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Consumer data and price discrimination by consideration sets

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ABSTRACT

In a homogeneous product oligopoly with probabilistic consideration, identical retailers compete in prices over two periods. In period two, purchase history data enables price discrimination based on consumers' consideration patterns. Retailers discriminate by conditioning prices on a consumer's period one supplier. Endogenously acquired consumer information is asymmetric across firms. Price discrimination underpins complete market segmentation. Sub-markets differ in market structure and competitive pressure. In unique symmetric sequential equilibrium, retailers fine-tune period two prices in response to competitive pressure and, compared to uniform pricing, charge (on average) higher period one prices and make larger expected profits, associated with lower expected consumer surplus.

1. Introduction

In recent years, a significant expansion of online markets and digital platforms has been accompanied by advances in tracking and computing technology. This has facilitated the collection and use of refined consumer data. When consumers make online purchases, they leave a digital 'trail'. Online retailers use data on consumers' choices and behaviors to increase their revenues through customized products and prices.

One prevalent retail practice that is shaped by increased data availability in online markets is price discrimination. Consumer information has implications for retailers' discriminatory pricing strategies and market outcomes. For example, refined data on consumers' purchase history and consideration sets allows retailers to better target their prices and use more granular forms of discrimination. This calls for a better understanding of how these new opportunities affect strategic interaction, competition, retailers' profits, and consumer surplus.

This paper considers an oligopoly platform where ex-ante identical retailers supply a homogeneous product and compete in prices for a unit mass of consumers over two periods. Consumers consider a retailer's product with some exogenous probability and so there is consideration set heterogeneity. This can be related to limited product awareness, availability, or visibility. The platform collects data on consumers' first period choices and shares it with retailers. Purchase history data provides information on consumers' consideration sets and degree of contestability, enabling price discrimination.

In period two, retailers price discriminate by conditioning prices on a consumer's period one supplier: they discriminate not only between new and past customers but also between different groups of new customers, depending on their past choices. Refined forms of price discrimination, which in digital markets are often inconspicuous, can be implemented in practice through discounts offered to specific consumer groups — see, for instance, AEMC (2018).

This analysis characterizes unique symmetric sequential equilibrium in the price discrimination regime by consideration sets described above, highlights its properties, and assesses equilibrium market outcomes against a uniform pricing benchmark, where retailers do not make use of consumer data and each charges one price to all customers that consider it in both periods. In both regimes, in equilibrium, retailers use mixed pricing strategies in both periods, and these underpin price dispersion and strictly positive expected profits.

Despite ex-ante symmetry, under price discrimination, the interaction between the order of first period (realized) prices and probabilistic consideration creates an asymmetry in retailers' information and so in their ability to discriminate between different consumer groups in period two. A more expensive period one retailer, in period two: (i) faces a smaller past customer group, which provides a more accurate signal of the likelihood that these consumers are captive, and (ii) competes in a larger set of new customer sub-markets, and so can discriminate more granularly.

Under price discrimination, in period two equilibrium, there is a complete segmentation of the market. The resulting segments differ in the share of captive consumers and the number of active competitors, and so in the intensity of competition. The more fragmented a segment is, the lower the average price paid by consumers in that segment, although there consumers who choose the same supplier as in period

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one (past customers) pay on average more than those who switch suppliers (new customers). Consumer data and price discrimination allow retailers to respond to differences in the degree of competitive pressure when targeting groups of customers that differ in their period one suppliers.

Equilibrium comparisons to uniform pricing reveal the following. In period two, the cheapest period one retailer makes the same expected profit, while all other retailers make strictly larger expected profits, and a retailer's incremental profit from price discrimination increases in its period one price. In period one, retailers charge a higher price (on average). In sequential game, each retailer's and the industry's expected profits are larger. As total surplus is determined by the consideration probability, a larger expected profit corresponds to lower expected consumer surplus.

