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1 Introduction

Personalized pricing by digital firms presents a familiar problem in law and economics: the same practice can create an efficiency justification and a legally relevant risk of harm. Digital platforms increasingly use detailed consumer data and algorithms to implement personalized pricing that was previously harder to implement in traditional markets (Ezrachi and Stucke 2016; Gautier et al. 2020). Recent work in marketing and economics shows how AI-based targeting, consumer tracking, and related tools support increasingly fine-grained personalization (Abrardi et al. 2022; Rafieian and Yoganarasimhan 2023). This research suggests that firms can infer purchase propensities and reservation prices from broad digital traces and combine targeting with discriminatory pricing (Esteves and Resende 2016; Shiller 2020). Other studies document personalized offers and price variation on e-commerce platforms, including in hospitality and ticketing (Mikians et al. 2012; Hannak et al. 2014; European Commission 2018). Recent empirical work further suggests that data-driven price discrimination can be effective (Shiller 2020; Dubé and Misra 2023; Smith et al. 2023), which has intensified debate about its welfare effects (Goldfarb and Tucker 2019; Wagner and Eidenmüller 2019).[1]

These developments have raised legal and policy concerns. Many studies warn that data-driven personalization and algorithmic pricing may let firms, including firms with strong market positions, extract surplus and reshape competitive conditions (Ezrachi and Stucke 2016; MacKay and Weinstein 2022). A related body of work in EU competition law, data law, and consumer law argues that algorithmic personalization raises concerns about exploitative conduct, transparency, and legal accountability, especially when opaque systems make individualized treatment hard for consumers or regulators to detect and assess (Townley et al. 2017; Botta and Wiedemann 2020; Zhao 2023; Ganesh 2025). Related comparative and data-protection scholarship raises similar concerns beyond the specific context of EU competition law (Porat 2025, 2026). At the same time, competition authorities have identified personalized pricing as a central challenge of the digital economy, stressing both its efficiency potential

[1] See Esteves and Resende (2016) and Ezrachi and Stucke (2016) for real-world examples of personalized offers.

and its risks of consumer harm and market distortion (Competition and Markets Authority (CMA) 2018; OECD 2018).

Economic analysis, however, has long emphasized that more refined pricing can expand trade and may improve efficiency under some conditions, although the welfare effects of price discrimination depend on context (Armstrong 2006; OECD 2018). More recent work also shows that personalized pricing can distort market outcomes through strategic interaction and may reduce consumer welfare under some conditions (Lu and Matsushima 2024; Rhodes and Zhou 2024). Existing models mainly study purchase decisions in one market at a time and therefore abstract from consumers' budget constraints and participation across multiple markets.[2] Once consumers face a binding budget constraint, however, spending in one market necessarily changes what is left for other markets. The central question is therefore not only whether personalized pricing expands trade in the market where it is used, but also whether it changes consumer participation in other markets.

This paper studies two monopoly markets linked by a common consumer budget constraint. One firm—interpreted as a data-rich digital firm—can use personalized pricing, while the other—representing a traditional firm—must rely on uniform pricing. The simple example uses negatively correlated valuations to isolate the cross-market budget mechanism in the most transparent way. The continuous-type model then considers independent valuations, so the analysis does not rely on perfect negative correlation. Across the two settings, the welfare effects arise from how personalization reallocates constrained spending across markets rather than from collusion, tying, or exclusionary conduct in the usual sense.

The paper highlights a simple trade-off. Personalized pricing can expand demand in the digital firm's market, but because purchases come from a shared budget, it can also weaken the residual demand faced by the traditional firm and reduce that firm's profit. The welfare effect in the traditional market is not identical to simple demand contraction: the traditional firm's equilibrium price response can partly or fully offset the demand-side distortion when budgets are

[2] Some papers study multi-product or multi-market settings with data and personalization, but budget constraints are not the main mechanism linking consumers' purchase decisions across markets in those settings (e.g., Chen et al. 2022; Cong and Matsushima 2026).

less tight. Overall, total surplus falls when the adjacent-market surplus loss generated by the common-budget constraint is large enough to outweigh the same-market expansion. This result explains why favorable evidence from the personalized-pricing market may be incomplete for legal or welfare assessments.

The welfare loss arises under perfect price discrimination by the data-rich firm, rather than under the group-based discrimination emphasized in much of the classic literature; the mechanism works through cross-market budget crowding-out, not through within-market misallocation (Varian 1985; Armstrong 2006). In line with empirical and marketing evidence that firms can use broad tracking and AI-based personalization tools to infer purchase propensities and, in some settings, willingness to pay, we treat personalized pricing as a reduced-form representation of modern data-driven pricing capabilities (Shiller 2020; Rafieian and Yoganarasimhan 2023). The analysis therefore provides a formal basis for concerns in the legal and policy literature that data-driven personalization, even without collusion or exclusionary conduct, may create allocative inefficiencies (Competition and Markets Authority (CMA) 2018; OECD 2018).

The analysis also has direct legal implications. It identifies a mechanism through which personalized pricing by a data-rich firm can crowd out spending in adjacent markets when consumers face a common budget constraint. This means that an assessment focusing only on within-market prices or output may miss an important part of the competitive effect. It also helps explain why observed expansion following personalization does not, by itself, show that the practice is benign under competition-law analysis. These implications speak directly to debates in competition law, consumer protection, and digital regulation about how personalized pricing by data-rich firms should be assessed.

The paper advances a competition-law proposition rather than an objection to personalized pricing. Once consumers allocate a common budget across markets, expansion or improved matching in the market with personalized pricing should not, by itself, be treated as conclusive evidence that the practice is benign. Article 102(b) is one especially natural application under EU law, because personalized pricing in one market may, under certain conditions, limit output, variety, or technical development in another market to the prejudice of consumers there. This conclusion is consistent with recent scholarship emphasizing a contextual, case-by-case assessment of personalized pricing under EU competition law (Botta and Wiedemann 2020; Bastidas Venegas 2023).

The paper contributes to three strands of work. First, it adds to the economics of personalized pricing by showing that the key welfare distortion can arise through cross-market budget crowding-out rather than only through within-market misallocation. Second, it adds to legal scholarship on personalized pricing by offering a formal reason, within a competition-law framework, to resist a purely same-market assessment of allegedly exploitative or discriminatory personalization. Third, it complements recent debates on ecosystem and cross-market theories of harm by identifying a specific budget-mediated mechanism that does not rely on merger, tying, or leverage-based foreclosure.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents a simple two-type example that shows the logic of the main result. Section 4 analyzes the continuous-type model with independent preferences. Section 5 applies the model to competition law and related legal regimes, with Article 102(b) as a specific application. Section 6 concludes. The derivations for Proposition 1 and Section 4 are given in Appendix A.

2 Related literature

This paper relates to several strands of work on personalized pricing, data-driven price discrimination, and legal scholarship on the practice.

The effect of personalized pricing on firms' profits has been extensively discussed since the classic paper by Thisse and Vives (1988). They show that personalized pricing can create a prisoner's dilemma in which all firms earn lower profits than under uniform pricing, and several later studies reinforce that result (Shaffer and Zhang 1995; Bester and Petrakis 1996; Zhang 2011). However, other papers show that this conclusion need not hold when firms are asymmetric, for example because of quality differences (Shaffer and Zhang 2002; Choudhary et al. 2005), endogenous quality choice (Ghose and Huang 2009), or initial cost differences with R&D (Matsumura and Matsushima 2015).

Another strand of the literature shows that personalized pricing can reduce consumer surplus in static environments that differ from the classic benchmark. Liu and Serfes (2013) compare the profits of two firms under uniform and personalized pricing in a duopolistic two-sided market. The firms employ personalized pricing on both sides. Liu and Serfes (2013) show that personalized pricing is better for the firms if and only if the degree of cross-market externality exceeds a threshold value (see also Lu et al. (2025) for further discussion of two-sided markets). Chen et al. (2020), Esteves (2022), Matsushima et al. (2023), Rhodes and Zhou (2024), and Lu and Matsushima (2024, 2025) also show, in different static settings, that the consumer-surplus effects of personalized pricing depend on key market features, including whether consumers can avoid unfavorable personalized offers, whether they differ in the quantities they demand, whether they differ in price elasticity, how consumers' preferences for products are determined, and whether consumers can buy from multiple firms.[3] These studies show that personalized pricing does not have a uniform effect on welfare and can harm consumers in a range of static market settings.

Although monopolistic perfect price discrimination is often viewed as efficient in standard partial-equilibrium settings, general-equilibrium analyses by Edlin et al. (1998) and Bejan (2021) show that a perfectly price-discriminating monopoly need not be Pareto efficient. Those papers do not compare price discrimination with uniform pricing. Instead, they ask whether monopoly price discrimination itself achieves Pareto efficiency. Our focus is different: we ask whether price discrimination can perform worse than uniform pricing as a welfare benchmark.

Further contributions on perfect price discrimination are provided by Bhaskar and To (2004) and Leeson and Sobel (2008). Bhaskar and To (2004) study perfect price discrimination under free entry and show that surplus extraction can induce excessive entry.[4] Leeson and Sobel (2008) compare textbook monopoly price discrimination with uniform pricing and show that the former can reduce social welfare when implementation costs are sufficiently high. Our contribution is complementary. We provide a partial-equilibrium setting in which perfect price discrimination by a data-rich monopolist reduces total surplus relative to uniform pricing through cross-market budget crowding-out, rather than through entry distortions or implementation costs.

Recent studies on personalized pricing also emphasize consumers' strategic

[3] Jullien et al. (2023) show that personalized pricing can serve as an exploitative device when a manufacturer designs an appropriate wholesale tariff.

[4] They also consider a case in which the number of firms is exogenous.

responses and the interaction between data-driven targeting and market competition. Ali et al. (2023) study a Hotelling duopoly in which consumers reveal their preferences to firms and show that consumers can strategically disclose their preferences to intensify competition. Anderson et al. (2023) study a two-stage game in which consumers can commit, before knowing their preferences, not to receive targeted discounts offered in the second stage. They show that this commitment can benefit both firms and consumers through lower uniform prices and smaller targeted discounts.

