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PERSONALIZED PRICING WHEN CONSUMERS CAN PURCHASE MULTIPLE ITEMS*

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We study the impact of competitive personalized pricing in a Hotelling duopoly model where consumers can purchase from both firms. We show that the impact crucially depends on the magnitude of the additional utility from consuming the second product. Compared with uniform pricing, personalized pricing benefits both consumers and firms when the additional utility is moderate; but it harms consumers while benefiting firms when the additional utility is large. These results contrast with the existing research on competitive personalized pricing, which assumes that consumers purchase one product only.

I. INTRODUCTION

PERSONALIZED PRICING IS INCREASINGLY GAINING PREVALENCE in some industries thanks to advances in information technology, exemplified by Amazon.com's utilization of algorithmic consumer price discrimination (Townley *et al.* [2017], p. 684). In particular, the widespread adoption of

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smartphones has facilitated the implementation of personalized offers, and may even enable real-time personalization (Esteves and Resende [2016]). Examples include route-based pricing on platforms like Uber and Safeway's "JustforU" program, demonstrating the prevalence of personalized pricing across both tech-driven and traditional retail sectors.[1] In addition to the anecdotal evidence, several academic studies report examples of personalized offers on e-commerce websites, including hotels and ticket vendors (Mikians *et al.* [2012]; Hannak *et al.* [2014]). The increasing relevance of personalized pricing has also prompted discussions in the policy circle about the pros and cons of personalized pricing (e.g., European Commission [2018]; OECD [2018]; Ofcom [2020]).

We contribute to the literature on competitive personalized pricing by studying a Hotelling duopoly model where consumers can purchase from both firms, the latter being the main innovation of our paper. Allowing consumers to purchase multiple items is not only realistic but also prominent in online businesses. For example, the low cost of visiting online retailers helps consumers purchase items from multiple online retailers or join multiple online services, including online music stores and games (Landsman and Stremersch [2011] for game consoles). Below, we provide two examples of multi-item purchases made by consumers where there is a possibility of personalized pricing.

Our first example of multi-item purchases is from the market for subscription video on demand (SVOD), in which more than one-third of consumers subscribe to multiple services (Ishihara and Oki [2021], p. 15). One of the leading firms in the SVOD market, Netflix, provides personalized recommendations to customers (Kim *et al.* [2017]), which opens up a potential for Netflix to use personalized pricing based on its recommendation system, as discussed in Shiller [2020].[2] The same would apply to Amazon Prime Video given Amazon's ability to provide personalized recommendations and anecdotal evidence of Amazon's personalized pricing (e.g., Townley *et al.* [2017]; Zhao [2023]).[3]

[1] The following articles provide the details of the related cases: Uber Testing New Policy: Charge What It Thinks You're Able to Pay (May 22, 2017) and Worth The Deal? Groceries Get a Personalized Price (August 20, 2012), respectively. The articles are available at: *http://www.thedrive.com/tech/10487/uber-testing-new-policy-charge-what-it-thinks-youre-able-to-pay* and *http://knkx.org/post/worth-deal-groceries-get-personalized-price*.

[2] Shiller [2020] examines the impact of personalized pricing on profits by simulating counterfactual scenarios in which Netflix hypothetically implements personalized pricing based on web browsing histories. Using data from website visits and transactions in 2006, he shows that history-based personalized pricing could potentially increase Netflix's profits by about 13%.

[3] Rafieian and Yoganarasimhan [2023] discuss the usefulness of AI based recommendation and personalization in several marketing tools (e.g., advertising, content recommendation, and pricing).

Our second example is from online games where playing multiple games of the same genre is common. Consider three well-known first-person shooter video game series: Call of Duty, Battlefield, and Halo. In a survey of 8,024 respondents in the US, UK, Germany, and France, almost half of respondents had played at least two of these games (Melcher [2021]). These game series sell some functionalities to users within the game applications. The inherent nature of these products implies that game producers can potentially use personalized pricing to sell tailored functionalities (Jiao *et al.* [2022]; Wu *et al.* [2023]).[4]

To explore competitive personalized pricing when consumers can purchase multiple items from both firms, we use the framework in Jeitschko *et al.* [2017]. They examine a Hotelling duopoly model in which consumers can purchase from both firms. In this framework, the additional intrinsic utility from consuming the second item (henceforth, the additional utility) is smaller than the intrinsic utility from consuming the first item when firms are symmetric. Consumers observe the prices offered by the firms and decide whether to purchase from one or both of them. We compare results across two regimes where firms compete in uniform pricing or firms compete in personalized pricing.