This analysis contributes to the price discrimination literature; see Armstrong (2006) and Stole (2007). It is related to work on discrimination by purchase history; see Chen (2005) and Fudenberg and Villas-Boas (2006). It focuses on a homogeneous product oligopoly with probabilistic consideration where purchase history reveals information on consumers' consideration sets.[1] It identifies a novel segmentation mechanism that allows competitive firms to benefit from consumer information. Since Thisse and Vives (1988), work on competitive targeted pricing stressed its pro-competitive effects. In contrast, this analysis explains how it can relax competition through market separation.

Most work on price discrimination focuses on the role of consumer preferences. One exception is the duopoly analysis in Armstrong and Vickers (2019) where sellers discriminate between captive and contested consumers. With perfect information, captives pay the monopoly price, while contested consumers pay the marginal cost. Compared to uniform pricing, consumers are worse off when sellers are approximately symmetric, but better off when sellers are sufficiently asymmetric.[2] With noisy signals on a consumer's type, price discrimination by segmentation can only boost profit.

This analysis presents qualitatively robust results in a symmetric oligopoly where sellers obtain noisy signals on consumers' captivity and endogenously acquired information is asymmetric. In both analyses, when symmetric firms' captives are pooled together (under uniform pricing), a firm's expected profit equals its captive profit. With noisy segmentation (under discrimination), in Armstrong and Vickers (2019) firms are still guaranteed their captive profit but can make additional profit if any segment is asymmetric; here, as firms' captives are fully separated, competitive segments are inherently asymmetric and so complete segmentation increases firms' profits.

A few recent papers have explored price discrimination based on behavioral characteristics like consumers' naivety or propensity to make strategic or statistical mistakes; see Heidhues and Kőszegi (2017), Johnen (2020), and Heidhues et al. (2023). Closest to the analysis here, Johnen (2020) considers a two period model and highlights an adverse selection mechanism through which endogenously acquired information softens competition and increases firms' profits.

2. Model

In a homogeneous product market, $n \geq 3$ retailers compete in prices over two periods for a unit mass of consumers with unit demands and common valuation $v = 1$. Retailers' marginal costs are normalized to zero. Consumers consider a given retailer with known probability $\alpha \in (0, 1)$, which is stable over time and independent across retailers. In each period, consumers purchase the cheapest product in their consideration set or defer purchase. Consumers are myopic and do not take into account the impact of purchase history on period two prices.

A consumer considers exactly k offers with probability $\alpha^k(1-\alpha)^{n-k}$, which is unique up to the identity of the firms (there are $C(n,k)$ such combinations). Each retailer has $\alpha(1-\alpha)^{n-1}$ captive consumers, and could charge these consumers the monopoly price, $p = 1$. Each retailer also faces contestable consumers. For instance, α^n consumers consider all retailers and, to attract this group, a retailer has to compete aggressively. The tension between the incentive to extract all surplus from captive consumers and the incentive to compete for contestable consumers rules out pure strategy price equilibrium in each period; this analysis characterizes mixed strategy equilibrium.

In period one, retailers compete in uniform prices. After consumers make choices, retailers obtain market-wide purchase history data that enables price discrimination in period two. A retailer can offer different prices to the consumers who consider its product, conditional on their period one supplier. Therefore, retailers can discriminate not only between new and past customers, but also amongst different new customer groups that differ in their purchase history.[3] One interpretation of this model is that competition takes place on a digital platform that collects market-wide purchase history data and makes it available to participating retailers.[4] Taking the information structure as given, the analysis focuses on retailers' price discrimination strategies and on market outcomes.

Unique symmetric sequential equilibrium under a uniform pricing benchmark is presented below. Next section characterizes unique symmetric sequential equilibrium under price discrimination using backward induction.