In addition, a large literature on behavior-based price discrimination (BBPD) studies settings in which firms condition prices on consumers' past behavior. A central insight is that BBPD can create inefficient customer poaching and reduce welfare even as it intensifies competition (Caminal and Matutes 1990; Bester and Petrakis 1996; Chen 1997; Villas-Boas 1999; Fudenberg and Tirole 2000; Chen 2005; Esteves 2009a,b; Miettinen and Stenbacka 2015; Choe et al. 2018). There is also a growing literature that combines BBPD with data-driven personalized pricing, including work on returning-customer personalization, data sharing, and cross-market use of consumer data (Choe et al. 2018, 2022; Laussel and Resende 2022; Chen et al. 2022; Laussel 2023; Cong and Matsushima 2026).

Legal scholarship on personalized pricing has developed along two main lines. One line studies the practice through competition law and focuses on fairness, exploitative abuse, and the potentially discriminatory effects of personalized pricing by dominant digital platforms (Townley et al. 2017; Graef 2018; Botta and Wiedemann 2020; Ganesh 2025); see also (Woodcock 2019). A second, partly overlapping line stresses consumer vulnerability, information deficits, and behavioral misperceptions (Bar-Gill 2019; Bar-Gill et al. 2023; Duivenvoorde 2023), and asks how consumer-protection law and data-protection law should respond to the opacity of algorithmic personalized pricing and related marketing practices (Esposito 2022; Grochowski et al. 2022; Hutchinson and Treščáková 2022; Chapdelaine 2024). Together, these contributions show that personalized pricing raises not only economic questions but also legal questions about transparency, fairness, and the proper standard for intervention.

More broadly, recent legal and antitrust scholarship has questioned market-by-market analysis in digital settings and has explored ecosystem or cross-market theories of harm (Batra et al. 2024; Garces et al. 2024; Stucke and

Ezrachi 2025); see also (Nakagawa and Matsushima 2023). This shift reflects a growing recognition that harm in digital markets may come from the interaction of connected services, data advantages, and ecosystem entrenchment rather than from a single market viewed in isolation. This paper adds a more specific mechanism to that discussion. We show that personalized pricing in one market can reduce welfare and weaken conditions in adjacent markets through consumers' shared budget constraint. Our analysis formalizes a budget-mediated cross-market channel that links the economic and legal debates on personalized pricing.

Existing writing on personalized pricing under EU competition law has focused mainly on exploitative abuse and discriminatory pricing, while the use of Article 102(b) to assess adjacent-market effects remains comparatively underdeveloped. This paper bridges two bodies of literature that have largely developed in parallel without being explicitly connected on this point: the economic literature on personalized pricing and the broader competition-law literature, using Article 102(b) as one concrete doctrinal application.

Among the writings most closely related to the present argument are Bar-Gill (2019) and Bar-Gill et al. (2023). Both focus primarily on consumer misperceptions and related behavioral economics concerns, while also acknowledging that wealth or budget constraints may shape willingness to pay, even though that issue is not central to either paper.

Bar-Gill (2019) is concerned primarily with the role of consumer (mis)perceptions in personalized pricing: its central claim is that the welfare effects of algorithmic price discrimination depend on whether willingness to pay reflects preferences or instead demand-inflating misperceptions. Building on that insight and related behavioral economics concerns, Bar-Gill et al. (2023) argue more broadly that consumer misperceptions and information deficits are central to understanding algorithmic harm and discuss the legal implications, including for competition law.

This paper takes a different step. It isolates the less-developed role that budget constraints may play in transmitting harm across markets and asks whether surplus extraction in one market can limit consumer participation in closely associated markets in a way that matters for competition-law analysis, including under the "limiting markets" language of Article 102(b). So far as we are aware, that specific connection has not been addressed directly in either the economics or the competition-law literature.

3 A simple example

We begin with a simple example in which the negative externality created by personalized pricing reduces total surplus by changing demand conditions. There are two consumer types, α and β, each with mass one. Each consumer has income I and may buy at most one unit in each market. Valuations of products A and B are negatively correlated across markets. Specifically, type-α consumers value products A and B at v_H and v_L, respectively, where $v_H > v_L > v_H/2 > 0$. Type β consumers value products A and B at v_L and v_H, respectively. These parameter assumptions imply that, under uniform monopoly pricing in a single market, the optimal uniform price is $p_i^U = v_L$ $(i = A, B)$.[5] Each consumer's income satisfies $2v_L < I < v_L + v_H$, so under uniform pricing the total payment is $p_A^U + p_B^U = 2v_L < I$.

type/value	value for product A	value for product B
α	v_H	v_L
β	v_L	v_H

Table 1: The case of two consumer types

In this setting, we consider two pricing scenarios. First, both firms use uniform pricing. Second, only firm A uses personalized pricing based on whether the consumer is type-α or type-β. The second scenario captures a setting in which a data-rich firm can use tracking and inference technologies. In practice, such firms can rely on signals such as consumers' access channels, device information, and past online behavior to personalize offers, rankings, and possibly prices (European Commission 2018; OECD 2018; Ofcom 2020). By contrast, traditional firms may find it harder to use such pricing because they lack comparable data and technology. The second scenario therefore captures the asymmetry

[5] If consumer preferences for the two products are independent, then—since our baseline model already includes two consumer types—we would need to introduce two additional types: type-η consumers, who value products A and B at v_H and v_H, respectively, and type-κ consumers, who value products A and B at v_L and v_L, respectively. We do not do so because this extension does not affect our results qualitatively.

in the firms' pricing possibilities. Our main interest is the effect of sophisticated pricing by data-rich firms on profits and welfare. This two-type example isolates the budget-crowding-out mechanism; unlike the continuous-type models that follow, it does not rely on demand expansion in market A.

In the second scenario (firm A's personalized pricing), the game is as follows. First, firm B sets a uniform price p_B. After observing p_B, firm A sets personalized prices $p_{A\alpha}$ and $p_{A\beta}$ for type-α and type-β consumers.

In the second scenario, the sequential timing captures an asymmetry between a traditional posted-price seller and a data-rich seller with flexible consumer-level pricing technology. Firm B's uniform price is interpreted as a posted price that is observable before consumers receive firm A's personalized offer. Firm A, by contrast, can adjust individualized offers through a digital interface after observing the relevant posted price. This timing is consistent with the staged-pricing structure commonly used in the personalized-pricing and behavior-based pricing literature (Thisse and Vives 1988; Shaffer and Zhang 2002; Choe et al. 2018). It also permits a clean characterization of the subgame-perfect equilibrium in pure strategies.

To make the mechanism transparent, we use the parameter values $v_H = 20$, $v_L = 11$, and $I = 25$. These values show how firm A's personalized pricing can reduce total surplus. Appendix A.1 derives the corresponding result for the general parameter set (v_H, v_L, I).

Uniform pricing Under uniform pricing, each firm compares the high price 20, which sells only to the high-valuation type and yields profit 20, with the low price 11, which sells to both types and yields profit 22. Hence $p_A^U = p_B^U = 11$.

Since $p_A^U + p_B^U = 22 < 25$, both consumer types buy both products. Thus $\pi_A^U = \pi_B^U = 22$, aggregate consumer surplus is $CS^U = (20 - 11) + (20 - 11) = 18$, and aggregate total surplus is $TS^U = 2(20 + 11) = 62$.

Firm A's personalized pricing Suppose now that firm A uses personalized pricing. Firm B first chooses a uniform price p_B, and firm A then sets type-contingent prices.

We solve by backward induction. Given p_B, firm A compares, for each type, the highest price that keeps the consumer buying both products with the highest price that induces the consumer to buy only product A. For type-α consumers, if $p_B > 11$, they do not buy product B. If $p_B \leqslant 11$, the highest price compatible with buying both products is $\min\{20, 25 - p_B\}$, while the highest price compatible with buying only product A is $p_B + 9$. Hence type-α consumers buy product B if and only if $\min\{20, 25 - p_B\} \geqslant p_B + 9$, or equivalently $p_B \leqslant 8$.

For type-β consumers, the highest price compatible with buying both products is $\min\{11, 25 - p_B\}$, while the highest price compatible with buying only product A is $p_B - 9$. Hence type-β consumers buy product B if and only if $\min\{11, 25 - p_B\} \geqslant p_B - 9$, or equivalently $p_B \leqslant 17$.

Therefore firm B sells to both types when $p_B \leqslant 8$, only to type-β consumers when $8 < p_B \leqslant 17$, and to no consumers when $p_B > 17$. Its best price when serving both types is $p_B = 8$, yielding profit 16. Its best price when serving only type-β consumers is $p_B = 17$, yielding profit 17. Hence firm B's optimal price is $p_B^* = 17$.

In sum, when firm A uses personalized pricing, firm B's optimal uniform price is $p_B^* = 17$. At this price, firm B serves only type-β consumers. Firm A sets $p_{A\alpha} = 20$ and $p_{A\beta} = 25 - 17 = 8$. Thus, type-α consumers buy only product A, while type-β consumers buy both products and spend their entire income.

Comparison Under the parameter set $v_H = 20$, $v_L = 11$, and $I = 25$, in the equilibrium with firm A's personalized pricing, $p_{A\alpha} = 20$, $p_{A\beta} = 8$, and $p_B^* = 17$. Compared with uniform pricing, firm A's profit increases from 22 to 28, firm B's profit decreases from 22 to 17, aggregate consumer surplus decreases from 18 to 6, and aggregate total surplus decreases from 62 to 51.

Personalized pricing raises firm A's profit even though demand in market A does not expand in this two-type example. The effect comes from firm A's ability to charge different prices to different consumer types. However, this pricing also changes demand conditions in market B: firm B raises its price from 11 to 17, and type-α consumers no longer buy product B. The total-surplus loss is therefore the lost consumption value of type-α consumers in market B, namely 11.

The parametric example above is a special case of the following result, whose derivation is given in Appendix A.

Proposition 1. *In the two-type case, firm A's personalized pricing always increases firm A's profit and decreases firm B's profit. It decreases total surplus* *if and only if* $2v_L < I < 3(v_H - v_L)$ *and* $v_L < 3v_H/5$*. It increases consumer surplus if and only if* $3(v_H - v_L) < I < (5v_L + v_H)/3$ *and* $4v_H/7 < v_L$*.*

The parameter values used above fall into the total-surplus-decreasing region because $2v_L < I < 3(v_H - v_L)$, that is, $22 < 25 < 27$, and $v_L < 3v_H/5$, that is, $11 < 12$. They do not fall into the consumer-surplus-increasing region, so both total surplus and consumer surplus decrease in the parametric example. More generally, Proposition 1 shows that the welfare effect depends on how firm B adjusts its uniform price. When consumers' budgets are tight, firm B raises its price and loses type-α consumers. When the budget is at an intermediate level, firm B lowers its price to keep both types, and consumer surplus can increase if this price reduction is sufficiently large.