We obtain the following results. The consumer surplus under personalized pricing is higher than under uniform pricing if the additional utility is insignificant. The result aligns with the existing literature where personalized pricing benefits consumers but harms firms when consumers purchase one item only. In contrast, firms benefit from personalized pricing if the additional utility is large. Further, both consumer surplus and profits under personalized pricing are higher than under uniform pricing if the additional utility is intermediate. In this case, personalized pricing increases consumption volume. Those results contrast sharply with the existing literature mentioned above.[5]

The intuition for these results is as follows. First, when the additional utility is insignificant, competition in personalized pricing benefits consumers but harms firms. This is consistent with the general insight from Thisse and Vives [1988], where asymmetric Bertrand competition at each point leads to intense price competition. But the results are reversed when the additional utility is significant because this case resembles a local monopoly and each

[4] Following their empirical findings, (Jiao *et al.* [2022], p. 3435) mention that game developers can design customized virtual item with personalized pricing. In addition, Wu *et al.* [2023] conduct counterfactual simulations on the effectiveness of targeted pricing, using data directly from the store website of Steam, a platform for PC-based video games. They show that price targeting can increase profits and that such targeting with increasing granularity does not always benefit firms.

[5] In an earlier version of this paper (Lu and Matsushima [2023]), we consider the endogenous choices of pricing policies and identify the possibility that both firms choose uniform pricing in some range of parameters. This finding complements that in Foros *et al.* [2024], where uniform pricing can be a dominant strategy in duopolistic price competition with non-price strategic variables (e.g., firms' locations).

firm effectively extracts rents through personalized pricing. Finally, when the additional utility is within an intermediate range, all consumers purchase from both firms under personalized pricing because of the standard mechanism for first-degree price discrimination. This is in contrast to the case where all consumers purchase from one of the firms under uniform pricing. In addition, the effect of rent extraction through personalized pricing is moderate. Thus, when the additional utility is in the intermediate range, competition in personalized pricing benefits both consumers and firms, hence increases total surplus.

Our main finding contributes to the ongoing policy debates on competitive personalized pricing (e.g., European Commission [2018]; OECD [2018]; Ofcom [2020]). These policy papers summarize the benefits and costs of competitive personalized pricing.[6] For instance, according to Ofcom [2020, p. 10],[7] personalized pricing allows firms to offer lower prices to new customers without reducing prices for existing ones. This fosters competition and reduces the average price. This effect is especially pronounced when all consumers participate and firms have access to similar consumer information. However, personalized pricing can lead to an increase in the average price when some consumers are not fully engaged in the market. Our paper reveals a new adverse effect of competitive personalized pricing: when consumers are inclined to buy multiple items, firms can set monopolistic prices for the second items, leading to lower consumer surplus and higher profits.

Our paper primarily contributes to the literature on competitive personalized pricing. Many researchers in the area investigate the impact of personalized pricing on profitability and welfare using the standard Hotelling model in which all consumers purchase from only one of the firms in equilibrium, or the so-called full coverage assumption (e.g., Thisse and Vives [1988]; Shaffer and Zhang [2002]; Choe *et al.* [2018]). They show that personalized pricing tends to increase competition and improve consumer welfare.[8] These studies also assume that consumers do not choose products from both firms. We relax this assumption and allow consumers to purchase from both firms.

In this literature, several studies show that personalized pricing can be a profitable pricing strategy in contrast to the standard impact of personalized pricing on profits and welfare. Liu and Serfes [2013] consider two-sided markets to investigate the profitability of personalized pricing. They show that personalized pricing is profitable but harms consumers if they can purchase from both firms.[9]

Chen *et al.* [2020] consider a static Hotelling duopoly model in which each firm has information about the locations of consumers on a particular range.

[6] Those papers also refer to the standard monopolistic personalized pricing.

[7] See also European Commission [2018, section 7.1.3] and OECD [2018, section 3.2].

[8] We refer to studies providing contrasting results later.

[9] We can calculate the consumer surplus on each side using the result in Liu and Serfes [2013], and we mention that personalized pricing worsens consumer surplus in the main text of our paper.

They assume that each firm offers a uniform price and personalized prices based on location information. They show that personalized pricing can harm consumers provided that consumers can actively avoid personalized prices, which are higher than uniform prices. Esteves [2022] examines when personalized pricing is more profitable for firms than uniform pricing in static Hotelling models, considering heterogeneity in the quantities demanded by consumers.[10]

Jullien *et al.* [2023] investigate the optimal distribution strategy of a monopolistic manufacturer that initially distributes its product through an independent retailer and can open a direct channel. They show that personalized pricing can be an exploitative device if the manufacturer designs a proper wholesale tariff.

Laussel and Resende [2022] extend the two-period model in Choe *et al.* [2018] to investigate the interaction between product customization and personalized pricing based on purchase histories in the first period.[11] They show that product-price personalization can be a profitable pricing strategy, contrasting with the findings in Choe *et al.* [2018].[12]

Rhodes and Zhou [2023] discuss generalized oligopoly models based on Perloff and Salop [1985] to investigate the effects of personalized pricing on profits and welfare. Each consumer chooses no more than one of the firms. They generalize a result in Thisse and Vives [1988], showing that personalized pricing improves consumer welfare but reduces profits in scenarios with fierce asymmetric Bertrand competition. They also show that the effects reverse when firms have some consumers that do not consider other firms as good alternatives. In Rhodes and Zhou [2023] and our paper, personalized pricing harms consumer welfare if firms can exert market power over certain consumers. However, the conditions that cause such situations differ: high marginal costs in Rhodes and Zhou [2023] and high additional utilities in our study.