2.1. Uniform pricing

Under uniform pricing, the two periods are identical and independent. In a given period, there is a unique symmetric mixed strategy price equilibrium where each retailer's expected profit is $\pi^U = \alpha(1-\alpha)^{n-1}$. The equilibrium price distribution function,

$$F^U(p) = \frac{1}{\alpha} - \frac{(1-\alpha)}{\alpha} p^{-\frac{1}{n-1}} \ ,$$

is continuous everywhere on its support $S^U = [(1-\alpha)^{n-1}, 1]$. See Ireland (1993) and McAfee (1994).[5] At any price $p \in S^U$, a retailer's expected profit is

$$\pi^U(p) = p\alpha(1-\alpha F(p))^{n-1} \tag{1}$$

A retailer serves consumers iff: (a) they consider its product, which happens with probability α, and (b) any other considered retailers are more expensive, the probability of which is given by the power term. The term in parenthesis gives the overall probability that the product sold by one of the $n-1$ competitors is either not considered or, if considered, it is more expensive: $\left[1-\alpha+\alpha(1-F^U(p))\right] = (1-\alpha F^U(p))$. The exponent in expression (1) takes into account that there are $n-1$ rivals. Uniqueness follows from Proposition 1 in Armstrong and Vickers (2022); see also Johnen and Ronayne (2021).

As the two periods are identical, next result follows.

[1] Armstrong and Vickers (2022) analyze uniform pricing in markets with heterogeneity in consumers' consideration sets and unify results from Butters (1977), Burdett and Judd (1983), Rosenthal (1980), Varian (1980), Baye et al. (1992) and Ireland (1993), and McAfee (1994).

[2] As consumer surplus is concave in profit, a trade-off between increases in aggregate profit and profit variance across consumer groups (both of which harm consumer surplus) underpins the comparison.

[3] In this setting, consumer myopia can be justified by retailers' increasingly sophisticated pricing strategies, informed by consumer data, which hinder consumers' ability to anticipate future prices.

[4] The information exchange might take other forms or involve data intermediaries; see FTC (2014).

[5] These papers analyze asymmetric models, but their results apply to the symmetric set-up examined here. Each firm has captive consumers and so a guaranteed profit of π^U. A firm would never set a price $p < (1-\alpha)^{n-1}$: at this low level, even if it sold to all the consumers who consider it (a group of measure α), its expected profit would be lower than π^U.

Lemma 1. *Suppose that retailers charge uniform prices in both periods. A firm's expected profit in unique sequential equilibrium is*

$\bar{\pi}^U = 2\alpha(1-\alpha)^{n-1}$

3. Price discrimination

Suppose that in period one retailers choose their prices according to a symmetric cumulative distribution function. This c.d.f. must be atomless: otherwise there would be a positive probability of a tie and a unilateral incentive to deviate to a slightly lower price as that would trigger a jump up in demand. This implies a strict ranking of retailers' realized prices in period one.

$p_1 < p_2 < \cdots < p_n$

The notation reflects this ranking: retailer 1 is cheapest, retailer 2 is second cheapest, and so on.

Given this price profile, all consumers in retailer 1's reach (a group of measure α) buy its product in period one. Retailer 1 cannot infer what competitors these consumers consider, if any. As it cannot refine its pricing strategy, it charges only one price in period two.

Consumers who do not consider retailer 1 but consider retailer 2 - a group of measure $\alpha(1-\alpha)$ - buy from the latter in period one. As consumers who buy from retailer $k \geq 3$ do not consider retailer 2 (they did not buy from it, though it was cheaper), retailer 2 can infer in period two that its new customers bought from retailer 1 in period one, so this group is of measure α^2. Under price discrimination, in period two, retailer 2 can charge two different prices: one to its new customers and another one to its past customers.

Consumers who do not consider retailers in $\{1, 2, \ldots, k-1\} \equiv N_{k-1}$, for $3 \leq k \leq n$, but consider retailer k - a group of measure $\alpha(1-\alpha)^{k-1}$ - buy from the latter in period one. As consumers who buy from retailer $j \geq k+1$ in period one do not consider retailer k (they did not buy from it, though it was cheaper), retailer k can infer in period two that its new customers bought from a retailer in N_{k-1} in period one and so it faces a measure $\alpha[1-(1-\alpha)^{k-1}]$ of new customers in period two.[6] Under price discrimination, in period two, retailer k can charge k different prices conditional on a customer's period one supplier: one price to its past customers and $k-1$ different prices to new customer groups that differ in their purchase history. For any $j \in N_{k-1}$, retailer j's past customers form a distinct group of new customers that retailer k can target. Overall, retailer k can discriminate between $k-1$ such new customer groups.

