Personalized Pricing and Competition

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Introduction

- Unprecedented amounts of consumer data being collected and exchanged
- Evermore sophisticated AI technologies available to analyze it and:
  - Infer things about consumers e.g., willingness-to-pay for different products
  - Offer consumers personalized prices, products, recommendations etc.

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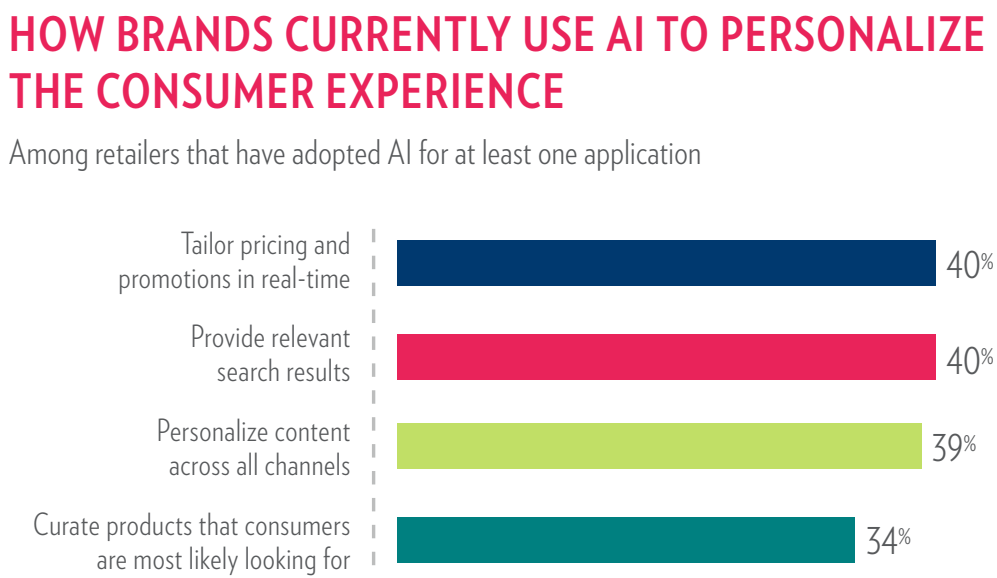

Deloitte (2018): "Consumer Experience in the Retail Renaissance"

Personalized pricing

- Our paper studies personalized pricing (first-degree price discrimination)
  - Charging different consumers different prices, based on willingness-to-pay

"The increased availability of behavioral data has also encouraged a shift from third-degree price discrimination based on broad demographic categories towards personalized pricing." (Council of Economic Advisers, 2015)

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"The increased availability of behavioral data has also encouraged a shift from third-degree price discrimination based on broad demographic categories towards personalized pricing." (Council of Economic Advisers, 2015)

- Goal is to understand:
  - How personalized pricing affects firm profit and consumer surplus
    - In both the short run and the long run (via changes in market structure)
  - Policy implications if only some firms are able to personalize prices

Is personalized pricing already happening?

- Plenty of anecdotal evidence that personalized pricing occurs
- According to a report by the OECD (2018):
  - Staples, Home Depot, and Rosetta Stone personalized prices based on location, income, and browsing history
  - Uber has even been accused of conditioning fares on battery level!

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- However much more limited formal evidence of it happening (so far):
  - May be hard to detect for some products that are already personalized e.g., certain financial products (FCA, 2019)
  - Firms may artificially make personalized prices harder to detect, via personalized discounts or "sticky targeted pricing" (Shiller, 2021)

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  - Firms may personalize prices indirectly via steering (Hannak et al, 2014)

Is personalized pricing already happening?

- A classic example: Orbitz showed Mac users more expensive hotels

TECHNOLOGY

On Orbitz, Mac Users Steered to Pricier Hotels

By Dana Mattioli

Updated Aug. 23, 2012 6 07 p.m. ET

Orbitz Worldwide Inc. has found that people who use Apple Inc.'s AAPL **1.10%** ▲ Mac computers spend as much as 30% more a night on hotels, so the online travel agency is starting to show them different, and sometimes costlier, travel options than Windows visitors see.