Furthermore, we refer to recent studies on personalized pricing. Ali *et al.* [2023] consider a Hotelling duopoly in which consumers reveal their preferences to firms and show that consumers can strategically disclose their preferences to amplify competition. Anderson *et al.* [2023] consider

[10] Esteves and Shuai [2022] and Matsushima *et al.* [2023] provide similar results using different demand systems (elastic demands and heterogeneous transportation costs with unit demand).

[11] Chen *et al.* [2022] consider a two-market model in which one market deals with electronic devices to gather consumer data and the other deals with data-applicable services (e.g., health care). A pair of firms in the former and latter markets merge and use customer data gathered in the device market. They then derive the condition that the merger leads to the monopolization of the two markets.

[12] Choe *et al.* [2022] also extend Choe *et al.* (2018) to investigate firms' incentive to precommit to sharing customer information gathered at the end of the first period. They show that at the beginning of the game, firms agree to share customer information to mitigate competition in the first period.

a two-stage game in which consumers can commit not to receive targeted discounts offered in the second stage before knowing their preferences for firms. They show that such commitment can benefit firms and consumers through lower uniform prices and smaller targeted discounts.

Aside from personalized pricing, several papers explore multi-item purchases. These studies address issues such as vertical differentiation (Gabszewicz *et al.* [2001]; Gabszewicz and Wauthy [2003]), location choices (Guo [2006]; Kim and Serfes [2006]), product functionalities and locations (Anderson *et al.* [2017]), and bundling and joint marketing (Jeitschko *et al.* [2017]). Notably, none of these papers delve into personalized pricing.

The remainder of the paper is as follows. Section II explains the model. Section III derives the equilibrium outcomes under uniform pricing and personalized pricing and compares them. Section IV confirms that our main insight still holds under some nonuniform distributions of consumers. Section V concludes the paper. Some mathematical details are available in the Appendix. In addition, several extensions are available in an earlier version of this paper; see Lu and Matsushima [2023].

II. MODEL

We adopt the framework in Jeitschko *et al.* [2017]. Consumers are uniformly distributed on a line segment of length one, $[0, 1]$. The mass of consumers is 1. Two firms 1 and 2 are at the two ends of the Hotelling line. The utility from purchasing firm 1's product, firm 2's product, or both products is:

$$(1)\qquad \begin{cases} U_1(x) \equiv w - tx - p_1, & \text{purchasing from only firm 1,} \\ U_2(x) \equiv w - t(1-x) - p_2, & \text{purchasing from only firm 2,} \\ U_{12} \equiv w + v - t - p_1 - p_2, & \text{purchasing from both firms,} \end{cases}$$

where w is the intrinsic utility of the first item, t is the unit transportation cost, $x \in [0, 1]$ denotes consumer's location, p_i is firm i's price, and v is the additional intrinsic utility of the second item (henceforth, the additional utility).[13] We assume that $w \geq 3t/2$ to ensure that each consumer purchases at least one of the items and also that $v \in (0, w)$ to exclude trivial outcomes (see the details in footnote 13).

We consider two one-shot games: (i) firms compete in uniform pricing; (ii) firms compete in personalized pricing. In the former, the firms simultaneously offer uniform prices to all consumers. In the latter, the firms recognize the locations of all consumers and simultaneously offer personalized prices to them. Thus, prices are a function of x, $p_i(x)$.

[13] See Lu and Matsushima [2023] for the case in which the firms' intrinsic utilities, w, differ.

III. RESULTS

III(i). *Uniform Pricing*

We describe the results under uniform pricing according to Proposition 1 in Jeitschko *et al.* [2017]. There are two types of equilibrium outcomes in Jeitschko *et al.* [2017]: (i) all consumers purchase from only one of the firms (referred to as Case S (single item)); (ii) at least some consumers purchase from both firms (referred to as Case M (multiple items)).

Figure 1 illustrates the two types of equilibrium outcomes. In Case S where the additional utility v is small, every consumer buys one item only, as in the standard Hotelling duopoly. In Case M where the additional utility v is large, some consumers opt for both items. These consumers are more likely to be located around the center because of lower transportation costs associated with obtaining the second item compared to those located close to the ends. In addition, these consumers achieve the same utility level because the sum of the transportation costs is the same, t.