Some of a retailer's past customers are captive, for $k \leq n-1$. A retailer's past customer group is a (noisy) signal of its captive consumer group. The more expensive a retailer is in period one, the smaller its past customer group, and the more accurate the signal. Retailer n identifies its captive consumers after period one. Despite ex-ante symmetry, access to purchase history data creates an asymmetry in information content in period two. As retailers are equally likely to be considered, the more expensive a retailer is in period one, the larger and more heterogeneous (in terms of purchase history) its new customers are in period two, and the larger the set of differential prices it offers.

Notation. *For $k \in N \equiv \{1, \ldots, n\}$, denote retailer k's past customer segment by $\gamma_k \equiv \alpha(1-\alpha)^{k-1}$. Let $N_k \equiv \{1, 2, \ldots, k\}$ with $N_n = N$. Let $p_0^k = (1-\alpha)^{n-k}$ with $p_0^n = 1$.*

3.1. Second period analysis

Retailer 1 charges one price to all its customers. Retailer 2 price discriminates between new customers (segment γ_1) and past customers (segment γ_2). Retailer $k \geq 3$ charges one price to its past customers (segment γ_k) and $k-1$ different prices to different new customer groups, that is, in each segment γ_j for $j \in N_{k-1}$ formed of consumers who purchased from firm j in period one.

Retailer k, for $k \leq n-1$, sets in segment γ_k a price p drawn from c.d.f. $F_k^k(p)$. Retailer n charges the monopoly price in segment γ_n. Retailer k, for $k \geq 2$, sets in segment γ_j (for $j \in N_{k-1}$) price p drawn from c.d.f. $F_k^j(p)$. So, retailer k sets one price to its past customers and $k-1$ (possibly different) prices to different groups of new customers.

For $k \leq n-1$, retailer k's expected profit in segment γ_k (its past customer group) is given by

$$\pi_k^k(p) = p\alpha(1-\alpha)^{k-1}\Pi_{i=k+1}^{i=n}(1-\alpha F_i^k(p)) = p\gamma_k \Pi_{i=k+1}^{i=n}(1-\alpha F_i^k(p)) \, . \tag{2}$$

Retailer k can retain its past customers only if any retailer $i \in N \setminus N_k$, whose price in this segment is drawn from c.d.f. $F_i^k(p)$, is either not considered or more expensive: in (2), the product gives the overall probability of this.

For $k \geq 2$ and $j \in N_{k-1}$, retailer k's expected profit from new customers in segment γ_j is

$$\pi_k^j(p) = p\alpha\gamma_j(1-F_j^j(p))\Pi_{i=j+1, i\neq k}^{i=n}(1-\alpha F_i^j(p)) \, . \tag{3}$$

Consumers in segment γ_j consider retailer k with probability α and buy from it provided that it is cheaper than: (i) retailer j whose price is a random draw from $F_j^j(p)$, and (ii) all retailers they consider from the set $N \setminus \{N_j \cup \{k\}\}$.

Under price discrimination, retailer k's new customers are effectively divided into $k-1$ mutually exclusive market segments where this retailer sets different prices. The number of retailers that compete for consumers differs across segments.[7] Retailer k operates in these $k-1$ new customer sub-markets and in the sub-market for its past customers. As a result, price discrimination implements a *complete segmentation* of the market. Each segment γ_k for $k \in N$ (i.e., each retailer's past customer group) forms a separate sub-market and overall there are n sub-markets.

Take, for instance, segment γ_k (for $k \leq n-1$). This is a sub-market where the retailers in the set $N \setminus N_{k-1}$ compete and so there are $n-k+1$ active retailers. Consumers consider retailer k for sure, so its *adjusted* consideration probability in this sub-market is $\bar{\alpha} = 1$. The consideration probability of retailer $l \in N \setminus N_k$ is α, as before. By analyzing competition in each separate segment, retailers' expected profits and c.d.f.s for each sub-market are identified.