For purposes of competition law. The simple example already shows why a same-market assessment can be misleading. Personalized pricing in market A can tighten the budgets that support demand in market B, so evidence from the personalized-pricing market alone does not resolve the legal assessment.[6] The continuous-type models below strengthen this point by showing that cross-market harm can arise even when personalized pricing expands demand in market A. In EU competition law, Article 102(b) is one possible application: in the parameter region illustrated above, personalized pricing can worsen conditions in market B by increasing price and reducing firm B's profit; if fixed entry costs matter, that combination could induce exit and reduce variety.

4 Continuous-type model

The main model studies two products, each supplied by a monopolist, whose valuations are independent and whose purchases are linked only through a common consumer budget. The independence assumption provides a natural benchmark when the products serve different purposes rather than being close substitutes or complements (Matutes and Regibeau 1988; Armstrong and Vickers 2010). Concretely, there is a continuum of consumers, each identified by a

[6] Firm A's personalized pricing does not expand demand in market A in this two-type case. Section 4 treats the continuous-type case in which firm A's personalized pricing expands demand in market A.

type $\theta = (\theta_A, \theta_B)$, where θ_i denotes the consumer's valuation for product $i \in \{A, B\}$. Types are distributed with unit density on the square $[0, a] \times [0, a]$. The total mass of consumers is therefore a^2.

Each consumer faces a common budget constraint: if the consumer buys both goods, total payment must satisfy $p_A + p_B \leqslant I$, where

$$\frac{a}{2} \leqslant I \leqslant \frac{3a}{2}.$$

The lower bound $I \geqslant a/2$ avoids a degenerate environment in which the budget is too small relative to the ordinary monopoly price. The upper bound $I \leqslant 3a/2$ focuses on the range in which the common budget can affect cross-market allocation. At $I = 3a/2$, firm B's equilibrium outcome under firm A's personalized pricing coincides with the uniform-pricing benchmark; for larger budgets, the cross-market budget effect disappears.

In this setting, we consider two pricing scenarios. First, both firms use uniform pricing. Second, only firm A uses personalized pricing based on consumer type θ. When firm A uses personalized pricing, it observes each consumer's θ. This full-information assumption is a simplifying reduced-form assumption: it captures the limiting case in which a firm can condition personalized prices on consumer-specific preference information, as is common in the literature (Thisse and Vives 1988; Shaffer and Zhang 2002; Choe et al. 2018). In the present setting, such information can be interpreted as being inferred from granular digital traces by a data-rich firm, an interpretation consistent with recent regulatory evidence on surveillance pricing and targeted online personalization (European Commission 2025; Federal Trade Commission (FTC) 2025).

The games in the two scenarios are as follows. In the first scenario, the firms simultaneously set uniform prices p_A and p_B. In the second scenario, firm B first sets a uniform price p_B. After observing p_B, firm A sets personalized prices $p_A(\theta)$. As assumed in Section 3, the sequential move in the second scenario reflects the flexibility with which data-rich firms can implement personalized discounts through digital interfaces and consumer-level data.

4.1 Uniform pricing

Under uniform pricing, the symmetric equilibrium price of each firm is:

$$p_A^U = p_B^U = p^U = \begin{cases} I/2, & \text{if } a/2 \leqslant I < a, \\ a/2, & \text{if } a \leqslant I \leqslant 3a/2. \end{cases} \tag{1}$$

The first line follows because, when $I < a$, the unconstrained monopoly prices $(a/2, a/2)$ are not jointly affordable. The symmetric affordable benchmark must therefore satisfy $2p^U \leqslant I$. Under joint affordability, each firm's profit is increasing in its own price below $a/2$. Thus, when $I < a$, $p_i^U = I/2$ is a best response to the other firm's price $p_j^U = I/2$, for $i, j \in \{A, B\}$ with $i \neq j$.[7] When $I \geqslant a$, the unconstrained monopoly prices are jointly affordable, so each firm sets $a/2$.

For each market $i \in \{A, B\}$, uniform-pricing demand is

$$Q_i^U = a(a - p^U).$$

Consumer surplus, total surplus, and profit in each market are

$$CS_i^U = \frac{a(a - p^U)^2}{2}, \qquad TS_i^U = \frac{a\{a^2 - (p^U)^2\}}{2}, \qquad \pi_i^U = p^U a(a - p^U). \tag{2}$$

Using (1) and (2), we obtain the following lemma.

Lemma 1 (Uniform-pricing benchmark). *Suppose that consumer types are distributed with unit density on* $[0, a] \times [0, a]$. *Under uniform pricing, the prices are* p_i^U *in* (1). *Profit, consumer surplus, and total surplus in each market are as follows:*

$$\begin{cases} \pi_i^U = \dfrac{aI(2a - I)}{4}, \quad CS_i^U = \dfrac{a(2a - I)^2}{8}, \quad TS_i^U = \dfrac{a(4a^2 - I^2)}{8} & \textit{if } a/2 \leqslant I < a, \\ \pi_i^U = \dfrac{a^3}{4}, \quad CS_i^U = \dfrac{a^3}{8}, \quad TS_i^U = \dfrac{3a^3}{8} & \textit{if } a \leqslant I \leqslant 3a/2. \end{cases} \tag{3}$$

[7] For details, see Appendix A.2. When $I < a$, other equilibrium price pairs may exist. We select the symmetric price pair in (1) because it treats the two independent monopoly products symmetrically and, among the affordable-boundary equilibria, yields the highest aggregate total surplus across the two markets.

4.2 Firm A's personalized pricing

Under firm A's personalized pricing, firm B first sets its uniform price p_B, and firm A then sets personalized prices $p_A(\theta)$ after observing p_B. We solve the problem by backward induction.

Firm A's pricing rule. If $\theta_B < p_B$, the consumer does not buy product B, so firm A charges the highest affordable price for product A, namely $\min\{\theta_A, I\}$. If $\theta_B \geqslant p_B$, firm A compares two prices. If it accommodates product B, the highest price that lets the consumer buy both products is $\min\{\theta_A, I - p_B\}$. If it induces the consumer to buy only product A, the consumer's outside option is buying only product B, which gives utility $\theta_B - p_B$. Thus, firm A can charge up to $\theta_A + p_B - \theta_B$, subject to the budget cap I. Comparing the accommodation and exclusion prices gives

$$p_A^*(\theta; p_B) = \begin{cases} \min\{\theta_A, I\}, & \text{if } \theta_B < p_B, \\ \theta_A, & \text{if } \theta_B \geqslant p_B,\ \theta_A \leqslant I - p_B, \\ \min\{\theta_A + p_B - \theta_B, I\}, & \text{if } \theta_B \geqslant p_B,\ \theta_A > I - p_B,\ \theta_B < \theta_A + 2p_B - I, \\ I - p_B, & \text{if } \theta_B \geqslant p_B,\ \theta_A > I - p_B,\ \theta_B \geqslant \theta_A + 2p_B - I. \end{cases} \tag{4}$$

Product B is purchased exactly when

$$\theta_B \geqslant p_B \quad \text{and} \quad \{\theta_A \leqslant I - p_B \text{ or } \theta_B \geqslant \theta_A + 2p_B - I\},$$

which is equivalent to

$$\theta_B \geqslant \underline{\theta}_B(\theta_A; p_B) \equiv \max\{p_B, \theta_A + 2p_B - I\}. \tag{5}$$

An increase in I decreases the second term of the maximum operator in (5), keeping the first term constant. This means that the lower bound of θ_B, $\underline{\theta}_B(\theta_A; p_B)$, weakly decreases in I.

The key point is the exclusion region in the third case of (4):

$$\theta_A > I - p_B \text{ and } p_B \leqslant \theta_B < \theta_A + 2p_B - I. \tag{6}$$

Consumers in this region value product B above its price, but firm A can profitably set a personalized price that uses the budget constraint to induce them to buy only product A.

Lemma 2 (Firm A's best response)**.** *Suppose that consumer types are distributed with unit density on* $[0, a] \times [0, a]$*. For a uniform price* p_B *set by firm* B*, firm* A*'s optimal personalized pricing schedule is* $p_A(\theta)$ *in* (4)*, and all consumers purchase from firm* A*. For each* θ_A*, consumers with* $\theta_B \in [\underline{\theta}_B(\theta_A; p_B), a]$ *also purchase product* B*, where the lower bound of* θ_B *can be strictly higher than* p_B*.* $\underline{\theta}_B(\theta_A; p_B)$ *weakly decreases in* I*.*

Firm B's uniform price. From (5), firm B's demand is

$$Q_B(p_B) = \int_0^a [a - \max\{p_B, \theta_A + 2p_B - I\}]_+ \, d\theta_A, \tag{7}$$

where $[z]_+ = \max\{z, 0\}$. Evaluating (7) gives the following piecewise demand function; Appendix A.3 provides the details:

$$Q_B(p_B) = \begin{cases} a(a - p_B), & \text{if } I > a \text{ and } 0 < p_B \leqslant I - a, \\ \dfrac{a^2 + 2aI - I^2 - 4ap_B + 2Ip_B - p_B^2}{2}, & \text{if } \max\{0, I - a\} < p_B \leqslant I/2, \\ \dfrac{(a - p_B)(a + 2I - 3p_B)}{2}, & \text{if } I/2 < p_B \leqslant \min\{a, I\}, \\ 0, & \text{if } p_B > \min\{a, I\}. \end{cases} \tag{8}$$

Firm B maximizes $p_B Q_B(p_B)$. The resulting equilibrium price is stated in the following lemma.

Lemma 3 (Firm B's optimal price)**.** *Suppose that consumer types are distributed with unit density on* $[0, a] \times [0, a]$*. The optimal uniform price of firm* B *is*

$$p_B^* = \begin{cases} \dfrac{2I + 4a - \sqrt{4I^2 - 2aI + 7a^2}}{9}, & \textit{if } a/2 \leqslant I < a(4 - 2\sqrt{3}) \simeq 0.536a, \\ \dfrac{2I - 4a + \sqrt{I^2 - 10aI + 19a^2}}{3}, & \textit{if } a(4 - 2\sqrt{3}) \leqslant I \leqslant 3a/2. \end{cases} \tag{9}$$

The cutoff $a(4-2\sqrt{3})$ is the point at which firm B's equilibrium price crosses $I/2$. For lower budgets, firm B sets a price above $I/2$; for higher budgets, firm B sets a price weakly below $I/2$.