Article from The Wall Street Journal

Some related literature

- **Price discrimination**

  Varian (1989), Armstrong (2007), Stole (2007), etc.

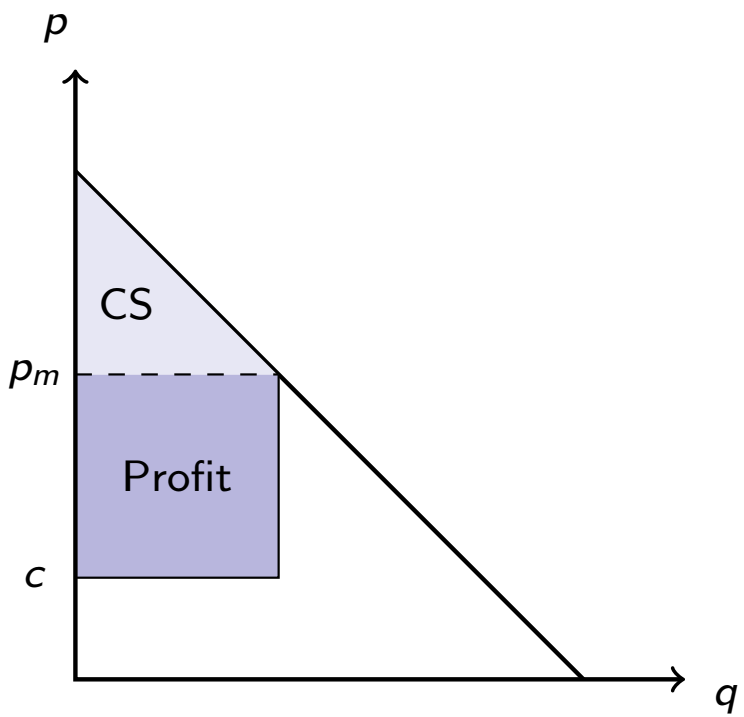
- **Personalized pricing**

  Thisse and Vives (1988), Shaffer and Zhang (2002), Chen and Iyer (2002), Anderson, Baik and Larson (2019), Montes, Sand-Zantman and Valletti (2019), Ali, Lewis and Vasserman (2020), Ichihashi (2020), Chen, Choe and Matsushima (2021), Jullien, Reisinger and Rey (2022), etc.

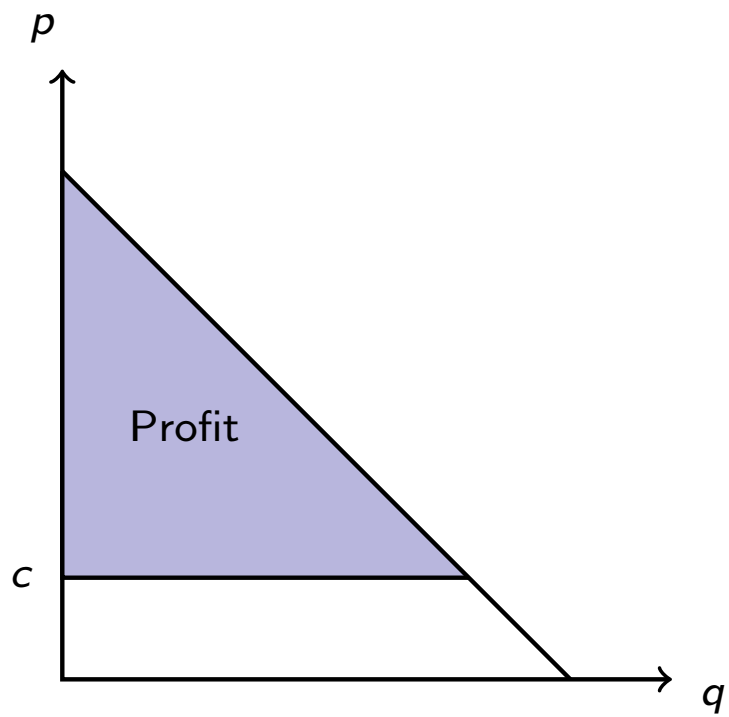
Outline

What is known about the impact of personalized pricing?