In each of these sub-markets active retailers set a uniform price. As a result, each sub-market is a scaled-down replica of the asymmetric price competition subgames in Ireland (1993) and McAfee (1994), and their equilibrium existence results can be invoked and adapted; see, for instance, Lemma 2 in McAfee (1994). Uniqueness of sub-market equilibrium follows from Szech (2011). In segment γ_k (for $k \leq n-1$), the configuration of retailers' consideration probabilities is $1 = \alpha_k > \alpha_l = \alpha$ for $\forall l \in N \setminus N_k$. Adjusting for the market size ($\gamma_k < 1$) and the number of competitors ($n-k+1$), for any $k \leq n-1$ and $l \in N \setminus N_k$, c.d.f.s in segment γ_k for $p \in [p_0^k, 1]$ are

$$F_k^k(p) = \alpha F_l^k(p) = 1-(1-\alpha)p^{-\frac{1}{(n-k)}} \, . \tag{4}$$

Then $F_k^k(p_0^k) = \alpha_l F_l^k(p_0^k) = 0$, $F_k^k(1) = \alpha$, and $F_l^k(1) = 1$. Retailer l's c.d.f. F_l^k is continuous everywhere, while retailer k's c.d.f. F_k^k has a mass point $\Phi_k^e = (1-\alpha)$ at the upper bound of its support (that is, at $p = 1$).

Next result characterizes unique sub-market equilibrium in period two.

[6] Retailer k's measure of new customers can also be written as $\sum_{i=1}^{k-1}\alpha^2(1-\alpha)^{i-1}$, where each term in the sum corresponds to the measure of consumers that purchased from the same supplier in period one.

[7] Let $j_1 < j_2 \leq k-1$. Consumers in segment j_1 are targeted by all retailers in the set $M_{j_1} = \{j_1, j_1+1, \ldots, n\}$, while the consumers in segment j_2 are targeted by all retailers in the set $M_{j_2} = \{j_2, j_2+1, \ldots, n\}$, so $\left|M_{j_1}\right| > \left|M_{j_2}\right|$.

Lemma 2. *Consider period two under price discrimination. Take segment γ_k for $k \leq n-1$ where only retailers in the set $N \setminus N_{k-1}$ compete. There exists a unique price equilibrium with the following properties. Retailer k draws its price from c.d.f. $F_k^k(p)$ and retailer l, for $l \in N \setminus N_k$, draws its price from c.d.f. $F_l^k(p)$, with $F_k^k(p) = \alpha F_l^k(p)$. These c.d.f.s are given in (4) and defined on $[p_0^k, 1]$. For $k = n$, retailer n is a monopolist and, in unique equilibrium, it charges $p = 1$ for sure. Retailer k's expected profit from past customers is $\pi_k^k = \gamma_k(1-\alpha)^{n-k} = \alpha(1-\alpha)^{n-1}$. For $k \leq n-1$, retailer l's expected profit from new customers is $\pi_l^k = \gamma_k \alpha(1-\alpha)^{n-k} = \alpha^2(1-\alpha)^{n-1}$.*

In period two, retailer 1 only makes profit from segment γ_1. For $k \geq 2$, retailer k makes profit in all segments γ_j for $j \leq k$; i.e., from past customers and from new customers from across all sub-markets where it operates (i.e., where consumers may consider its product). Lemma 2 and sub-market separation underpin next result; the corollary immediately follows from expression (5).

Proposition 1. *Consider period two under price discrimination. There exists a unique price equilibrium with the following properties. Retailer k charges one price to its past customers and $k-1$ prices to new customers who are divided in $k-1$ sub-markets depending on their past choices. Retailer k competes in segment γ_k and in all segments γ_j for $j \in N_{k-1}$. Price equilibrium in each sub-market is presented in Lemma 2. Retailers' total expected profits are*

$$\pi_k^D = \alpha(1-\alpha)^{n-1}[1+(k-1)\alpha] \text{ for all } k\ . \tag{5}$$

