2}^{Cap} = \frac{a^2\left((\lambda+1)^2+4\bar{p}\right)-4a\bar{p}\left(\lambda^2+\bar{p}\right)+\lambda^2\bar{p}(3\bar{p}-\lambda)}{\left(\lambda^2-2a\right)^2}$. This conjectured equilibrium can be sustained if $\bar{p} > p_L^{Cap}$ and $\bar{p} < p_H^O$, which is equivalent to $\frac{a(1+\lambda)}{2a+\lambda-\lambda^2} \leq \bar{p} \leq p_H^O = \frac{a(2a+\lambda)}{4a-\lambda^2}$. We also confirm that in this region $\alpha_L^{Cap} < 1$ and $\alpha_H^{Cap} < 1$.

**Case 3:** $\lambda < \bar{p} < \frac{a(1+\lambda)}{2a+\lambda-\lambda^2}$**.** Finally, when the price cap is sufficiently low, i.e., $\bar{p} < \frac{a(1+\lambda)}{2a+\lambda-\lambda^2}$, then the above solved $p_L^{Cap}$ cannot be sustained in equilibrium. We thus conjecture that $p_L = p_H = \bar{p}$ when $\bar{p} < \frac{a(1+\lambda)}{2a+\lambda-\lambda^2}$. We will prove that given the consumers' belief $\hat{p}_L = \hat{p}_H = \bar{p}$, the firm will have no incentives to deviate to $(p_L, p_H)$, where $p_L < \bar{p}$ or $p_H < \bar{p}$.

In equilibrium, $L$ will purchase if $v_L + \lambda\hat{\alpha}_H \geq \bar{p}$, which occurs with probability $\alpha_L = 1 - (\bar{p} - \lambda\hat{\alpha}_H)$. Similarly, $H$ will purchase if $v_H + \lambda\hat{\alpha}_L \geq \bar{p}$, which occurs with probability $\alpha_H = 1 - \frac{1}{a}(\bar{p} - \lambda\hat{\alpha}_L)$. Since the prices are fixed at the cap, the two consumers effectively can observe each other's price, i.e., $\alpha_L = \hat{\alpha}_L$ and $\alpha_H = \hat{\alpha}_H$. The joint of the two equations yields

$$\alpha_L^{Cap} = \frac{a(1+\lambda) - \bar{p}(a+\lambda)}{a-\lambda^2} \text{ and } \alpha_H^{Cap} = \frac{a+\lambda-\bar{p}(1+\lambda)}{a-\lambda^2}. \tag{A.48}$$

It is immediate that when $\bar{p} > \lambda$, we obtain $\alpha_L^{Cap}, \alpha_H^{Cap} < 1$; otherwise, $\alpha_L^{Cap} = \alpha_H^{Cap} = 1$. We will concentrate on the more realistic scenario with a less restrictive price cap, specifically when $\bar{p} > \lambda$. The resulting profit is $\pi_{Case2}^{Cap} = \frac{\bar{p}(a(2+\lambda-\bar{p}+\lambda-\bar{p}(2\lambda+1)))}{a-\lambda^2}$.

We next prove that the firm will have no incentives to deviate from the conjectured equilibrium. Consider the off-equilibrium prices $(p_L, p_H) \neq (\bar{p}, \bar{p})$. After receiving $p_L$, consumer $L$ knows that consumer $H$'s price stays at $\bar{p}$ and the resulting purchase probability is at the equilibrium level given by (A.48). Thus, consumer $L$ computes her purchase probability as follows:

$$\alpha_L = 1 - \left(p_L - \lambda\alpha_H^{Cap}\right) = 1 - \left(p_L - \lambda\frac{a+\lambda-\bar{p}(1+\lambda)}{a-\lambda^2}\right).$$

Similarly, after observing the off-equilibrium price $p_H$, consumer $H$'s purchase probability becomes:

$$\alpha_H = 1 - \frac{1}{a}\left(p_H - \lambda\alpha_L^{Cap}\right) = 1 - \frac{1}{a}\left(p_H - \lambda\frac{a(1+\lambda)-\bar{p}(a+\lambda)}{a-\lambda^2}\right).$$

Thus, after offering the prices $(p_L, p_H)$, the firm makes profits $\pi = p_L\alpha_L + p_H\alpha_H$, which can be simplified to the following:

$$\pi(p_L, p_H) = p_L\left(1 - \left(p_L - \lambda\frac{a+\lambda-\bar{p}(1+\lambda)}{a-\lambda^2}\right)\right) + p_H\left(1 - \frac{1}{a}\left(p_H - \lambda\frac{a(1+\lambda)-\bar{p}(a+\lambda)}{a-\lambda^2}\right)\right).$$