- In the textbook monopoly case, personalized pricing increases total welfare but redistributes surplus from consumers to the firm



Uniform pricing



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- Personalized prices are

$$p_0(x) = c + \max\{v_0(x) - v_1(x), 0\}$$

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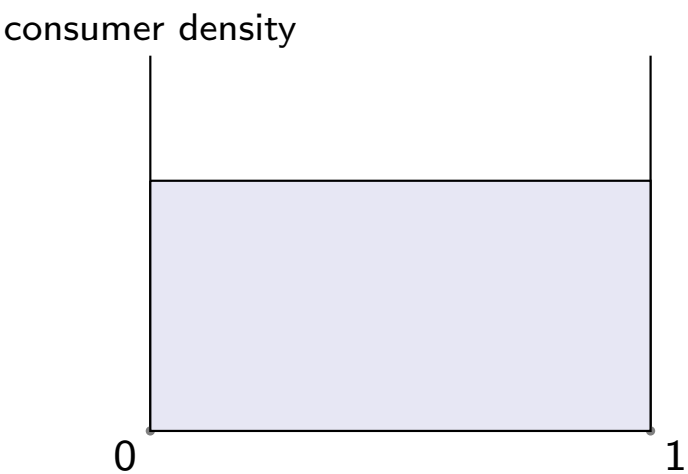

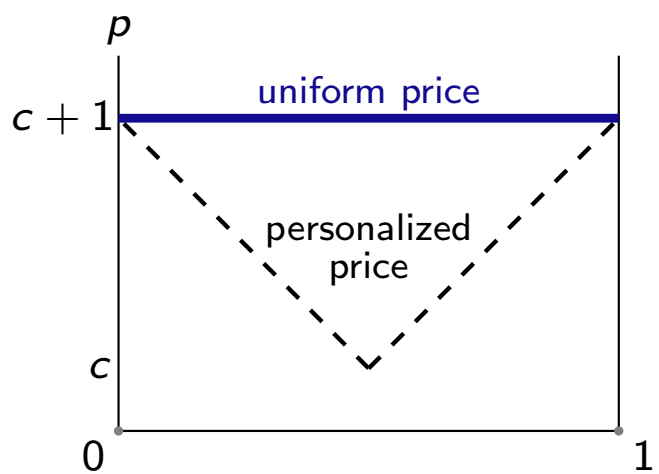

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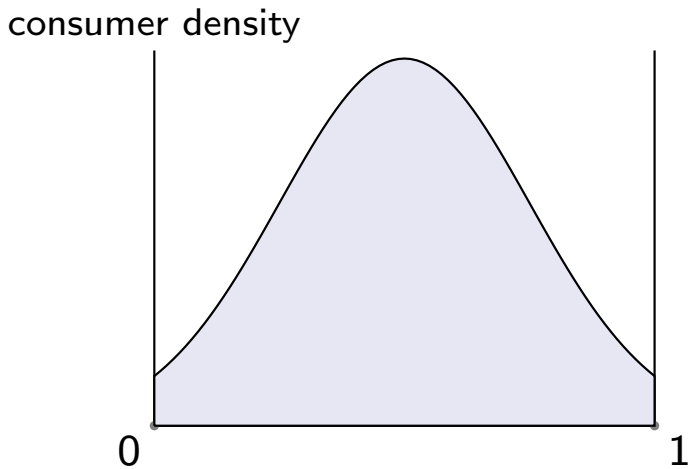