Equilibrium prices. Using (4) and Lemma 3, we summarize the equilibrium in the continuous-type case.

Proposition 2 (Equilibrium under personalized pricing by firm A)**.** *Suppose that consumer types are distributed with unit density on $[0,a]\times[0,a]$. Firm B sets the uniform price p_B^* in* (9)*, and firm A sets personalized prices according to* (4) *under $p_B = p_B^*$ in* (9)*. Product B is purchased if and only if $\theta_B \geqslant \max\{p_B^*, \theta_A + 2p_B^* - I\}$. Product A is purchased by all consumers.*

4.3 Comparison between uniform pricing and personalized pricing

We compare the equilibrium outcome under personalized pricing with that under uniform pricing, using the uniform-pricing outcomes in Lemma 1 and the personalized-pricing outcomes derived in Appendix A.3. Appendix A.4 derives the comparison results. For $z \in \{U,P\}$, let CS_i^z, TS_i^z, and π_i^z denote consumer surplus, total surplus, and firm i's profit in market i under pricing regime z.

First, we compare the outcomes in market A. Personalized pricing has the standard perfect-price-discrimination effect in this market.

Proposition 3 (Comparison in market A)**.** *Suppose that consumer types are distributed with unit density on $[0,a]\times[0,a]$. Relative to the uniform-pricing benchmark, personalized pricing expands output in market A, raises total surplus in market A, lowers consumer surplus in market A, and increases firm A's profit. That is, for all $I \in [a/2, 3a/2]$,*

$$TS_A^P > TS_A^U, \qquad CS_A^P < CS_A^U, \qquad \pi_A^P > \pi_A^U.$$

Second, we consider market B. The effect in this market is the cross-market effect. Firm A's personalized prices create the exclusion region in (6). Consumers in this region value product B above firm B's price, but firm A's personalized price induces them to spend their constrained budget on product A instead. This weakens firm B's residual demand. Firm B partly offsets this distortion by adjusting its uniform price. The resulting comparison is as follows.

Proposition 4 (Comparison in market B)**.** *Suppose that consumer types are distributed with unit density on* $[0, a] \times [0, a]$*, and let* $I \in [a/2, 3a/2]$*. Define* $\Delta CS_B(I) \equiv CS_B^P - CS_B^U$*,* $\Delta TS_B(I) \equiv TS_B^P - TS_B^U$*, and* $\Delta\pi_B(I) \equiv \pi_B^P - \pi_B^U$*. Then there exist threshold values* $\widehat{I}_{CS_B} \simeq 0.7449a$ *and* $\widehat{I}_{TS_B} \simeq 0.9637a$ *such that the following statements hold.*

(i) Firm B's profit is lower under firm A's personalized pricing: $\Delta\pi_B(I) < 0$ *for* $a/2 \leqslant I < 3a/2$*, while* $\Delta\pi_B(3a/2) = 0$*.*

(ii) Consumer surplus in market B is lower under personalized pricing when $a/2 \leqslant I < \widehat{I}_{CS_B}$*, equal under the two pricing regimes when* $I = \widehat{I}_{CS_B}$ *or* $I = 3a/2$*, and higher under personalized pricing when* $\widehat{I}_{CS_B} < I < 3a/2$*.*

(iii) Total surplus in market B is lower under personalized pricing when $a/2 \leqslant I < \widehat{I}_{TS_B}$*, equal under the two pricing regimes when* $I = \widehat{I}_{TS_B}$ *or* $I = 3a/2$*, and higher under personalized pricing when* $\widehat{I}_{TS_B} < I < 3a/2$*.*

We explain the intuition behind Proposition 4. The first part of Proposition 4 follows from the cross-market distortion created by firm A's personalized pricing. Even after firm B's price adjustment, firm B's profit is lower than under uniform pricing, except at the endpoint $I = 3a/2$. The surplus effects in market B are more nuanced. Lemma 3 shows that firm B's price under personalized pricing is lower than the benchmark when $a(4 - 2\sqrt{3}) < I < 3a/2$. Thus, when I is large, firm B's price reduction can raise consumer surplus in market B. Total surplus in market B combines the effect on consumer surplus with the effect on firm B's profit. The increase in consumer surplus dominates the fall in firm B's profit only when the budget is sufficiently large. This is why $\widehat{I}_{TS_B}$ is larger than $\widehat{I}_{CS_B}$.

Finally, we consider the aggregate effect across the two markets. The aggregate effect combines the standard output-expansion effect in market A with the cross-market effect in market B. The following proposition summarizes the comparison.

Proposition 5 (Comparison in the two markets)**.** *Suppose that consumer types are distributed with unit density on* $[0, a] \times [0, a]$*, and let* $I \in [a/2, 3a/2]$*. Relative* *to the uniform-pricing benchmark, personalized pricing by firm A decreases aggregate total surplus for $a/2 \leqslant I < \widehat{I}_{TS} \simeq 0.7442a$, leaves aggregate total surplus unchanged at $I = \widehat{I}_{TS}$, and increases aggregate total surplus for $\widehat{I}_{TS} < I \leqslant 3a/2$. Aggregate consumer surplus decreases for all $I \in [a/2, 3a/2]$. Industry profit increases for all $I \in [a/2, 3a/2]$.*

Thus, with independent preferences, personalized pricing always transfers surplus away from consumers and toward firm A, and it weakly reduces firm B's profit, with equality only at the endpoint $I = 3a/2$. Its total-surplus effect, however, is not monotone. When the common budget is tight, the loss in market B generated by the weakened residual demand is strong enough to dominate the output expansion in market A. When the budget is larger, the output expansion in market A and firm B's price adjustment can dominate the cross-market loss. Thus, demand contraction in market B should not be understood as an unconditional fall in market-B consumer surplus or total surplus. The precise result is that firm A's personalized pricing weakens firm B's residual demand and lowers firm B's profit throughout the relevant range, while consumer surplus and total surplus in market B fall only when the common budget is sufficiently tight. The model therefore preserves the central legal point: favorable evidence from market A alone is not sufficient, because the same conduct can weaken residual demand, reduce firm B's profit, and sometimes reduce total surplus in market B.

5 Applying the model to competition law

This section translates the model's results into competition-law terms. The paper's claim is that when a data-rich firm can personalize prices while consumers allocate a common budget across markets, expansion in the market with personalized pricing is not, by itself, sufficient to show that the practice is benign. The reason is the trade-off identified above: personalized pricing can expand demand in the focal market while weakening residual demand in adjacent markets by reallocating expenditure. In the continuous-type model, this adjacent-market effect always lowers firm B's profit, but it lowers consumer surplus or total surplus in market B only below the corresponding budget thresholds. The subsections below first identify the legal-inference problem, then specify the scope conditions and evidentiary burden, and finally discuss Article 102(b) and complementary legal regimes.

5.1 The legal-inference problem

The main logic of the paper matters because legal and policy analysis often proceeds market by market, and recent antitrust scholarship has criticized that approach for missing the cross-market interactions (Stucke and Ezrachi 2025). In our framework, however, the market with personalized pricing may expand while the adjacent firm faces weaker residual demand and lower profit. When budgets are sufficiently tight, or when viability constraints bind, that adjacent-market effect can also reduce consumer surplus, total surplus, output, or variety. Favorable same-market evidence, therefore, does not by itself show that personalized pricing is benign.

For purposes of competition law, the model has two main implications. First, the assessment should not stop at the market where personalized pricing is observed: the challenged conduct may reallocate expenditure and reduce output, variety, or viability in adjacent markets, so same-market expansion through personalized pricing is relevant but not decisive. Second, the model does not imply that any loss of profits by other firms is enough: the legally relevant concern is deterioration in consumer welfare or competitive conditions in a relevant or closely linked market. The core concern in the model is exploitative extraction by a dominant firm that can capture more surplus in market A, thereby worsening conditions elsewhere when consumers face a shared budget.

The distinction between a mere loss of profit and a consumer-facing harm can be expressed with a simple viability condition. Let π_B^U denote firm B's profit under the uniform-pricing benchmark, let π_B^P denote firm B's profit when firm A personalizes prices, and let F denote a fixed cost that firm B, or a variety in market B, must cover to remain viable. If

$$\pi_B^P < F \leqslant \pi_B^U,$$

then firm B, or the variety in market B, remains viable under the uniform-pricing benchmark but ceases to be viable when firm A personalizes prices. Thus, the legal concern is not lower profit for firm B as such. It is that weaker residual demand and lower profits in adjacent markets can lead to exit, reduced variety, or weaker entry when firms in those markets face fixed costs or other viability constraints.

In this respect, our analysis complements recent legal work that stresses the need for a context-sensitive, case-by-case assessment of personalized pricing under EU competition law rather than a simple presumption of harm or harmlessness (Botta and Wiedemann 2020; Bastidas Venegas 2023). Same-market expansion remains relevant evidence, but it is not a safe harbor when dominance, data advantage, common-budget expenditure shifts, and deterioration in adjacent markets all coincide.

5.2 Scope conditions for a cross-market theory of harm

The concern comes from the central trade-off: personalized pricing by a data-rich firm can change how consumers allocate spending across markets and can thereby worsen welfare or competitive conditions elsewhere. In that sense, the theory in this paper is related both to recent work on data-driven cross-market effects (Chen et al. 2022; Nakagawa and Matsushima 2023) and to emerging legal discussions of ecosystem and adjacent-market theories of harm (Graef 2019; Deutscher 2021; Batra et al. 2024; Garces et al. 2024). Recent ecosystem discussions have focused mainly on mergers, ecosystem expansion, and intermarket leverage of market power. By contrast, our mechanism arises because personalized pricing by a data-rich firm can directly reduce the budget available for purchases in adjacent markets, thereby weakening the residual demand faced by adjacent sellers. For sufficiently tight budgets, this residual-demand distortion can generate negative welfare effects through cross-market expenditure reallocation. In sum, when the same consumers participate in both markets, expenditure reallocation becomes part of the competitive and welfare assessment of the challenged conduct.

Note that this cross-market concern should not be overstated. The mechanism is strongest when the data-rich firm's product makes up a substantial share of the consumer's spending bundle and when personalized pricing extracts a meaningful amount of rent. The model should therefore be understood as identifying conditions under which legal concern is plausible, not as claiming that every instance of personalized pricing will create large cross-market harms. When the market with personalized pricing accounts for only a trivial share of expenditure, or when personalized pricing changes transfers without materially tightening the remaining budget, the theory of harm is weaker.