We discuss the details of the two equilibria. In Case S, the equilibrium prices, profit of each firm, and resulting consumer and total surpluses are the same as in the standard Hotelling model with unit demand. Specifically,

$$p_i^{US} = t, \quad \pi_i^{US} = \frac{t}{2}, \quad CS^{US} = w - \frac{5t}{4}, \quad TS^{US} = w - \frac{t}{4}.$$

In Case M, the equilibrium prices, profit of each firm, and resulting consumer and total surpluses are

$$p_i^{UM} = \begin{cases} v - t & \text{if } 2t \le v, \\ \dfrac{v}{2} & \text{if } v < 2t, \end{cases} \quad \pi_i^{UM} = \begin{cases} v - t & \text{if } 2t \le v, \\ \dfrac{v^2}{4t} & \text{if } v < 2t, \end{cases}$$

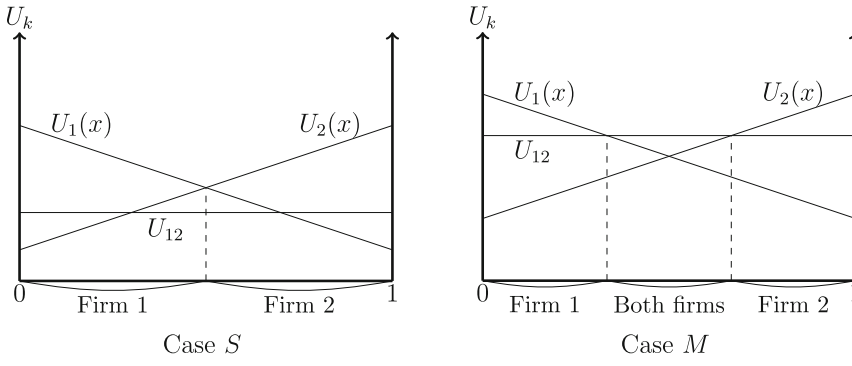

Figure 1
The Two Types of Equilibrium Outcomes Under Uniform Pricing

$$CS^{UM} = \begin{cases} w - v + t & \text{if } 2t \le v, \\ w + \dfrac{v(v-4t)}{4t} & \text{if } v < 2t, \end{cases} \quad TS^{UM} = \begin{cases} w + v - t & \text{if } 2t \le v, \\ w + \dfrac{v(3v-4t)}{4t} & \text{if } v < 2t. \end{cases}$$

The conditions for the equilibria are as follows.

Result 1 *(Proposition 1 in Jeitschko* et al. *[2017]).* If $v \le \sqrt{2}t \equiv v^S \simeq 1.414t$, there is an equilibrium in which every consumer buys one item only, and Case S applies. If $v \ge 2(2\sqrt{2}+1)t/7 \equiv v^M \simeq 1.094t$, there is an equilibrium in which some consumers buy both items, and Case M applies. When $v^M \le v \le v^S$, both types of equilibria are possible, hence both Cases S and M apply.

An increase in v monotonically increases profits and the total surplus but monotonically decreases the consumer surplus in Case M, CS^{UM}. These outcomes imply that firms exert monopoly power if some consumers purchase multiple items.

III(ii). *Personalized Pricing*

We derive the results in which firms can use personalized pricing. We consider two cases regarding whether firm i can sell its product to consumers at x: when firm j sells to those consumers; and when firm j does not sell to those consumers.

First, given that consumers at x purchase from firm j at a positive personalized price, they also buy from firm i if and only if

(2)
$$w + v - t - p_i(x) - p_j(x) \ge w - td_j(x) - p_j(x) \;\Rightarrow\; p_i(x) \le v - t(1 - d_j(x)),$$

where $d_j(x)$ is the distance between firm j and consumers at x.[14] The upper bound of $p_i(x)$ in equation (2) means that firm i fully extracts the additional utility of consumers at x from the second item. The monopolistic price is the key factor when consumers are more likely to purchase both items.

Second, given that firm j cannot attract consumers at x at a nonnegative personalized price and sets $p_j(x) = 0$, firm i's personalized price is acceptable for consumers at x if and only if

(3) $$w - td_i(x) - p_i(x) \ge w - td_j(x) - 0 \;\Rightarrow\; p_i(x) \le t(d_j(x) - d_i(x)).$$

[14] When $v > w$ (the additional utility is larger than the utility from the first item), we also need to consider the condition, $w + v - t - p_i(x) - p_j(x) \ge 0$, which is redundant in the case of $v \le w$. When $v > w$, the equilibrium personalized prices $p_1(x)$ and $p_2(x)$ are indeterminate such that $w + v - t - p_i(x) - p_j(x) = 0$ and all consumers purchase from both firms.