We find that regardless of the value of $p_H$, $\frac{\partial\pi(p_L,p_H)}{\partial p_L} = -2p_L + \frac{(1+\lambda)(a-\lambda\bar{p})}{a-\lambda^2} > -\frac{2a+\lambda-\lambda^2}{a-\lambda^2}\bar{p} + \frac{a(1+\lambda)}{a-\lambda^2} > 0$, where the first inequality follows because $p_L < \bar{p}$ and the second follows because $\bar{p} < \frac{a(1+\lambda)}{2a+\lambda-\lambda^2}$. Thus, the firm always has incentives to increase $p_L$. However, due to the price cap, the best the firm can do is $p_L = \bar{p}$. Similarly, regardless of the value of $p_L$, we have $\frac{\partial\pi(p_L,p_H)}{\partial p_H} = -\frac{2}{a}p_H + \frac{(a+\lambda)(a-\lambda\bar{p})}{a(a-\lambda^2)} > -\frac{\lambda^2-a(2+\lambda)}{a(a-\lambda^2)}\bar{p} + \frac{a+\lambda}{1-\lambda^2} > \frac{2(a-1)}{2a+\lambda-\lambda^2} > 0$, where the first inequality follows because $p_H < \bar{p}$ and the second follows because $\bar{p} < \frac{a(1+\lambda)}{2a+\lambda-\lambda^2}$. Thus, the firm wants to increase $p_H$ as much as possible and will not deviate from $p_H = \bar{p}$.

In summary, there exists a unique equilibrium as follows, which depends on the value of $\bar{p}$:

(1) When $\bar{p} \geq \frac{a(2a+\lambda)}{4a-\lambda^2}$, the equilibrium is identical to that characterized in Lemma 2;

(2) When $\frac{a(1+\lambda)}{2a+\lambda-\lambda^2} < \bar{p} < \frac{a(2a+\lambda)}{4a-\lambda^2}$, the prices charged to the two consumers are $p_L^{Cap} = \frac{a(1+\lambda)-\lambda\bar{p}}{2a-\lambda^2}$ and $p_H^{Cap} = \bar{p}$. Consumer $L$ purchases if and only if $v_L \geq \frac{a(1-\lambda)+\lambda(\bar{p}-\lambda)}{2a-\lambda^2}$, whereas consumer $H$ purchases if and only if $v_H \geq \frac{2(a-\bar{p})+\lambda}{2a-\lambda^2}$;

(3) When $\lambda < \bar{p} < \frac{a(1+\lambda)}{2a+\lambda-\lambda^2}$, the prices charged to the two consumers are $p_L^{Cap} = p_H^{Cap} = \bar{p}$. Consumer $L$ purchases if and only if $v_L \geq \frac{(\bar{p}-\lambda)(a+\lambda)}{a-\lambda^2}$, whereas consumer $H$ purchases if and only if $v_H \geq \frac{a(\bar{p}-\lambda)(1+\lambda)}{a-\lambda^2}$.

Furthermore, for a given price cap $\bar{p}$, the firm's equilibrium profit is as follows:

$$\pi(\bar{p}) = \begin{cases} \frac{a\left(4a^2+\lambda^2+a(4+8\lambda+\lambda^2)\right)}{(4a-\lambda^2)^2} & \bar{p} \geq \frac{a(2a+\lambda)}{4a-\lambda^2} \\ \frac{a^2\left((\lambda+1)^2+4\bar{p}\right)-4a\bar{p}\left(\lambda^2+\bar{p}\right)+\lambda^2\bar{p}(3\bar{p}-\lambda)}{\left(\lambda^2-2a\right)^2} & \frac{a(1+\lambda)}{2a+\lambda-\lambda^2} < \bar{p} < \frac{a(2a+\lambda)}{4a-\lambda^2} \\ \frac{\bar{p}(a(2+\lambda-\bar{p}+\lambda-\bar{p}(2\lambda+1)))}{a-\lambda^2} & \lambda < \bar{p} < \frac{a(1+\lambda)}{2a+\lambda-\lambda^2} \end{cases}. \tag{A.49}$$

We next characterize that the optimal price cap chosen by the firm features $\bar{p} < \frac{a(2a+\lambda)}{4a-\lambda^2}$. This indicates that the firm finds it optimal to impose some constraints on its pricing strategy. Thus, in equilibrium consumer $H$ must be charged a price at the cap: $p_H^* = \bar{p}$. Specifically, based on equation (A.49), we know that

$$\lim_{\bar{p} \to \bar{p} = \frac{a(2a+\lambda)}{4a-\lambda^2}} \frac{\partial \pi(\bar{p})}{\partial \bar{p}} = -\frac{\lambda(\lambda^2 + 4a(1+\lambda))}{8a^2 - 6a\lambda^2 + \lambda^4} < 0. \tag{A.50}$$

Thus, the optimal price cap $\bar{p}^*$ must satisfy $\bar{p}^* < \frac{a(2a+\lambda)}{4a-\lambda^2}$. In other words, in equilibrium, $p_H \leq \bar{p}$ must be binding, while $p_L \leq \bar{p}$ may or may not be binding.

## Data availability

No data was used for the research described in the article.

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