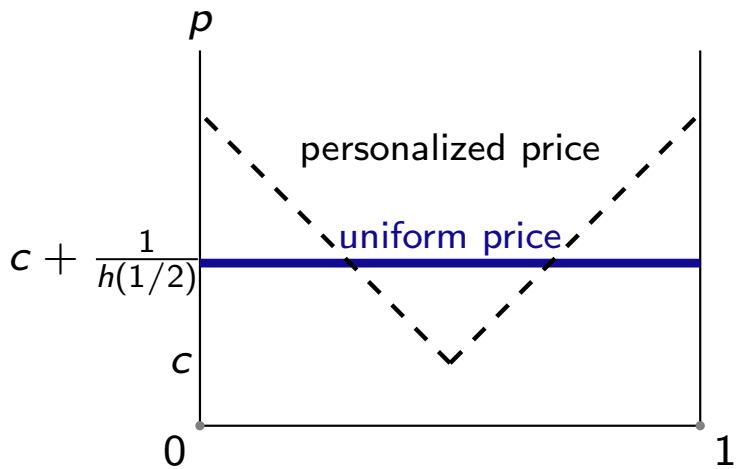

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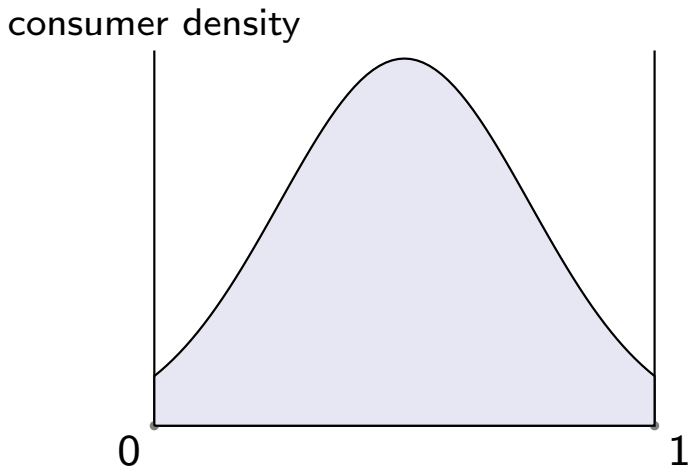

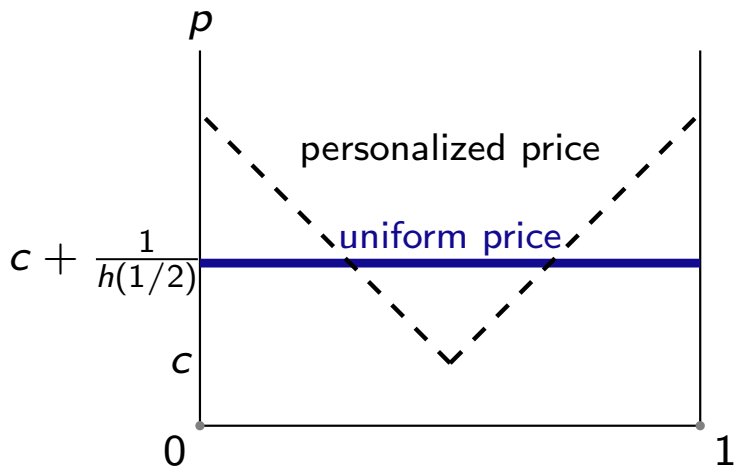

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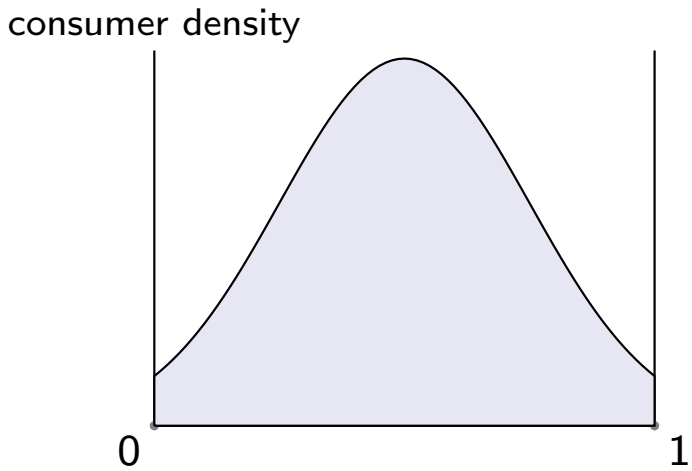