For purposes of competition law, the main value of the model is to help specify the conditions under which a cross-market theory of harm is plausible. Several conditions follow from the analysis. First, consumers' budgets must be tight enough for personalized pricing to affect purchases elsewhere. Second, the same consumers must participate in both markets, so that expenditure reallocation matters. Third, the data-rich firm must have an informational or technological advantage that allows it to personalize prices. Fourth, the market with personalized pricing must make up a sufficiently important part of consumers' spending bundles. Fifth, if the argument is extended from welfare loss to market-structure effects, firms in adjacent markets must face fixed costs, entry constraints, or other fragilities that cause weaker residual demand or lower sales to translate into exit or reduced variety.

5.3 Evidence and burden of proof

The conditions above are not merely theoretical in digital commerce. Online personalization technologies can condition offers on consumers' access channel, device, and past behavior. Empirical studies have also documented price steering and price discrimination on some e-commerce sites, including cases linked to device characteristics, account history, and prior browsing or purchasing behavior (Mikians et al. 2012; Hannak et al. 2014). More recently, the European Commission reported in 2025 that 93% of online shoppers were worried about online targeted advertising, including 63% who were worried about unavoidable personalization (European Commission 2025). The FTC likewise reported initial findings that firms use detailed personal data—including precise location, browsing history, demographics, mouse movements, and shopping history—to set individualized prices (Federal Trade Commission (FTC) 2025). However, these observations do not show that the harmful mechanism identified here is always present, and both the OECD and the European Commission caution that systematic personalized pricing remains hard to detect and is not universal (OECD 2018; European Commission 2018).

For that reason, the evidentiary burden is important. Authorities should examine whether consumers subject to personalized prices shift expenditure away from adjacent markets, whether the adjacent firm's residual demand or profitability weakens after accounting for its price response, whether the firm can identify users across transactions and condition prices on willingness-to-pay proxies rather than on cost differences, and whether firms in adjacent markets experience lower sales, weaker viability, or less variety. In practice, this may require transaction-level or panel data showing expenditure shifts across categories, as well as internal documents or model specifications showing that prices are conditioned on willingness-to-pay proxies. When the theory of harm extends to market structure, relevant evidence may also include reduced assortment, reduced viability, or lower entry in adjacent markets. The evidence should therefore connect personalized pricing to cross-market expenditure shifts and then to consumer-facing deterioration, rather than treating a rival's lost profit as sufficient by itself.

5.4 Article 102(b) as a doctrinal application

The main doctrinal payoff of our model is to clarify which legal questions Article 102(b) is comparatively well suited to answer. Article 102(b) is a particularly relevant doctrinal route because the model centers on exploitative extraction by a dominant firm while requiring a consumer-facing deterioration in a relevant or closely associated market (Bastidas Venegas 2023; Schweitzer and de Ridder 2024; Akman et al. 2025). The theory is therefore narrower than a claim that personalized pricing is unlawful. Its legal relevance is strongest when exploitative extraction in market A is connected to evidence of reduced output, variety, or viability in a closely linked market B.

The mechanism in this paper is different from, but complementary to, the concerns emphasized by Bar-Gill (2019) and Bar-Gill et al. (2023). Those papers focus on harms arising from consumer misperceptions and behavioral features of personalized pricing. In contrast, our paper shows that even without such misperceptions, personalized pricing may distort spending across linked markets, thereby creating adjacent-market harm that may be relevant under Article 102(b).

5.5 Complementary legal regimes

At the same time, the paper is also relevant to EU consumer law and data-protection law. EU law already recognizes personalized pricing as a practice that raises distinctive transparency concerns. Under Article 6(1)(ea) of the Consumer Rights Directive, as amended by Directive (EU) 2019/2161, traders must inform consumers, where applicable, "that the price was personalised on the basis of automated decision-making."[8] More broadly, legal scholarship has argued that the Unfair Commercial Practices Directive is a natural tool for addressing the exploitation of consumer vulnerabilities in personalized marketing (Duivenvoorde 2023). Data-protection scholarship has argued that the GDPR can support a right to resist or avoid personalized pricing and, in some accounts, a right to the impersonal price (Esposito 2022; Hutchinson and Treščáková 2022).[9] These consumer-law and data-law perspectives complement the competition-law concerns identified by our model.

6 Conclusion

This section first summarizes the results and discusses their legal implications. It then considers the limitations and possible extensions of the main model.

6.1 Summary of results and legal implications

This paper develops simple models of two monopoly markets linked by a common consumer budget constraint. We assume an asymmetry in pricing technology: a data-rich digital firm can set personalized prices for each consumer, while a

[8] Directive 2011/83/EU, art. 6(1)(ea), as amended by Directive (EU) 2019/2161; see also recital 45 of Directive (EU) 2019/2161.

[9] At the same time, economic research on GDPR-style data regulation shows that privacy protections are not necessarily welfare-improving in all environments: depending on market structure and how data are used, they may reduce consumer surplus and/or total surplus (Ke and Sudhir 2023; Choe et al. 2025; Cong and Matsushima 2026).

traditional firm must charge a uniform price. The purpose of the analysis is to clarify how unequal data capabilities in digital markets affect welfare when consumers allocate limited spending across multiple markets.

We show two sets of results. In the two-type example, personalized pricing always raises the digital firm's profit and lowers the traditional firm's profit. Its welfare effects depend on the parameters. When consumers' budgets are tight enough, the reduction in realized demand in the traditional market can reduce total surplus. Consumer surplus, however, can rise when the traditional firm lowers its price enough to offset part of the digital firm's surplus extraction.

In the continuous-type model with independent preferences, personalized pricing induces all consumers to buy from the digital firm, raises total surplus in that market, lowers consumer surplus in that market, and raises the digital firm's profit. At the same time, it weakens the residual demand faced by the traditional firm and lowers that firm's profit throughout the relevant budget range. The traditional firm's equilibrium price response implies that consumer surplus and total surplus in the traditional market may fall or rise depending on the budget level, so the adjacent-market effect should not be summarized as a simple demand contraction. Aggregate consumer surplus nevertheless falls throughout, and aggregate total surplus falls only when consumers' budgets are sufficiently tight. Overall, the welfare effect of personalized pricing depends on the balance between same-market demand expansion, adjacent-market residual-demand weakening, and the traditional firm's price response.

The main competition-law implication is as follows. The model shows why expansion or improved matching in a market with personalized pricing cannot, by itself, establish that the practice is benign. The reason is that the same conduct may reallocate constrained spending away from a closely linked adjacent market, reducing output, variety, or viability there and harming consumers. That point reinforces the need for a case-specific legal evaluation of personalized pricing that examines cross-market expenditure shifts and consumer-facing deterioration in adjacent markets rather than only within-market outcomes.

6.2 Limitations and extensions of the main model

The analysis has limitations. To isolate the cross-market budget mechanism, the models use simple demand systems and therefore do not cover the full range of demand environments relevant to digital markets.

Relatedly, one useful extension would distinguish among three groups of consumers: those who purchase only from firm A, those who purchase only from firm B, and those who purchase in both markets. Such an extension would lead to the following outcomes. First, personalized pricing is likely to increase total surplus more strongly when the share of consumers who purchase only from firm A is relatively high compared with the share of consumers who purchase only from firm B, because more of the demand expansion occurs without drawing expenditure away from the adjacent market. Second, the cross-market budget mechanism becomes more important when the share of consumers active in both markets is larger, since those consumers are precisely the ones whose expenditure is reallocated across markets. This extension would clarify the scope of the mechanism without changing its core logic.

A second meaningful extension would allow richer correlation structures between valuations for the two products. In this paper, the simple example uses negative correlation, while the continuous-type model studies independence. Even if we considered a continuous-type model with negative preference correlation, we would obtain results similar to those in Section 4.

Another extension would introduce competition in market B. Although not essential here, it would test the robustness of the mechanism under strategic interaction. If residual-demand weakening in market B continues to matter, then introducing competition would not alter the key mechanism.

Finally, other possible extensions would allow consumers to differ in their budget levels or would consider alternative demand functions. These changes would make the model more realistic, but the main mechanism would remain largely unchanged. Such extensions would mainly change the quantitative balance between the positive and negative effects of personalized pricing.

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thor carefully reviewed and edited the content as needed. The author takes full responsibility for the content of the published article.

A Proofs and derivations

A.1 Derivation of Proposition 1

Sections A.1.1–A.1.4 rovide the analysis for the environment summarized in Table 1 in Section 3.

A.1.1 Uniform pricing in Section 3

If both firms set uniform prices, the monopoly price in each market is $p_i = v_L$. Each consumer then buys both goods.

Lemma A.1. *When there are two consumer types as shown in Table 1, each firm's profit, consumer surplus, and total surplus under uniform pricing are:*

$$\pi_A^U = \pi_B^U = 2v_L, \quad CS_i^U = (v_H - v_L), \quad TS_i^U = v_H + v_L. \tag{10}$$

A.1.2 Firm A's personalized pricing in Section 3

We now consider the case in which firm A uses personalized pricing. We solve the problem by backward induction.

Firm A's best response. Given p_B, we divide the analysis into two cases: (i) $v_L < p_B \leqslant v_H$, and (ii) $p_B \leqslant v_L$ (we ignore $p_B > v_H$ because firm B would then earn zero profit). In case (i), type-α consumers do not buy product B because their gross valuation for it is only v_L. In case (ii), they prefer buying B to buying nothing.

We first consider prices for type-α and type-β consumers in case (i) ($v_L < p_B \leqslant v_H$). When $p_B \in (v_L, v_H]$, type-α consumers buy only A. Firm A therefore sets the following price (recall that $v_H < 2v_L < I$ by assumption):

$$p_{A\alpha} = \min\{v_H, I\} = v_H.$$

Firm A then considers two possible purchase patterns for type-β consumers. First, if firm A wants type-β consumers to buy both products, $p_{A\beta}$ must satisfy:

$$v_H + v_L - p_B - p_{A\beta} \geqslant v_H - p_B \quad s.t. \quad p_{A\beta} \leqslant I - p_B \quad \Rightarrow \quad p_{A\beta} \leqslant v_L \quad s.t. \; p_{A\beta} \leqslant I - p_B.$$

Thus, the highest price compatible with joint purchase is:

$$p_{A\beta}^{\text{both}} = \min\{v_L, I - p_B\} = \begin{cases} v_L & \text{if } p_B \leqslant I - v_L, \\ I - p_B & \text{if } p_B > I - v_L. \end{cases}$$

Second, firm A may induce type-β consumers to buy only product A:

$$v_L - p_{A\beta} \geqslant v_H - p_B \quad \Rightarrow \quad p_{A\beta} \leqslant p_B - (v_H - v_L), \text{ so}$$
$$p_{A\beta}^{A} = p_B - (v_H - v_L).$$

Firm A compares the two prices above, $p_{A\beta}^{\text{both}} = \min\{v_L, I - p_B\}$ and $p_{A\beta}^{A} = p_B - (v_H - v_L)$, which gives three cases. Specifically, $p_{A\beta}^{\text{both}}$ equals v_L when $p_B \leqslant I - v_L$ and equals $I - p_B$ when $p_B \geqslant I - v_L$. The latter range can be split into $I - v_L \leqslant p_B \leqslant (I + v_H - v_L)/2$ and $p_B \geqslant (I + v_H - v_L)/2$.