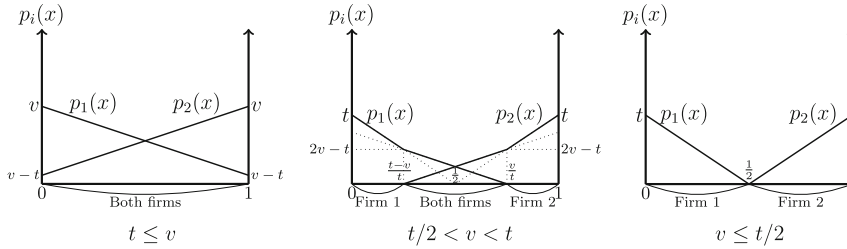

Figure 2
Personalized Prices and Purchasing Decisions Under Different v

The upper bound of $p_i(x)$ in equation (3) is similar to the optimal personalized price in Thisse and Vives [1988] because this price is offered to consumers choosing only one of the items.[15]

From (2) and (3), we obtain the following proposition (see also Figure 2):

Proposition 1. The equilibrium outcome of personalized pricing depends on v and t. If $t \leq v$, all consumers purchase from both firms. If $t/2 < v < t$, consumers on $[0, (t-v)/t]$ purchase from firm 1; consumers on $((t-v)/t, v/t)$ purchase from both firms; and consumers on $[v/t, 1]$ purchase from firm 2. If $v \leq t/2$, all consumers purchase from one of the firms. The personalized prices of firms 1 and 2 are:

$$p_1(x) = \begin{cases} v - tx & \text{if } t \leq v, \\ \begin{cases} \max\{t(1-2x), 0\} & \text{for } x \in [0, (t-v)/t] \\ \max\{v - tx, 0\} & \text{for } x \in [(t-v)/t, 1] \end{cases} & \text{if } t/2 < v < t, \\ \max\{t(1-2x), 0\} & \text{if } v \leq t/2, \end{cases}$$

$$p_2(x) = \begin{cases} v - t(1-x) & \text{if } t \leq v, \\ \begin{cases} \max\{t(2x-1), 0\} & \text{for } x \in [v/t, 1] \\ \max\{v - t(1-x), 0\} & \text{for } x \in [0, v/t] \end{cases} & \text{if } t/2 < v < t, \\ \max\{t(2x-1), 0\} & \text{if } v \leq t/2. \end{cases}$$

Proposition 1 implies that the consumption volume under personalized pricing is always at least as large as that under uniform pricing, and strictly larger if $t/2 < v < 2t$. This is because personalized pricing is useful for offering low prices to consumers with a low willingness to pay.

[15] The pricing policies in (2) and (3) imply that each firm offers personalized prices that depend on whether consumers at point x purchase from the rival.

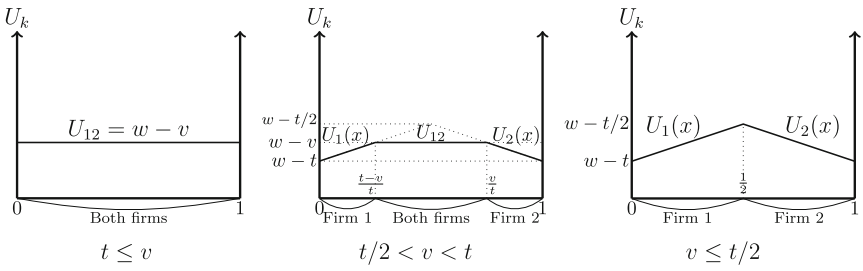

Figure 3
Consumer Utility Levels Under Personalized Pricing

Figure 3 shows that when consumers purchase from both firms, *all these consumers obtain* $w - v$, *which monotonically decreases as* v *increases (for* $v > t/2$*)* because firms completely extract the *additional* utility v from the second item (see (2)). In other words, the option of purchasing multiple items does not benefit consumers when firms use personalized pricing. Additionally, consumers around the ends never achieve higher utility levels than those near the center under personalized pricing, although the opposite is true for uniform pricing (see Figure 1).

Using Proposition 1, we derive the profits, consumer surplus, and total surplus:

Corollary 1. The profit of firm i ($i = 1, 2$), consumer surplus, and total surplus for the three cases in Proposition 1 are:

$$\pi_i^P = \begin{cases} v - \frac{t}{2} & \text{if } t \le v, \\ \frac{t}{2} - \frac{v(t-v)}{t} & \text{if } t/2 < v < t, \\ \frac{t}{4} & \text{if } v \le t/2, \end{cases} \quad CS^P = \begin{cases} w - v & \text{if } t \le v, \\ w + v - t - \frac{v^2}{t} & \text{if } t/2 < v < t, \\ w - \frac{3t}{4} & \text{if } v \le t/2, \end{cases}$$

$$TS^P = CS^P + \pi_1^P + \pi_2^P = \begin{cases} w + v - t & \text{if } t \le v, \\ w - v + \frac{v^2}{t} & \text{if } t/2 < v < t, \\ w - \frac{t}{4} & \text{if } v \le t/2. \end{cases}$$

III(iii). *Comparison of the Two Pricing Policies*

We compare the outcome under personalized pricing with those in the two cases under uniform pricing, Cases S and M. Using the results in Section III(i) and Corollary 1, we plot the profits, consumer surplus, and total surplus for the two pricing policies (see Figure 4).