Corollary 1. *Consider period two equilibrium under price discrimination. The kth cheapest period one retailer makes the kth lowest expected profit:*

$$\pi_1^D < \pi_2^D < \cdots < \pi_k^D < \cdots \pi_n^D\ .$$

For an intra-firm comparison of equilibrium price strategies in different market segments, take retailer k for $k \geq 2$. Its price c.d.f. for new customers in segment γ_{j_2} first order stochastically dominates its c.d.f. for new customers in segment γ_{j_1} for $j_1 < j_2 \leq k-1$: $F_k^{j_1}(p) > F_k^{j_2}(p)$. Its price c.d.f. for past customers first order stochastically dominates its c.d.f. for new customers in segment γ_j for $j \leq k-1$: $F_k^k(p) < F_k^j(p)$. The more fragmented a sub-market is, the cheaper an active retailer's expected price for new customers is in that segment. A retailer charges its new customers (on average) less than its past customers.

Consider now an inter-firm comparison focusing on past customer segments. Retailer k's c.d.f. for past customers first order stochastically dominates retailer $k-1$'s c.d.f. for past customers, $F_k^k(p) < F_{k-1}^{k-1}(p)$.[8] The ranking of retailers' average prices for past customers mirrors the ranking of their realized first period prices. A relatively more expensive period one retailer obtains a better signal of its captive consumer group and charges a higher average price in period two.

For an inter-firm comparison of equilibrium pricing in new customer segments, take first a given sub-market γ_{j_1}. By Lemma 2, all retailers competing for new customers in this segment choose in equilibrium prices from symmetric distributions: for $j_1 \leq k_1 < k_2$, $F_{k_1}^{j_1}(p) = F_{k_2}^{j_1}(p)$. So active retailers offer the same average price to new customers in a given segment. Consider now another sub-market γ_{j_2}, where retailers k_1 and k_2 compete for new customers and suppose now that $j_1 < j_2 \leq k_1 < k_2$. Using (4) and comparing the two segments, $F_{k_1}^{j_1}(p) = F_{k_2}^{j_1}(p) > F_{k_1}^{j_2}(p) = F_{k_2}^{j_2}(p)$, so active retailers' equilibrium c.d.f. in segment γ_{j_2} first order stochastically dominates active retailers' equilibrium c.d.f. in segment γ_{j_1}; segment j_1 is more fragmented (see footnote 7) and retailer j_1 competes more aggressively for its past customers (as the share of captives is lower).

Under price discrimination, the only segment where all n retailers compete is γ_1. In this sub-market, retailer 1 is considered for sure, while all other retailers' consideration probability is α. For $k \geq 2$, retailer k's c.d.f. is the same as under uniform pricing ($F_k^1(p) = F^U(p)$), while retailer 1's c.d.f. ($F_1^1(p)$) first order stochastically dominates $F^U(p)$.

Corollary 2. *Consider period two equilibrium under price discrimination. Compared to uniform pricing, retailer 1 obtains the same expected profit, retailer $k \geq 2$ makes strictly larger expected profit, and a more expensive period one retailer obtains a larger incremental profit from price discrimination.*

Expected industry profit and consumer surplus are

$$\pi_{IND}^D = \alpha(1-\alpha)^{n-1} n\,[2+(n-1)\alpha]/2 \text{ and } CS_{IND}^D = 1-(1-\alpha)^n - \pi_{IND}^D\ , \tag{6}$$

with $\lim_{n\to\infty} \pi_{IND}^D = 0$ and $\lim_{n\to\infty} CS_{IND}^D = 1$.

3.2. First period analysis

In period one, retailers' uniform prices are random draws from a symmetric atomless price distribution, $F^D(p)$. In reduced form game, a retailer's expected profit is the sum of its expected profits over the two periods. Expected second period profit depends on the ranking of a retailer's period one price and aggregates all possible outcomes. For instance, at price p, with probability $(1-F^D(p))^{n-k}F^D(p)^{k-1}$, a retailer's offer is the kth cheapest in period one and its period two profit is π_k^D, as given in (5). There are $C(n-1,k-1)$ such combinations, depending on competitors' identity.