We now derive the optimal price in these three cases. When $p_B \leqslant I - v_L$, $p_{A\beta}^{\text{both}} = \min\{v_L, I - p_B\} = v_L$ is at least as large as $p_{A\beta}^{A}$ because $v_L - (p_B - (v_H - v_L)) = v_H - p_B \geqslant 0$. Firm A therefore sets $p_{A\beta}^{\text{both}} = v_L$, and type-$\beta$ consumers buy both products. When $I - v_L \leqslant p_B \leqslant (I + v_H - v_L)/2$, $p_{A\beta}^{\text{both}} = \min\{v_L, I - p_B\} = I - p_B$ is at least as large as $p_{A\beta}^{A} = p_B - (v_H - v_L)$. Thus, firm A sets $p_{A\beta}^{\text{both}} = I - p_B$, and type-$\beta$ consumers buy both products. When $p_B > (I + v_H - v_L)/2$, $p_{A\beta}^{A}$ is larger than $p_{A\beta}^{\text{both}}$. Firm A then sets $p_{A\beta}^{A} = p_B - (v_H - v_L)$, and type-$\beta$ consumers buy only product A. The following lemma summarizes the result:

Lemma A.2. *Suppose that there are two consumer types as shown in Table 1. When firm B sets $p_B \in (v_L, v_H]$, firm A's optimal prices for type-α and type-β consumers are:*

$$p_{A\alpha} = v_H, \quad p_{A\beta} = \begin{cases} v_L & \textit{if } p_B \leqslant I - v_L & A \textit{ and } B, \\ I - p_B & \textit{if } I - v_L < p_B \leqslant \dfrac{I + v_H - v_L}{2} & A \textit{ and } B, \\ p_B - (v_H - v_L) & \textit{if } \dfrac{I + v_H - v_L}{2} < p_B & \textit{Only } A. \end{cases}$$

The best response in Lemma A.2 implies that type-β consumers do not buy product B when p_B is higher than $(I + v_H - v_L)/2$, even though that level is still below their valuation for product B, namely v_H.

We next consider prices for type-α and type-β consumers in case (ii) ($p_B \leqslant v_L$). Type β consumers have enough budget to buy product A because $I - p_B \geqslant 2v_L - v_L = v_L$. Firm A therefore sets

$$p_{A\beta} = v_L.$$

Type α consumers value product B at v_L. If firm A wants them to buy both products, $p_{A\alpha}$ must satisfy:

$$v_H + v_L - p_B - p_{A\alpha} \geqslant v_L - p_B \;\; s.t. \;\; p_{A\alpha} \leqslant I - p_B \quad \Rightarrow \quad p_{A\alpha} \leqslant v_H \;\; s.t. \; p_{A\alpha} \leqslant I - p_B.$$

Thus, the highest price compatible with joint purchase is:

$$p_{A\alpha}^{\text{both}} = \min\{v_H, I - p_B\} = \begin{cases} v_H & \text{if } p_B \leqslant I - v_H, \\ I - p_B & \text{if } p_B > I - v_H. \end{cases}$$

Alternatively, firm A may induce type-α consumers to buy only product A:

$$v_H - p_{A\alpha} \geqslant v_L - p_B \quad \Rightarrow \quad p_{A\alpha} \leqslant p_B + (v_H - v_L). \text{ Thus,}$$
$$p_{A\alpha}^{A} = p_B + (v_H - v_L).$$

Firm A compares the two prices, $\min\{v_H, I - p_B\}$ and $p_B + (v_H - v_L)$. When $p_B \leqslant I - v_H$, $p_{A\alpha}^{\text{both}} = v_H$ is at least as large as $p_{A\alpha}^{A} = p_B + (v_H - v_L)$ because $v_H - (p_B + (v_H - v_L)) = v_L - p_B \geqslant 0$. Firm A then sets $p_{A\alpha}^{\text{both}} = v_H$, and type-$\alpha$ consumers buy both products. When $p_B > I - v_H$, $\min\{v_H, I - p_B\} = I - p_B$, which is at least as large as $p_B + (v_H - v_L)$ if and only if $p_B \leqslant (I - v_H + v_L)/2$. Thus, when $I - v_H < p_B \leqslant (I - v_H + v_L)/2$, firm A sets $p_{A\alpha}^{\text{both}} = I - p_B$, and type-$\alpha$ consumers buy both products. When $p_B > (I - v_H + v_L)/2$, firm A sets $p_{A\alpha}^{A} = p_B + (v_H - v_L)$, and type-$\alpha$ consumers buy only product A. The following lemma summarizes the result:

Lemma A.3. *Suppose that there are two consumer types as shown in Table 1. When firm B sets $p_B (\leqslant v_L)$, firm A's optimal prices for type-α and type-β consumers* *are:*

$$p_{A\alpha} = \begin{cases} v_H & \textit{if } p_B \leqslant I - v_H & A \textit{ and } B, \\ I - p_B & \textit{if } I - v_H < p_B \leqslant \dfrac{I - v_H + v_L}{2} & A \textit{ and } B, \\ p_B + (v_H - v_L) & \textit{if } \dfrac{I - v_H + v_L}{2} < p_B & \textit{Only } A, \end{cases} \qquad p_{A\beta} = v_L.$$

The best response in Lemma A.3 implies that type-α consumers do not buy product B when p_B is higher than $(I - v_H + v_L)/2$, even though that level is still below their valuation for product B, namely v_L.

Firm B's uniform price In the range $v_L < p_B \leqslant v_H$ (case (i)), firm B sets the highest price that still induces type-β consumers to buy both products and earns

$$p_B = \frac{I + v_H - v_L}{2}, \quad \pi_B = \frac{I + v_H - v_L}{2}.$$

In the range $p_B \leqslant v_L$ (case (ii)), firm B has two candidate prices: $p_B = (I - v_H + v_L)/2$ and $p_B = v_L$. The corresponding profits are $I - v_H + v_L$ and v_L. The former is larger if and only if $I > v_H$. Finally, comparing the best prices from cases (i) and (ii), firm B chooses the price from case (i) if and only if

$$\begin{cases} \dfrac{I + v_H - v_L}{2} - (I - v_H + v_L) > 0 \quad \Leftrightarrow \quad v_H < I < 3(v_H - v_L) & \text{if } v_H < I, \\ \dfrac{I + v_H - v_L}{2} - v_L > 0 \quad \Leftrightarrow \quad 3v_L - v_H < 2v_L < I \leqslant v_H & \text{if } I \leqslant v_H. \end{cases}$$

Rearranging the conditions gives the following lemma:

Lemma A.4. *Suppose that there are two consumer types as shown in Table 1. The optimal price of firm B is*

$$p_B^* = \begin{cases} \dfrac{I + v_H - v_L}{2} & \textit{if } 2v_L < I < 3(v_H - v_L) \textit{ and } v_L < 3v_H/5, \\ \dfrac{I - v_H + v_L}{2} & \textit{if } 3(v_H - v_L) \leqslant I \textit{ or } 3v_H/5 \leqslant v_L. \end{cases}$$

In the first case of Lemma A.4, firm B serves only type-β consumers, so personalized pricing reduces realized demand in market B when I and v_L are small enough. In the second case, firm B serves both type-α and type-β consumers.

A.1.3 Comparison in Section 3

Proposition 1 summarizes the effect of personalized pricing on profits, total surplus, and consumer surplus. Personalized pricing allows firm A to extract more surplus in market A by tailoring prices to consumer type, which raises its profit even though demand in market A does not expand in this two-type example. However, personalized pricing also tightens some consumers' budget constraints in market B and changes firm B's residual demand. In the first case of Lemma A.4, this reduces realized demand for product B: firm B charges a higher price than under uniform pricing and serves only type-β consumers. In the second case, firm B lowers its price relative to the uniform-pricing benchmark and keeps both types.

A.1.4 Proof of Proposition 1 in Section 3

Under uniform pricing, each firm's profit is $2v_L$. Under personalized pricing, firm A's equilibrium profit is $(I + v_H + v_L)/2$ in either case of Lemma A.4. Since $I > 2v_L$ and $v_H > v_L$, we have $(I + v_H + v_L)/2 > 2v_L$. Hence firm A's profit increases.

Firm B's profit decreases. In the first case of Lemma A.4, firm B's profit is $(I + v_H - v_L)/2$. Since $I < v_H + v_L$ and $v_L > v_H/2$, we have $(I + v_H - v_L)/2 < v_H < 2v_L$. In the second case, firm B's profit is $I - v_H + v_L$, which is less than $2v_L$ because $I < v_H + v_L$. Thus firm B earns less than under uniform pricing in either case.

Total surplus in market A is unchanged because both consumer types still buy product A. Therefore, the total-surplus effect is determined by market B. In the first case of Lemma A.4, only type-β consumers buy product B, so total surplus in market B falls by v_L. In the second case, both types continue to buy product B, so total surplus is unchanged. Hence personalized pricing decreases total surplus if and only if the first case of Lemma A.4 applies, namely $2v_L < I < 3(v_H - v_L)$ and $v_L < 3v_H/5$.

It remains to prove the consumer-surplus statement. In the first case of Lemma A.4, type-α consumers buy only product A and obtain zero surplus, while type-β consumers buy both products, spend their entire budget, and obtain $v_H + v_L - I$. Since $I > 2v_L$, the surplus of type-β consumers is lower than under uniform pricing, and type-α consumers lose their previous surplus. Hence consumer surplus falls in the first case.