We first consider the outcome under uniform pricing such that v is small and so Case S applies. The differences between the values under personalized

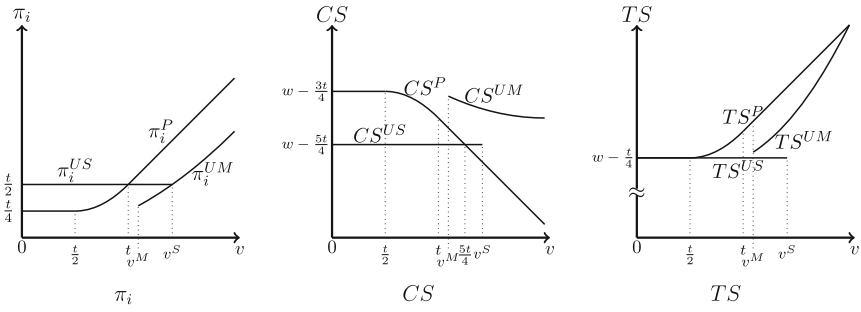

Figure 4
Profits, Consumer Surplus, and Total Surplus Under the Two Pricing Policies

pricing and those under uniform pricing in Case S are as follows:

$$\Delta\pi_i^S = \begin{cases} v-t & \text{if } t \le v \le v^S, \\ -\frac{v(t-v)}{t} & \text{if } t/2 < v < t, \\ -\frac{t}{4} & \text{if } v \le t/2, \end{cases} \quad \Delta CS^S = \begin{cases} \frac{5t}{4}-v & \text{if } t \le v \le v^S, \\ \frac{t}{4}+\frac{v(t-v)}{t} & \text{if } t/2 < v < t, \\ \frac{t}{2} & \text{if } v \le t/2, \end{cases}$$

$$\Delta TS^S = \begin{cases} v-\frac{3t}{4} & \text{if } t \le v \le v^S, \\ \frac{(t-2v)^2}{4t} & \text{if } t/2 < v < t, \\ 0 & \text{if } v \le t/2. \end{cases}$$

We summarize the comparison as Proposition 2 (see also Figure 5).

Proposition 2. When v is small such that all consumers purchase from only one of the firms under uniform pricing ($v \le v^S$), compared with uniform pricing,

- If $v \le t/2$, personalized pricing increases consumer surplus, decreases each firm's profit, and has no impact on total surplus.
- If $t/2 < v \le t$, personalized pricing increases consumer surplus and total surplus, and decreases each firm's profit (has no impact on profits if $v = t$).
- If $t < v < 5t/4$, personalized pricing increases consumer surplus, each firm's profit, and total surplus.
- If $5t/4 \le v \le v^S$, personalized pricing increases each firm's profit and total surplus, but decreases consumer surplus (has no impact on consumer surplus if $v = 5t/4$).

Now consider the outcome in the case of uniform pricing where v is large and so Case M applies. The differences between the values under personalized pricing and those under uniform pricing in Case M are as follows:

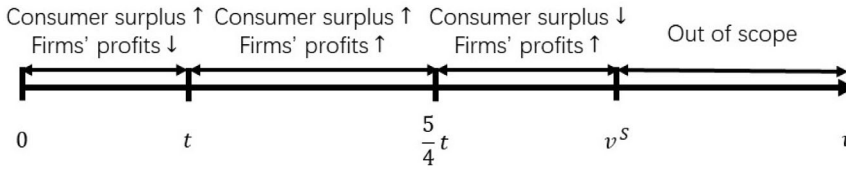

Figure 5
The Changes in Consumer Surplus and Firm Profits (Case *S*)

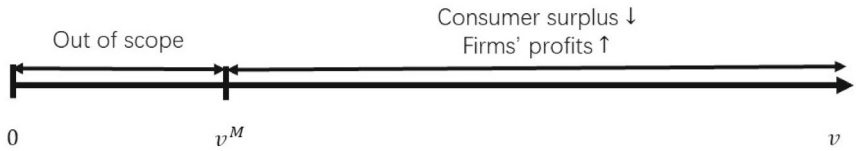

Figure 6
The Changes in Consumer Surplus and Firm Profits (Case *M*)

$$\Delta CS^M = \begin{cases} -t & \text{if } 2t \le v, \\ -\dfrac{v^2}{4t} & \text{if } v^M \le v < 2t, \end{cases} \quad \Delta \pi_i^M = \begin{cases} \dfrac{t}{2} & \text{if } 2t \le v, \\ \dfrac{t}{2} - \dfrac{(2t-v)^2}{4t} & \text{if } v^M \le v < 2t \end{cases}$$

$$\Delta TS^M = \begin{cases} 0 & \text{if } 2t \le v, \\ \dfrac{(2t-v)(3v-2t)}{4t} & \text{if } v^M \le v < 2t. \end{cases}$$

We summarize the comparison (see also Figure 6).

Proposition 3. When v is large such that some consumers purchase from both firms under uniform pricing ($v^M \le v$), compared with uniform pricing,

- If $v^M \le v < 2t$, personalize pricing increases each firm's profit and total surplus, but decreases consumer surplus.
- If $2t \le v$, personalize pricing increases each firm's profit, decreases consumer surplus, and has no impact on total surplus.

