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Pareto price discrimination

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HIGHLIGHTS

- Personalized pricing has increased with consumer data collection.
- Pareto price discrimination utilizes prices ceilings and personalized pricing.
- Pareto price discrimination achieves Pareto efficiency over uniform pricing.

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ABSTRACT

As the collection of consumer data becomes more common, online merchants are better equipped to price discriminate now more than ever before. While standard first-degree price discrimination benefits merchants and harms consumers relative to uniform pricing, I derive an alternative first-degree pricing strategy that achieves efficiency and Pareto improves upon the uniform pricing equilibrium. Furthermore, I show that price ceilings can enforce these Pareto price discrimination strategies, making Pareto price discrimination a viable option for merchants and policy makers.

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1. Introduction

First-degree price discrimination provides a theoretical benchmark where a merchant collects, as revenue, each consumer's willingness to pay for each unit of the product. Practically, however, the ability to price discriminate has been limited by the difficulty in acquiring information on individual consumers. While this information barrier has likely road blocked first-degree price discrimination in the past, many online retailers now use individual data to price discriminate. For example, Amazon has used cookies to implement "dynamic pricing" dating back to the early 2000s, Capital One has offered different interest rates for the same loans depending on the users web browser, and Orbitz posted higher prices to Mac users than to PC users.[1]

While price discrimination is generally allowed, companies caught using price discrimination often face consumer backlash. This backlash should be expected since, even though first-degree price discrimination achieves efficiency, all economic surplus goes to the retailer. However, this detriment to consumers need not occur if perfect price discrimination is constrained. For example, if a merchant offers prices below the equilibrium uniform price to all consumers, then first-degree price discrimination benefits consumers. I call this *Pareto Price Discrimination*, and I find that Pareto price discrimination generates a Pareto improvement over the uniform pricing equilibrium across a variety of demand structures.

On the technological side, Pareto price discrimination is feasible through existing technology developed by Freshplum.[2] Specifically, Freshplum's software allows merchants to offer consumer specific discounts based on geographic location and customer history, or to consumers seen as unlikely to make purchases based on browsing activity.[3] One potential issue with Freshplum's technology is that it incentivizes the merchant to raise its prices. By imposing price ceilings below the equilibrium uniform

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[1] See "On Orbitz, Mac Users Steered to Pricier Hotels", August 23, 2012, Wall Street Journal; "Capital One Made Me Different Loan Offers Depending On Which Browser I Used", November, 1 2010, Consumerist; and "Lawsuit alleges Amazon charges Prime members for free shipping", March 14, 2014, Consumer Affairs.

[2] As further evidence, Shiller (2014) uses a structural model to show that online merchant profit increases by more than 10% when using individual web browsing data.

[3] See "Different Customers, Different Prices, Thanks To Big Data", March 26, 2014, Forbes.

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price, Freshplum's technology allows merchants to Pareto price discriminate.

Price discrimination has received significant attention in the literature. Much of it has focused on third-degree price discrimination.[4] However, some have discussed price constraints similar to price ceilings. Specifically, Armstrong and Vickers (1991) and Aguirre et al. (2010) consider caps on price differences in third-degree price discrimination. Armstrong and Vickers (1991) find that a price constraint on the average price index increases welfare; similarly, Aguirre et al. (2010) find that welfare is typically concave with respect to the third-degree price difference so that a cap on this difference increases welfare.[5]

One paper that overlaps with Pareto price discrimination is Bergemann et al. (2015). They consider how a monopolist's ability to segment the market, using consumer information beyond the prior distribution, impacts obtainable welfare allocations.[6] Of their Pareto efficient allocations, Pareto price discrimination generates the allocations that Pareto improve upon the uniform pricing equilibrium. Given that these Pareto pricing strategies can be easily regulated with a price ceiling, this welfare result highlights how Pareto price discrimination offers a novel strategy for merchants and policy makers to achieve Pareto efficiency.[7]

2. The model

Consider a market with a unit mass of consumers who are interested in a product offered by a merchant. Consumer values, $v \in (v_L, v_H)$, are drawn from distribution $F(\cdot)$ that is twice continuously differentiable and covers the full support. The merchant has production costs $c(q) > 0$, where $c'(q) > 0$ and $c'(q)$ is monotone.

With a uniform price, demand is given by $q = 1 - F(p)$ and inverse demand is $p = F^{-1}(1-q) \equiv p(q)$, where $\frac{\partial p}{\partial q} \leq 0$ since $F(\cdot)$ is increasing. Merchant profits are given by:

$$\Pi = p(q) \cdot q - c(q). \tag{1}$$

Suppose that profit is sufficiently concave in q, $p''(q^*)q^* + 2p'(q^*) - c''(q^*) < 0$, so that maximization generates a unique solution. Solving the uniform pricing problem implies:

Lemma 1. *With a uniform price, the merchant has a unique equilibrium given by q^* and $p^* = p(q^*)$.*

Lemma proofs are provided in an online appendix.

Notice that the market reaches the efficient outcome when $p(q) = c'(q)$. Let q^E be implicitly defined by $p(q^E) = c'(q^E)$ and let $p^E = p(q^E)$. Then,

Lemma 2. *The equilibrium uniform price is greater than the efficient price: $p^* > p^E$.*

This captures the classic result: a monopolist uses its market power to earn markups which reduces sales and creates an inefficiency.