At price p, given rivals' c.d.f. $F^D(p)$, a retailer's expected profit is

$$\begin{aligned}\bar{\pi}^D(p) &= p\alpha(1-\alpha F^D(p))^{n-1} + \sum_{k=1}^{n}\Big[\pi_k^D C(n-1,k-1)\left(F^D(p)\right)^{k-1} \\ &\qquad \times (1-F^D(p))^{n-k}\Big] \\ &= p\alpha(1-\alpha F^D(p))^{n-1} + \alpha(1-\alpha)^{n-1}[1+(n-1)\alpha F^D(p)]\ . \end{aligned} \tag{7}$$

Evaluating (7) at $p = 1$, where $F^D(1) = 1$, a retailer's expected profit in equilibrium obtains:

$$\bar{\pi}^D = \alpha(1-\alpha)^{n-1} + \pi_n^D = \alpha(1-\alpha)^{n-1}\,[2+(n-1)\alpha]\ . \tag{8}$$

The c.d.f. $F^D(p)$ is implicitly defined by the constant profit condition $\bar{\pi}^D(p) = \bar{\pi}^D$. Letting $G(p) = (1-\alpha F^D(p))$, this condition gives an expression for p:

$$p = \frac{(n-1)(1-\alpha)^{n-1}G - (1-\alpha)^{n-1}[(n-1)(1-\alpha)-1]}{G^{n-1}} \equiv \Psi(G)\ . \tag{9}$$

For $G \in [(1-\alpha), 1]$ - which corresponds to $F^D \in [0,1]$ - the function $\Psi(G)$ is continuous and differentiable. If $G = 1$ then $\Psi = 1$ and if $G = (1-\alpha)$ then $\Psi = (1-\alpha)^{n-1}[1+(n-1)\alpha] \equiv p_0^D$. Furthermore, for G in this range,

$$\frac{dp}{dG} = -\frac{(n-1)(1-\alpha)^{n-1}[(n-1)\alpha-(n-2)(1-G)]}{G^n} < 0$$

Hence, the constant profit condition $\bar{\pi}^D(p) = \bar{\pi}^D$ implies the existence of a strictly decreasing function $p : [(1-\alpha),1] \to [p_0^D, 1]$ with $p(G) = \Psi(G)$. But then, as $p(G)$ is injective, there exists a well defined inverse function $G(p) = \Psi^{-1}(p)$ with $G : [p_0^D, 1] \to [(1-\alpha), 1]$ and $dG/dp < 0$. This implies the existence of a well-defined c.d.f. $F^D : [p_0^D, 1] \to [0,1]$, where $F^D(p) = (1-G(p))/\alpha$ and $p_0^D = (1-\alpha)^{n-1}[1+(n-1)\alpha]$, with $dF^D/dp > 0$.[9]

[8] For any k, retailer k's price support is contained in retailer $k-1$'s support: they share an upper bound and the lower bounds satisfy $p_0^{k-1} < p_0^k$. Using (4), it is clear that $F_k^k(p) < F_{k-1}^{k-1}(p)$.

[9] For $n = 3$, there is a closed form solution as $(1-\alpha F^D(p)) = [(1-\alpha)^2 + \sqrt{(1-\alpha)^4 + p(1-\alpha)^2(2\alpha-1)}]p^{-1}$; see also De Nijs (2017) for a related triopoly analysis. However, this is not the case for $n \geq 4$.

Proposition 2. *Under price discrimination, there exists a unique symmetric sequential equilibrium where each retailer makes expected profit $\bar{\pi}^D$, given in (8), and in period one randomizes on prices from $[p_0^D, 1]$, using the c.d.f. $F^D(p)$ defined implicitly by the constant profit condition $\bar{\pi}^D(p) = \bar{\pi}^D$, where $\bar{\pi}^D(p)$ is given in (7).*

Next result compares retailers' period one c.d.f.s in symmetric equilibrium under uniform pricing (see Section 2.1) and price discrimination.

Proposition 3. *In symmetric equilibrium, period one price c.d.f.s under uniform pricing and price discrimination satisfy $F^U(p) \geq F^D(p)$, with strict inequality whenever $F^U(p) > 0$ and $p < 1$. The lower bounds of the corresponding price supports satisfy $p_0^U < p_0^D$.*

Under price discrimination, the higher a retailer's period one price, the better the information on its captive consumers it obtains after period one and the larger the number of new customer sub-markets that the retailer can target in period two.