The intuition behind Propositions 2 and 3 is as follows. When v is sufficiently small, personalized pricing benefits consumers but harms firms, as in Thisse and Vives [1988]; when v is sufficiently large, the effects reverse because all consumers obtain surplus $w - v$ and each firm effectively exploits their surpluses through personalized pricing ($p_i(x) = v - td_i(x)$). When v is larger than t but close to t, all consumers purchase from both firms under personalized pricing, contrasting with that where all consumers purchase from one of

the firms under uniform pricing (Case S). In addition, all consumers under personalized pricing obtain surplus $w - v$, implying that rent extractions through personalized pricing are moderate. Therefore, when v is larger than t but close to t, personalized pricing improves profits and consumer surplus (see Figure 5).[16]

We compare our results with those in Rhodes and Zhou [2023]. They discuss generalized oligopoly models based on Perloff and Salop [1985] to investigate the effects of personalized pricing on profits and welfare. Each consumer chooses at most one of the firms. When all consumers choose preferred firms, personalized pricing improves consumer welfare but reduces profits, generalizing the result in Thisse and Vives [1988]. This is because competition between the best and second-best firms intensifies, like our case in which the additional utility v is small. However, when some consumers do not purchase, the effects can reverse. The best firm for each consumer gains more market power, as consumers with good alternatives thin out. This scenario relates to ours, where the additional utility is large, allowing firms to offer certain consumers monopoly prices for the second items. In both papers, personalized pricing harms consumer welfare if firms can exert market power over certain consumers. However, the conditions that cause such strong market power differ. Those are instead consumer limited options given high marginal costs in Rhodes and Zhou [2023] and multiple items because of high additional utilities in our paper.

IV. NONUNIFORM CONSUMER DISTRIBUTION

We extend our model by considering some nonuniform distributions of consumers:

$$f(x) = \begin{cases} h + 4(1-h)x & \text{if } 0 \le x \le 1/2, \\ 4 - 3h - 4(1-h)x & \text{if } 1/2 \le x \le 1, \end{cases}$$

where $0 \le h \le 1$ (see Figure 7). If $h = 1$, the consumer distribution is uniform; if $h = 0$, the distribution is triangular.

The results in the extension are qualitatively similar to those in the main model.[17] As in Proposition 2, consider the case where v is small, leading all consumers to purchase one item only under uniform pricing ($v \le v^S(h)$, where $v^S(h)$ is the upper bound of v in this case). $v^S(h)$ is increasing in h because a firm's price reduction, transitioning from Case S to Case M, leads to a smaller

[16] Concretely, under uniform pricing, consumers positioned near the ends of the Hotelling line consistently earn higher utilities than those located near the center (see Figure 1). Therefore, when v is slightly above t, personalized pricing adversely affects consumers near the ends while simultaneously benefiting those near the center. The latter benefits dominate the former losses.

[17] The detail is available upon request.

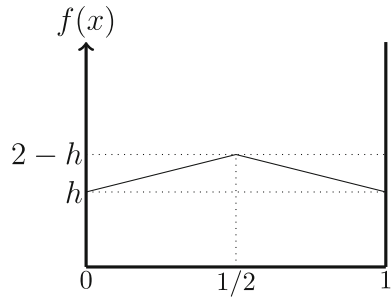

Figure 7
Nonuniform Distribution of Consumers

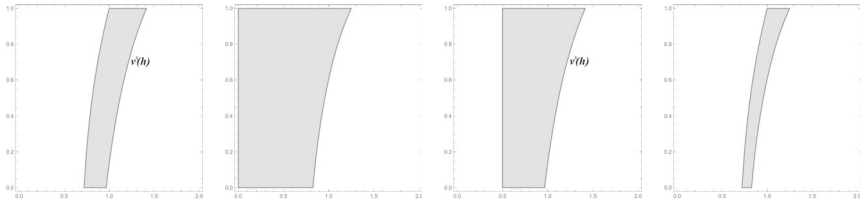

Figure 8
The Parametric Areas in Which Personalized Pricing Increases the Values

demand expansion for this firm as the consumer density around the center becomes lower.

As summarized in Figure 8, in comparison with uniform pricing, personalized pricing results in the following outcomes: each firm's profit increases if v exceeds a threshold value for each h (see "π_i (Case S)"); the consumer surplus increases if v is smaller than a threshold value for each h (see "CS"); and the total surplus increases if $v > t/2$, which is the condition that some consumers purchase from both firms under personalized pricing (see "TS").[18] Moreover, if v falls within an intermediate range for each h, both each firm's profit and the consumer surplus increase (see "π_i and CS").

Also, as in Proposition 3, consider the case where v is large, leading not all but some consumers to purchase from both firms under uniform pricing ($v^M(h) \leq v < (1+h)t/h$, where $v^M(h)$ is the lower bound of v in this case, and

[18] This is because the price schedules under personalized pricing do not depend on the distribution of consumers (see Proposition 1).