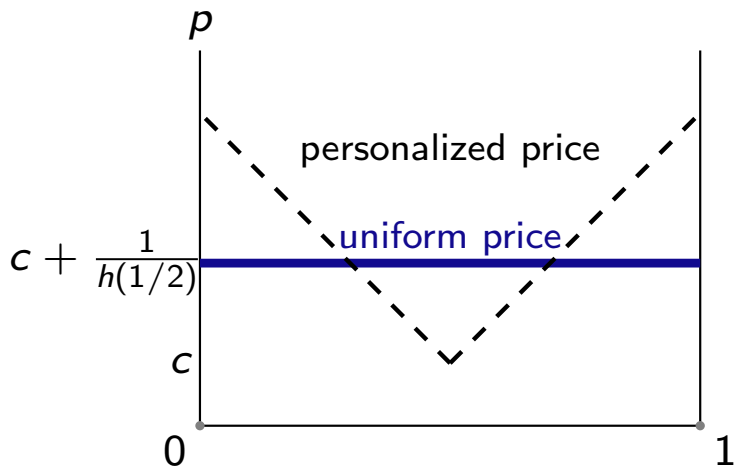

- Of course depending on $h(x)$ total consumer surplus can still go up
- Our paper: investigate using a more general demand model

Outline

Model

- n firms, each supplying a differentiated product at marginal cost c
- A unit mass of consumers, each wishing to buy at most one product
  - $\boldsymbol{v} = (v_1, ..., v_n) \in [\underline{v}, \overline{v}]^n$ is a consumer's valuations for the n products
  - $\boldsymbol{v}$ is distributed according to a *symmetric* joint cdf $\tilde{F}(\boldsymbol{v})$
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- Two pricing regimes:
  1. Uniform pricing: each firm offers the same price to all consumers
  2. Personalized pricing: firms observe each consumer's $\boldsymbol{v} = (v_1, ..., v_n)$, and offer personalized prices accordingly
- Timing: firms set prices simultaneously, then consumers choose

Preliminaries

- Introduce the following notation: $x_z \equiv v_i - \max_{j \neq i}\{z, v_j\}$
- Let $H_z(x)$ and $h_z(x)$ be respectively its cdf and pdf

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Assumption 1

$1 - H_z(x)$ is logconcave in x, and $[1 - H_z(0)]/h_z(0)$ is non-increasing in z

- Satisfied, e.g., in the IID case when each v_i has a logconcave density

Uniform pricing

- Focus on symmetric pricing equilibrium with uniform price p
- If firm i charges p_i its demand is

$$Pr[v_i - p_i > \max_{j \neq i}\{0, v_j - p\}]$$

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Lemma 1

There exists a threshold $\tilde{c}$ such that, under uniform pricing, the market is fully covered if and only if $c \leq \tilde{c}$.

Personalized pricing

- For each consumer, firms engage in asymmetric Bertrand competition
- Focus on the "usual" equilibrium in which:

$$p(v_i, \boldsymbol{v}_{-i}) = \begin{cases} c + \underbrace{v_i - \max\limits_{j \neq i}\{c, v_j\}}_{x_c} & \text{if } v_i \geq \max_{j \neq i}\{c, v_j\} \\ c & \text{otherwise} \end{cases}$$

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- Note: under personalized pricing, the market is fully covered iff $c \leq \underline{v}$
- Unlike Thisse and Vives, under mild conditions, compared to uniform pricing, consumers with high x_c pay more while those with low x_c pay less

Comparison under full market coverage

Proposition 1 (Full market coverage)

Suppose $c \leq \tilde{c}$ and $n \geq 2$. Personalized pricing harms firms and benefits consumers, but has no impact on total welfare.

- Generalizes aggregate surplus result from Thisse and Vives (1988)
- Proof exploits logconcavity of $1 - H_z(x)$ DETAILS

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- Proof exploits logconcavity of $1 - H_z(x)$ DETAILS
- Intuition: given logconcavity, relatively more consumers gain than lose

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- Now suppose $c > \tilde{c}$ s.t. $p > \underline{v}$ i.e., partial coverage with uniform pricing

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In the IID exponential case, personalized pricing:

- Has no impact on profit or consumer surplus under full market coverage

- Benefits firms and harms consumers under partial market coverage

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Proposition 2

In the IID exponential case, personalized pricing:

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Proposition 3

Suppose $f(\overline{v}) > 0$ or valuations are IID and $f(v)$ is log-concave.