In the second case of Lemma A.4, both types buy both products, so total gross valuation is the same as under uniform pricing. Consumer surplus therefore increases if and only if aggregate expenditure falls. Under personalized pricing, type-α consumers spend I, and type-β consumers spend $v_L + (I - v_H + v_L)/2$. Aggregate expenditure is therefore $(3I - v_H + 3v_L)/2$. Under uniform pricing, aggregate expenditure is $4v_L$. Personalized pricing increases consumer surplus if and only if $(3I - v_H + 3v_L)/2 < 4v_L$, or equivalently $I < (5v_L + v_H)/3$. Combining this inequality with the condition for the second case of Lemma A.4 and the maintained assumption $I > 2v_L$ gives $3(v_H - v_L) < I < (5v_L + v_H)/3$. This interval is nonempty if and only if $4v_H/7 < v_L$, which gives the condition stated in the proposition.

A.2 Derivation of the uniform-pricing benchmark with independent preferences

This subsection derives the uniform-pricing benchmark in Section 4.1. The nontrivial case is $a/2 \leqslant I < a$. Suppose firm B sets

$$p_B^U = \frac{I}{2}.$$

Let p_A be firm A's uniform price. If $p_A > I$, product A is unaffordable and firm A's demand is zero, so restrict attention to $0 \leqslant p_A \leqslant I$.

First suppose $0 \leqslant p_A \leqslant I/2$. Then $p_A + p_B^U \leqslant I$, so the consumer can afford both products. The purchase decision for product A is separable: the consumer buys product A if and only if $\theta_A \geqslant p_A$. Hence, for every fixed $\theta_B \in [0, a]$, the mass of consumers willing to buy product A is

$$m_A(\theta_B; p_A) = \int_0^a \mathbf{1}\{\theta_A \geqslant p_A\}\, d\theta_A = a - p_A.$$

Integrating over θ_B gives

$$M_A(p_A) = \int_0^a m_A(\theta_B; p_A) d\theta_B = a(a - p_A).$$

Firm A's profit is $p_A M_A(p_A) = p_A a(a - p_A)$, which is strictly increasing on $[0, I/2]$

because $I < a$ implies $I/2 < a/2$. Thus the best price in this region is $p_A = I/2$.

Now suppose $I/2 < p_A \leqslant I$. Then $p_A + p_B^U > I$, so the consumer cannot buy both products. For a fixed θ_B, if $\theta_B < I/2$, product B yields negative utility and the mass of consumers willing to buy product A is $a - p_A$. If $\theta_B \geqslant I/2$, the consumer buys product A only when

$$\theta_A - p_A \geqslant \theta_B - \frac{I}{2},$$

yielding $\theta_A \geqslant p_A + \theta_B - I/2$. Therefore

$$m_A(\theta_B; p_A) = \begin{cases} a - p_A, & 0 \leqslant \theta_B < I/2, \\ a - p_A - \theta_B + I/2, & I/2 \leqslant \theta_B \leqslant a - p_A + I/2, \\ 0, & a - p_A + I/2 < \theta_B \leqslant a. \end{cases}$$

The integrated mass of consumers buying product A is

$$\begin{aligned} M_A(p_A) &= \int_0^{I/2} (a - p_A) d\theta_B + \int_{I/2}^{a - p_A + I/2} \left(a - p_A - \theta_B + \frac{I}{2} \right) d\theta_B \\ &= \frac{I}{2}(a - p_A) + \frac{(a - p_A)^2}{2} = \frac{(a - p_A)(a + I - p_A)}{2}. \end{aligned}$$

Firm A's profit in this region is

$$p_A M_A(p_A) = \frac{p_A(a - p_A)(a + I - p_A)}{2}.$$

This branch is below the payoff at $p_A = I/2$. To see this, note that $p_A > I/2$ implies $a + I - p_A < a + I/2$, and $p_A(a - p_A) \leqslant a^2/4$. Hence

$$p_A M_A(p_A) < \frac{a^2(a + I/2)}{8}.$$

For $I \in [a/2, a)$,

$$\frac{a^2(a + I/2)}{8} < \frac{I}{2} a \left(a - \frac{I}{2} \right),$$

where the right-hand side is firm A's profit at $p_A = I/2$. Thus no price $p_A > I/2$ yields a higher profit than $p_A = I/2$. Therefore, firm A's best response to $p_B^U = I/2$ is $p_A = I/2$. By symmetry, the same reasoning applies to firm B, so $p_A^U = p_B^U = I/2$ when $a/2 \leqslant I < a$.

When $a \leqslant I \leqslant 3a/2$, the unconstrained monopoly prices $p_A = p_B = a/2$ are jointly affordable because $p_A + p_B = a \leqslant I$. Each firm therefore sets the ordinary monopoly price $a/2$.

A.3 Derivation of the personalized-pricing equilibrium and equilibrium outcomes with independent preferences

Firm B's demand and optimal price. From (5), firm B's demand is

$$Q_B(p_B) = \int_0^a [a - \max\{p_B, \theta_A + 2p_B - I\}]_+ \, d\theta_A.$$

If $I > a$ and $0 < p_B \leqslant I - a$, then $\theta_A + 2p_B - I \leqslant p_B$ for all $\theta_A \in [0, a]$, so

$$Q_B(p_B) = a(a - p_B).$$

If $\max\{0, I-a\} < p_B \leqslant I/2$, then the lower bound is p_B for $\theta_A \leqslant I - p_B$ and $\theta_A + 2p_B - I$ for $\theta_A > I - p_B$. The purchase region is not truncated at $\theta_A = a$, so

$$\begin{aligned} Q_B(p_B) &= \int_0^{I-p_B} (a - p_B) d\theta_A + \int_{I-p_B}^{a} (a - \theta_A - 2p_B + I) d\theta_A \\ &= \frac{a^2 + 2aI - I^2 - 4ap_B + 2Ip_B - p_B^2}{2}. \end{aligned}$$

If $I/2 < p_B \leqslant \min\{a, I\}$, then the upper endpoint of the second region is $a + I - 2p_B < a$, and

$$\begin{aligned} Q_B(p_B) &= \int_0^{I-p_B} (a - p_B) d\theta_A + \int_{I-p_B}^{a+I-2p_B} (a - \theta_A - 2p_B + I) d\theta_A \\ &= \frac{(a - p_B)(a + 2I - 3p_B)}{2}. \end{aligned}$$

Combining these cases gives (8).

In the region $I/2 < p_B \leqslant \min\{a, I\}$, firm B maximizes

$$p_B Q_B(p_B) = \frac{p_B(a - p_B)(a + 2I - 3p_B)}{2}.$$

The first-order condition is

$$9p_B^2 - 4(I + 2a)p_B + a(a + 2I) = 0,$$

and the relevant root is

$$p_B = \frac{2I + 4a - \sqrt{4I^2 - 2aI + 7a^2}}{9}.$$

In the region $\max\{0, I - a\} < p_B \leqslant I/2$, firm B maximizes

$$p_B Q_B(p_B) = p_B \frac{a^2 + 2aI - I^2 - 4ap_B + 2Ip_B - p_B^2}{2}.$$

The first-order condition is

$$a^2 + 2aI - I^2 + 4(I - 2a)p_B - 3p_B^2 = 0,$$

and the relevant root is

$$p_B = \frac{2I - 4a + \sqrt{I^2 - 10aI + 19a^2}}{3}.$$

The two regions meet when $p_B = I/2$, which occurs at $I = a(4 - 2\sqrt{3})$. This gives the equilibrium price in (9).

Equilibrium surplus and profits. We next derive the surplus and profit expressions and record the closed-form equilibrium outcomes. The expressions are obtained by integrating market-specific surplus and profit over the purchase regions implied by (5) and then substituting the relevant equilibrium price of firm B. To avoid ambiguity, each outcome variable in Case k carries the subscript k ($k = 1, 2, 3$), and the superscript P denotes the equilibrium under firm A's personalized pricing. To shorten notation in this paragraph, write

$$b_k \equiv p_{B,k}^*, \qquad k = 1, 2, 3.$$

The total surplus in market A is common in all three cases because firm A sells product A to every consumer:

$$TS^P_{A,k} = \int_0^a \int_0^a \theta_A \, d\theta_B \, d\theta_A = \frac{a^3}{2}, \qquad k = 1, 2, 3.$$

Case 1: $a/2 \leqslant I < a(4 - 2\sqrt{3})$**.** In this region, firm B's equilibrium price is above $I/2$. Define

$$b_1 \equiv p^*_{B,1} = \frac{2I + 4a - \sqrt{4I^2 - 2aI + 7a^2}}{9}.$$

Firm B's demand is

$$Q^P_{B,1} = \frac{(a - b_1)(a + 2I - 3b_1)}{2}.$$

The purchase region for product B consists of

$$0 \leqslant \theta_A \leqslant I - b_1, \quad b_1 \leqslant \theta_B \leqslant a,$$

and

$$I - b_1 \leqslant \theta_A \leqslant a + I - 2b_1, \quad \theta_A + 2b_1 - I \leqslant \theta_B \leqslant a.$$

Therefore, consumer surplus in market B is

$$\begin{aligned} CS^P_{B,1} &= \int_0^{I-b_1} \int_{b_1}^{a} (\theta_B - b_1) d\theta_B \, d\theta_A + \int_{I-b_1}^{a+I-2b_1} \int_{\theta_A+2b_1-I}^{a} (\theta_B - b_1) d\theta_B \, d\theta_A \\ &= \frac{(a - b_1)^2(3I + 2a - 5b_1)}{6}. \end{aligned}$$

Total surplus in market B is

$$\begin{aligned} TS^P_{B,1} &= \int_0^{I-b_1} \int_{b_1}^{a} \theta_B \, d\theta_B \, d\theta_A + \int_{I-b_1}^{a+I-2b_1} \int_{\theta_A+2b_1-I}^{a} \theta_B \, d\theta_B \, d\theta_A \\ &= \frac{(a - b_1)\{2a^2 + 3aI + 3Ib_1 - 4ab_1 - 4b_1^2\}}{6}. \end{aligned}$$