$v^M(h) < v^S(h)$). $v^M(h)$ is increasing in h because a firm's price increase, transitioning from Case M to Case S, results in a smaller demand reduction for this firm as the consumer density around the center becomes lower.

When $v^M(h) \leq v < (1+h)t/h$, in comparison with uniform pricing, personalized pricing results in the following outcomes: each firm's profit increases for any v and h; the consumer surplus decreases for any v and h; and the total surplus increases for any v and h.

V. CONCLUSION

This paper studies the impact of competition in personalized pricing when consumers can purchase multiple items. Our formulation complements Jeitschko *et al.* [2017] by considering personalized pricing and Thisse and Vives [1988] by adopting multi-item purchases in the standard Hotelling model.

We obtain the following results. Consumers benefit from personalized pricing only if no consumer purchases from both firms under uniform pricing. Under the necessary condition, consumer surplus improves if the additional intrinsic utility from the second item is smaller than a threshold value. Firms benefit from personalized pricing if at least some consumers purchase from both firms under uniform pricing or if the additional gain from the second item is larger than the unit transportation cost. There is a parameter range such that personalized pricing improves both consumer surplus and profits. These results contrast with the standard results in the competitive personalized pricing literature based on Hotelling models and complement the findings in Jeitschko *et al.* [2017] and Rhodes and Zhou [2023].

There are several possibilities for extending our paper. First, we can consider an n-firm case in a random utility model based on Perloff and Salop [1985]. Second, we can allow consumers to purchase two units from a firm. Third, we can consider a multiproduct duopoly model based on Armstrong and Vickers [2010]. These extensions remain as future research.

APPENDIX

COROLLARY 1

We derive the outcome in Corollary 1.

First, we derive the consumer surplus in the three cases of Proposition 1. When $t \leq v$, all consumers purchase from both firms under $p_1(x) = v - tx$ and $p_2(x) = v - t(1-x)$. The total payments of the consumer at x are:

$$p_1(x) + p_2(x) = 2v - t.$$

The net utility of each consumer is:

$$w + v - t - (2v - t) = w - v (> 0).$$

When $t/2 < v < t$, consumers on $[0, 1 - v/t]$ purchase from firm 1 under $p_1(x) = t(1 - 2x)$, consumers on $(1 - v/t, v/t)$ purchase from both firms under $p_1(x) = v - tx$ and $p_2(x) = v - t(1 - x)$, and consumers on $[v/t, 1]$ purchase from firm 2 under $p_2(x) = t(2x - 1)$. Consumer surplus when $t/2 < v < t$ is:

$$\int_0^{1-v/t} (w - tx - t(1 - 2x))dx + (w - v)(2v/t - 1) + \int_{v/t}^1 (w - t(1 - x) - t(2x - 1))dx.$$

When $v \leq t/2$, consumers on $[0, 1/2]$ purchase from firm 1 under $p_1(x) = t(1 - 2x)$ and consumers on $(1/2, 1]$ purchase from firm 2 under $p_2(x) = t(2x - 1)$. Consumer surplus when $v \leq t/2$ is:

$$\int_0^{1/2} (w - tx - t(1 - 2x))dx + \int_{1/2}^1 (w - t(1 - x) - t(2x - 1))dx.$$

In sum, consumer surplus is:

$$CS^P = \begin{cases} w - v & \text{if } t \leq v, \\ w + v - t - \frac{v^2}{t} & \text{if } t/2 < v < t, \\ w - \frac{3t}{4} & \text{if } v \leq t/2. \end{cases}$$

Second, we derive the profit of each firm in the three cases of Proposition 1. When $t \leq v$, the profit of each firm is:

$$\pi_1^P = \pi_2^P = \int_0^1 (v - tx)dx = v - \frac{t}{2}.$$

When $t/2 < v < t$, the profit of each firm is:

$$\pi_1^P = \pi_2^P = \int_0^{1-v/t} t(1 - 2x)dx + \int_{1-v/t}^{v/t} (v - tx)dx = \frac{t}{2} - \frac{v(t - v)}{t}.$$

When $v \leq t/2$, the profit of each firm is:

$$\pi_1^P = \pi_2^P = \int_0^{1/2} t(1 - 2x)dx = \frac{t}{4}.$$

In sum, the profit of each firm is:

$$\pi_1^P = \pi_2^P = \begin{cases} v - \frac{t}{2} & \text{if } t \leq v, \\ \frac{t}{2} - \frac{v(t-v)}{t} & \text{if } t/2 < v < t, \\ \frac{t}{4} & \text{if } v \leq t/2. \end{cases}$$

Finally, using the outcomes derived earlier, we obtain the total surplus:

$$TS^P = CS^P + \pi_1^P + \pi_2^P = \begin{cases} w + v - t & \text{if } t \leq v, \\ w - v + \frac{v^2}{t} & \text{if } t/2 < v < t, \\ w - \frac{t}{4} & \text{if } v \leq t/2. \end{cases}$$

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