Now suppose that the merchant has the technology to first-degree price discriminate. The merchant might not use this technology in fear of backlash from consumers or policy makers. To alleviate concerns, the merchant can self-impose a price ceiling while revealing the price discrimination technologies. Consider the following pricing strategy:

Definition 1. A price discrimination path, $\mathcal{P}(q)$, is a *Pareto Price Discrimination Path* if

(i) $\mathcal{P}(q) < p^*$ for all $q \in (0, q^E)$,
(ii) $\mathcal{P}(q) \leq p(q)$ for all $q \in (0, q^E)$ with $\mathcal{P}(q^E) = p^E$, and
(iii) $\Pi(\mathcal{P}(q)) > \Pi^*$.

A Pareto Price Discrimination Path (PPDP) achieves the efficient outcome, generates merchant profit greater than with uniform pricing, and requires that every consumer specific price be less than (i) the equilibrium uniform price and (ii) each consumer's willingness to pay. If a price path exists, then it Pareto improves upon the uniform pricing equilibrium. However, note that a PPDP might not exist since a price path that satisfies conditions (i) and (ii) might not satisfy (iii). Fortunately, there exists a continuum of PPDP:

Proposition 1. *Let $\mathcal{P}(q) = \overline{p}$ for $q \in (0, q(\overline{p}))$ and $\mathcal{P}(q) = p(q)$ for $q \in [q(\overline{p}), q^E]$, then there exists a $p_* < p^*$ so that $\mathcal{P}(q)$ is a PPDP if and only if $\overline{p} \in (p_*, p^*)$.*

Proof. First, $\mathcal{P}(q)$ satisfies conditions (i) and (ii) of Definition 1. For condition (iii), note that the difference in profit between a PPDP and a uniform price is given by

$$\Delta(\overline{p}) = -(p^* - \overline{p}) \cdot q^* + \int_{q^*}^{q(\overline{p})} \left(\overline{p} - c'(q)\right) dq + \int_{q(\overline{p})}^{q^E} \left(p(q) - c'(q)\right) dq.$$

Note that $\Delta(p^*) > 0$, since the first two terms are zero and the third term is positive in this case, and $\Delta(0) < 0$, since all three terms are negative in this case. In addition,

$$\frac{\partial \Delta}{\partial \overline{p}} = q^* + \left(\overline{p} - c'(q(\overline{p}))\right) \cdot q'(\overline{p}) + \int_{q^*}^{q(\overline{p})} dq - \left(\overline{p} - c'(q(\overline{p}))\right) \cdot q'(\overline{p})$$
$$= q(\overline{p}),$$

so that $\frac{\partial \Delta}{\partial \overline{p}} = q(\overline{p}) > 0$ for all $\overline{p} \in [0, p^*]$. This implies that there exists a $p_* \in (0, p^*)$ where $\Delta(p_*) = 0$, $\Delta(\overline{p}) < 0$ for $\overline{p} \in (0, p_*)$, and $\Delta(\overline{p}) > 0$ for $\overline{p} \in (p_*, p^*)$. □

While this result is clearly important for policy makers, it has implications for merchants as well. More specifically, a merchant can implement a PPDP without receiving consumer backlash or requiring policy intervention by revealing information so that the unobserved uniform price can be determined. While merchants are typically hesitant to disclose private information, this setting provides a situation where merchants could have an incentive to reveal.

[4] Schmalensee (1981), Varian (1985), Schwartz (1990), Cowan (2007), and Aguirre et al. (2010) consider the welfare effects from third-degree price discrimination. Others analyze important consumer asymmetries; for example, Chen and Schwartz (2015) examine asymmetric costs to serve different markets and Heidhues and Kőszegi (2017) investigate consumer naïveté-based discrimination.

[5] Malueg and Schwartz (1994) consider third-degree price discrimination in international trade where a firm charges different prices across countries when parallel (unauthorized) imports exist. They toy with the implications of a price ceiling at the uniform price and discuss how sales would increase while avoiding misallocation in this case. While their setting and welfare effects are quite different, their idea coincides with Pareto price discrimination.

[6] For example, with no information beyond the prior distribution, there is no segmentation and the uniform price occurs. At the other extreme, full information corresponds to perfect segmentation and first-degree price discrimination. Finally, partial information results in partial segmentation and third-degree price discrimination.

[7] A few other papers have also considered the impact of personalized pricing; however, the models involve competitive firms. Specifically, Choe et al. (2017) and Chen et al. (2019) show that competing firms who perfectly price discriminate to a subset of consumers, either previous consumers or naive consumers, do worse than in the uniform pricing equilibrium while consumers do better.

3. Concluding remarks

A merchant's ability to price discriminate in the first-degree has always been a concern for consumers. This is unfortunate from a welfare perspective because first-degree price discrimination achieves efficiency. Fortunately, any merchant with the technology to first-degree price discriminate is also able to Pareto price discriminate so that a Pareto improvement is achieved. Thus, first-degree price discrimination should not necessarily come as an alarm to consumers who benefit from Pareto price discrimination practices.

Appendix A. Lemma proofs

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econlet.2019.108559.

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