Next result compares retailers' expected profits and expected consumer surplus in symmetric sequential equilibrium in the two regimes.

Proposition 4. *In symmetric equilibrium, a retailer's expected profit is larger under price discrimination than under uniform pricing. Expected consumer surplus is greater under uniform pricing than under price discrimination.*

4. Conclusions

In a homogeneous product market with probabilistic product consideration, price discrimination enabled by granular consumer data underpins a complete segmentation of the market, and leads to larger expected industry profit and lower expected consumer surplus. This analysis suggests that, in markets with heterogeneity in consumers' consideration sets, increased consumer data availability creates scope for policies that raise awareness and improve consumer protection.

Data availability

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

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Appendix

Below, U refers to uniform pricing and D to price discrimination.

A.1. Proof of Corollary 2

A retailer's expected profit in period two equilibrium is given in Section 2.1 for U and in (5) for D. It follows immediately that $\pi^U = \alpha(1-\alpha)^{n-1} < \alpha(1-\alpha)^{n-1}[1+(k-1)\alpha] = \pi^D$.

A.2. Proof of Proposition 3

Period one equilibrium c.d.f.s in U and D are identified in Sections 2.1 and 3.2. Their supports have a common upper bound $p = 1$, and their lower bounds satisfy $p_0^U = (1-\alpha)^{n-1} < (1-\alpha)^{n-1}[(1+(n-1)\alpha)] = p_0^D$. (i) Consider a price $p \in [p_0^U, p_0^D)$. Then, $F^U(p) > 0 = F^D(p)$.

(ii) Consider a price $p \in [p_0^D, 1)$. Define the following real-valued functions with domain $(0,1)$:

$\Omega(F) = p(1-\alpha F)^{n-1} - (1-\alpha)^{n-1}$, $\Omega^U(F) = 0$, and $\Omega^D(F) = (1-\alpha)^{n-1}\alpha(1-F)(n-1)$.

Note that $\Omega^D(F) > \Omega^U(F)$. For $p \in [p_0^U, 1]$, the c.d.f. $F^U(p)$ solves $\Omega(F) = \Omega^U(F)$. For $p \in [p_0^D, 1]$, re-arranging the constant profit condition in Section 3.2, $F^D(p)$ solves $\Omega(F) = \Omega^D(F)$.

- $\Omega(F)$ is strictly decreasing with $\lim_{F\to 0}\Omega(F) = p - (1-\alpha)^{n-1} > (1-\alpha)^{n-1}\alpha(n-1)$ and $\lim_{F\to 1}\Omega(F) = (p-1)(1-\alpha)^{n-1} < 0$. So, $\Omega(F)$ crosses the horizontal line at a value $F \in (0,1)$.
- $\Omega^U(F)$ is constant and when it crosses $\Omega(F)$ then $F = F^U(p)$ obtains.
- $\Omega^D(F)$ is strictly decreasing, with $\lim_{F\to 0}\Omega^D(F) = (1-\alpha)^{n-1}\alpha(n-1) < \lim_{F\to 0}\Omega(F)$ and $\lim_{F\to 1}\Omega^D(F) = 0$. As $\Omega^D(F) > \Omega^U(F)$, $\Omega(F)$ crosses $\Omega^D(F)$ to the left of $F^U(p)$ or, equivalently, $F^U(p) > F^D(p)$.

It then follows that for $p \in [p_0^D, 1)$, $F^U(p) > F^D(p)$.

(iii) Consider $p = 1$. It is easy to check that $F^U(1) = F^D(1)$.

Combining (i)–(iii), the result follows.

A.3. Proof of Proposition 4

Using expected profit expressions in Section 2.1 and expression (8), $\bar{\pi}^U = 2\alpha(1-\alpha)^{n-1} < \alpha(1-\alpha)^{n-1}[2+(n-1)\alpha] = \bar{\pi}^D$. As total surplus is fixed and equal to $1-(1-\alpha)^n$, expected consumer surplus comparison follows.

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