There exists a $\hat{c} < \overline{v}$ such that when $c > \hat{c}$ personalized pricing benefits firms and harms consumers

- Intuition: when c is high each firm is (almost) like a monopolist

Comparison under partial market coverage

- Suggests a possible cutoff result for (non-exponential) distributions

Comparison under partial market coverage

- Suggests a possible cutoff result for (non-exponential) distributions
- Analytical result for Generalized Pareto Distribution duopoly case

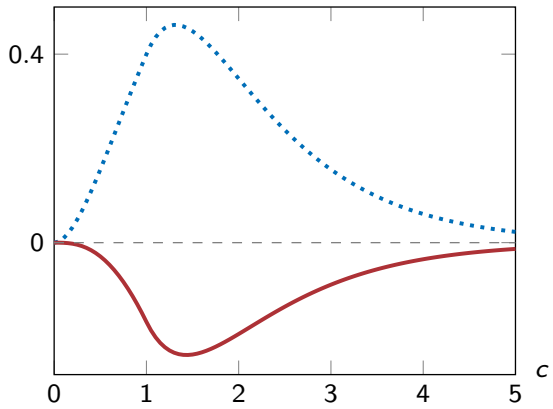
Proposition 4

Suppose $n = 2$ and valuations are drawn IID on the support $[\underline{v}, \underline{v} + \frac{1}{a}]$ using $F(v) = 1 - [1 - a(v - \underline{v})]^{\frac{1}{a}}$, where $a \in (0, 1]$.

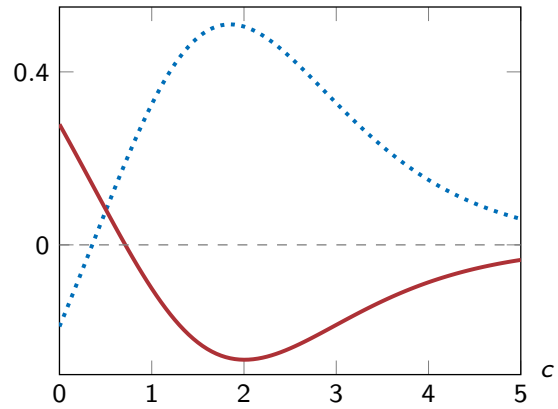
There exist c_π and $c_v > c_\pi$ such that personalized pricing raises profit if and only if $c > c_\pi$, and lowers consumer surplus if and only if $c > c_v$

Impact of the production cost

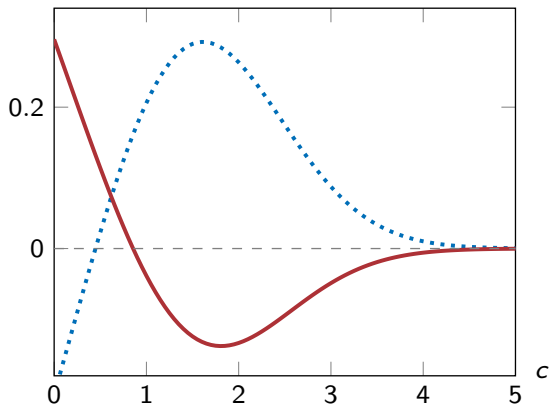
- Personalized pricing amplifies the existing degree of market competition



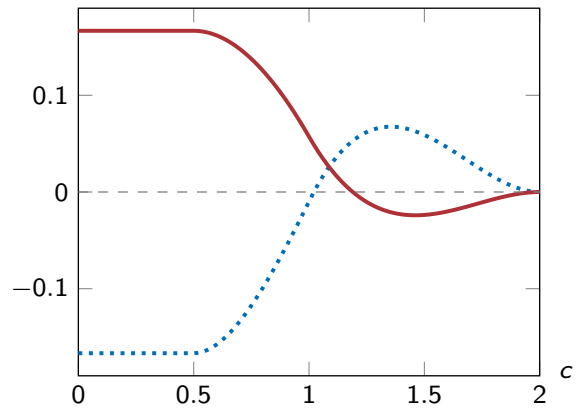
Exponential



Extreme value



Normal



Uniform

The impact of personalized pricing on industry profit and consumer surplus (fixing n)