Consumer surplus in market A is obtained by integrating $\theta_A - p_A^*(\theta; b_1)$ over firm A's pricing regions:

$$
\begin{aligned}
CS_{A,1}^P = b_1 \int_I^a (\theta_A - I) d\theta_A \\
&+ \int_{I-b_1}^{I} \left[\int_{b_1}^{\theta_A+2b_1-I} (\theta_B - b_1) d\theta_B + \int_{\theta_A+2b_1-I}^{a} (\theta_A + b_1 - I) d\theta_B \right] d\theta_A \\
&+ \int_{I}^{a+I-2b_1} \left[\int_{b_1}^{\theta_A+b_1-I} (\theta_A - I) d\theta_B + \int_{\theta_A+b_1-I}^{\theta_A+2b_1-I} (\theta_B - b_1) d\theta_B \right. \\
&\qquad\qquad \left. + \int_{\theta_A+2b_1-I}^{a} (\theta_A + b_1 - I) d\theta_B \right] d\theta_A \\
&+ \int_{a+I-2b_1}^{a} \left[\int_{b_1}^{\theta_A+b_1-I} (\theta_A - I) d\theta_B + \int_{\theta_A+b_1-I}^{a} (\theta_B - b_1) d\theta_B \right] d\theta_A \\
= \frac{4b_1^3 - 3Ib_1^2 - 6ab_1^2 + 3I^2 b_1 + 3a^2 b_1 - I^3 + 3aI^2 - 6a^2 I + 3a^3}{6}.
\end{aligned}
$$

Profits are

$$
\pi_{A,1}^P = \frac{a^3}{2} - CS_{A,1}^P, \qquad \pi_{B,1}^P = b_1 Q_{B,1}^P.
$$

Case 2: $a(4 - 2\sqrt{3}) \leqslant I < a$**.** In this region, firm B's equilibrium price is weakly below $I/2$, while the budget is still below a. Define

$$
b_2 \equiv p_{B,2}^* = \frac{2I - 4a + \sqrt{I^2 - 10aI + 19a^2}}{3}.
$$

Firm B's demand is

$$
Q_{B,2}^P = \frac{a^2 + 2aI - I^2 - 4ab_2 + 2Ib_2 - b_2^2}{2}.
$$

The purchase region for product B consists of

$$
0 \leqslant \theta_A \leqslant I - b_2, \quad b_2 \leqslant \theta_B \leqslant a,
$$

and

$$
I - b_2 \leqslant \theta_A \leqslant a, \quad \theta_A + 2b_2 - I \leqslant \theta_B \leqslant a.
$$

Therefore, consumer surplus in market B is

$$\begin{aligned} CS^P_{B,2} &= \int_0^{I-b_2}\int_{b_2}^{a}(\theta_B - b_2)d\theta_B\, d\theta_A + \int_{I-b_2}^{a}\int_{\theta_A+2b_2-I}^{a}(\theta_B - b_2)d\theta_B\, d\theta_A \\ &= \frac{I^3 - 3aI^2 + 3a^2I + 2a^3 - b_2^3 + 3Ib_2^2 - 3I^2b_2 + 6aIb_2 - 9a^2b_2}{6}. \end{aligned}$$

Total surplus in market B is

$$\begin{aligned} TS^P_{B,2} &= \int_0^{I-b_2}\int_{b_2}^{a}\theta_B\, d\theta_B\, d\theta_A + \int_{I-b_2}^{a}\int_{\theta_A+2b_2-I}^{a}\theta_B\, d\theta_B\, d\theta_A \\ &= \frac{I^3 - 3aI^2 + 3a^2I + 2a^3 - 6b_2(I-a)^2 + 3(3I-4a)b_2^2 - 4b_2^3}{6}. \end{aligned}$$

Consumer surplus in market A is

$$\begin{aligned} CS^P_{A,2} = b_2 &\int_I^a(\theta_A - I)d\theta_A \\ &+ \int_{I-b_2}^{I}\left[\int_{b_2}^{\theta_A+2b_2-I}(\theta_B - b_2)d\theta_B + \int_{\theta_A+2b_2-I}^{a}(\theta_A + b_2 - I)d\theta_B\right]d\theta_A \\ &+ \int_I^a\left[\int_{b_2}^{\theta_A+b_2-I}(\theta_A - I)d\theta_B + \int_{\theta_A+b_2-I}^{\theta_A+2b_2-I}(\theta_B - b_2)d\theta_B \right. \\ &\qquad\qquad \left. + \int_{\theta_A+2b_2-I}^{a}(\theta_A + b_2 - I)d\theta_B\right]d\theta_A \\ = &\frac{-4b_2^3 + 9Ib_2^2 - 6ab_2^2 - 3I^2b_2 + 3a^2b_2 + 3aI^2 - 6a^2I + 3a^3}{6}. \end{aligned}$$

Profits are

$$\pi^P_{A,2} = \frac{a^3}{2} - CS^P_{A,2}, \qquad \pi^P_{B,2} = b_2Q^P_{B,2}.$$

Case 3: $a \leqslant I \leqslant 3a/2$**.** In this region, firm B's equilibrium price is again weakly below $I/2$, but the budget is at least a. Define

$$b_3 \equiv p^*_{B,3} = \frac{2I - 4a + \sqrt{I^2 - 10aI + 19a^2}}{3}.$$

Firm B's demand is

$$Q^P_{B,3} = \frac{a^2 + 2aI - I^2 - 4ab_3 + 2Ib_3 - b_3^2}{2}.$$

The purchase region for product B is the same as in Case 2, with b_3 in place of b_2. Thus

$$\begin{aligned} CS^P_{B,3} &= \int_0^{I-b_3}\int_{b_3}^{a}(\theta_B - b_3)d\theta_B\, d\theta_A + \int_{I-b_3}^{a}\int_{\theta_A+2b_3-I}^{a}(\theta_B - b_3)d\theta_B\, d\theta_A \\ &= \frac{I^3 - 3aI^2 + 3a^2I + 2a^3 - b_3^3 + 3Ib_3^2 - 3I^2b_3 + 6aIb_3 - 9a^2b_3}{6}, \end{aligned}$$

and

$$\begin{aligned} TS^P_{B,3} &= \int_0^{I-b_3}\int_{b_3}^{a}\theta_B\, d\theta_B\, d\theta_A + \int_{I-b_3}^{a}\int_{\theta_A+2b_3-I}^{a}\theta_B\, d\theta_B\, d\theta_A \\ &= \frac{I^3 - 3aI^2 + 3a^2I + 2a^3 - 6b_3(I-a)^2 + 3(3I-4a)b_3^2 - 4b_3^3}{6}. \end{aligned}$$

The expression for consumer surplus in market A changes because $I \geqslant a$ eliminates the budget-cap surplus term for consumers with $\theta_B < b_3$. Hence

$$\begin{aligned} CS^P_{A,3} &= \int_{I-b_3}^{a}\left[\int_{b_3}^{\theta_A+2b_3-I}(\theta_B - b_3)d\theta_B + \int_{\theta_A+2b_3-I}^{a}(\theta_A + b_3 - I)d\theta_B\right]d\theta_A \\ &= \frac{(I+2a-4b_3)(a+b_3-I)^2}{6}. \end{aligned}$$

Profits are

$$\pi^P_{A,3} = \frac{a^3}{2} - CS^P_{A,3}, \qquad \pi^P_{B,3} = b_3 Q^P_{B,3}.$$

A.4 Derivation of the comparison result

The comparison in Section 4 follows by substituting the relevant case-specific equilibrium price from (9) into the closed-form expressions in Appendix A.3 and comparing them with the uniform-pricing expression in (3). For market A, the total-surplus comparison is immediate:

$$TS^P_A - TS^U_A = \frac{a^3}{2} - \frac{a\{a^2 - (p^U)^2\}}{2} = \frac{a(p^U)^2}{2} > 0.$$

The profit and consumer-surplus comparisons in market A follow directly from the expressions for CS^P_A, CS^U_A, and $\pi^P_A = a^3/2 - CS^P_A$.

For market B and for aggregate surplus, define

$$\Delta_{CS_B}(I) = CS_B^P - CS_B^U, \quad \Delta_{TS_B}(I) = TS_B^P - TS_B^U, \quad \Delta_{TS}(I) = TS_A^P + TS_B^P - TS_A^U - TS_B^U.$$

After substituting the relevant equilibrium price, these functions are homogeneous of degree three in a. Their roots are therefore proportional to a. Direct evaluation of the closed-form expressions gives the unique interior roots

$$\Delta_{CS_B}(I) = 0 \quad \Longleftrightarrow \quad I \simeq 0.7449a,$$

$$\Delta_{TS_B}(I) = 0 \quad \Longleftrightarrow \quad I \simeq 0.9637a,$$

and

$$\Delta_{TS}(I) = 0 \quad \Longleftrightarrow \quad I \simeq 0.7442a.$$

Denote these interior roots by $\widehat{I}_{CS_B}$, $\widehat{I}_{TS_B}$, and $\widehat{I}_{TS}$, respectively. The endpoint $I = 3a/2$ also gives equality for CS_B, TS_B, and π_B, because then $p_B^* = a/2$ and firm B's market outcome coincides with the uniform-pricing outcome. Evaluating the closed-form differences on the intervals separated by the roots above gives the following comparison outcomes:

$$TS_A^P > TS_A^U, \qquad CS_A^P < CS_A^U, \qquad \pi_A^P > \pi_A^U \quad \text{for all } I \in [a/2, 3a/2].$$

For market B,

$$\pi_B^P < \pi_B^U \quad \text{for } a/2 \leqslant I < 3a/2, \qquad \pi_B^P = \pi_B^U \quad \text{at } I = 3a/2,$$

$$CS_B^P < CS_B^U \quad \text{for } a/2 \leqslant I < \widehat{I}_{CS_B}, \qquad CS_B^P > CS_B^U \quad \text{for } \widehat{I}_{CS_B} < I < 3a/2,$$

with equality at $I = \widehat{I}_{CS_B}$ and at $I = 3a/2$, and

$$TS_B^P < TS_B^U \quad \text{for } a/2 \leqslant I < \widehat{I}_{TS_B}, \qquad TS_B^P > TS_B^U \quad \text{for } \widehat{I}_{TS_B} < I < 3a/2,$$

with equality at $I = \widehat{I}_{TS_B}$ and at $I = 3a/2$. Aggregating over the two markets,

$$CS_A^P + CS_B^P < CS_A^U + CS_B^U \quad \text{for all } I \in [a/2, 3a/2],$$

$$\pi_A^P + \pi_B^P > \pi_A^U + \pi_B^U \quad \text{for all } I \in [a/2, 3a/2],$$

and

$$TS_A^P + TS_B^P < TS_A^U + TS_B^U \quad \text{for } a/2 \leqslant I < \widehat{I}_{TS},$$

while

$$TS_A^P + TS_B^P > TS_A^U + TS_B^U \quad \text{for } \widehat{I}_{TS} < I \leqslant 3a/2,$$

with equality at $I = \widehat{I}_{TS}$.

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