Impact of the number of firms

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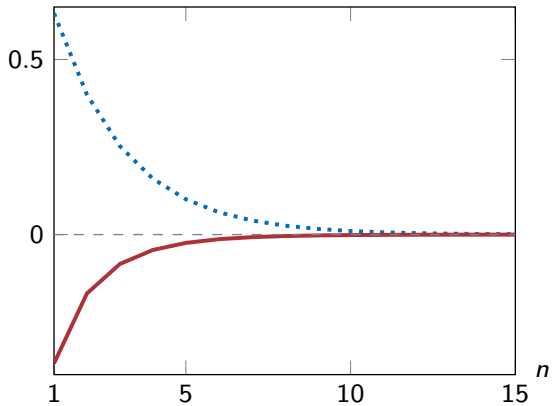

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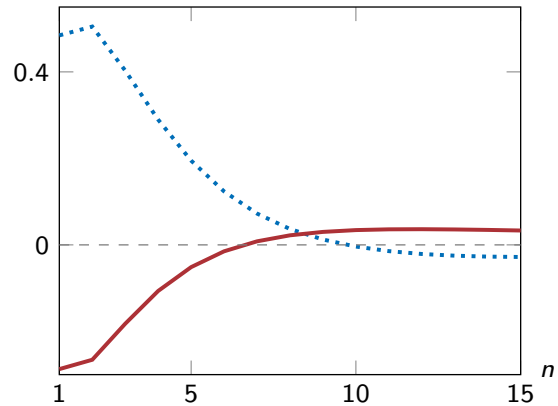

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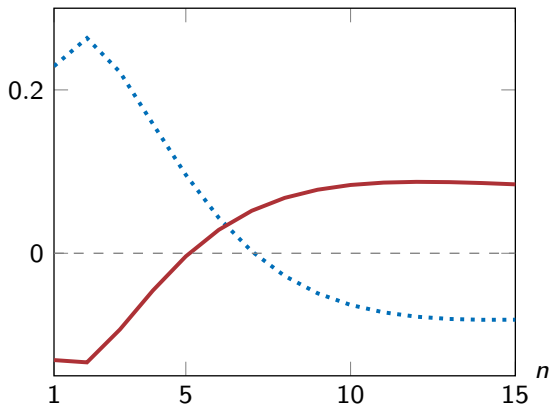

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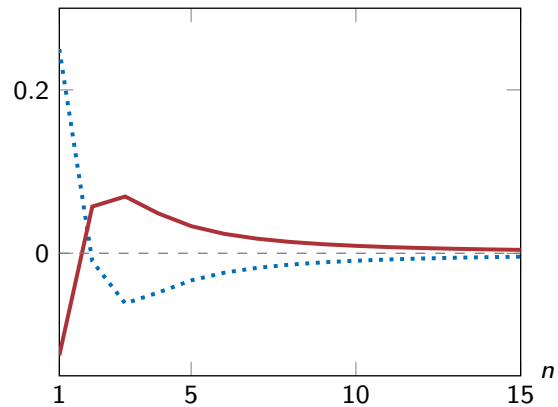

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The impact of personalized pricing on industry profit and consumer surplus (fixing c)

Outline

The long-run impact of personalized pricing

- By changing profit, personalized pricing could also affect market structure

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  - Firms choose whether or not to enter at cost $\kappa > 0$
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Lemma 2 (Personalized Pricing)

Suppose entry of a new firm does not affect valuations for old products.

Then the free-entry outcome under personalized pricing is socially optimal

- Intuition: recall that $x_c = v_n - \max_{j<n}\{c, v_j\}$
  - If $x_c \leq 0$ no social gain from entry and no (variable) profit for firm n
  - But if $x_c > 0$ social gain from entry is x_c and firm n expropriates all of it

The long-run impact of personalized pricing

Proposition 5

Absent integer constraints, personalized pricing benefits consumers in the long run

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- If consumers lose in the short run, they gain in the long run due to entry
- If consumers gain in the short run, any firm exit does not overturn this

Conclusion

- We study the impact of (competitive) personalized pricing
- In the short run, its welfare effect hinges on the extent of market coverage
- In the long run, it tends to induce the socially optimal market structure
- Extensions:
  - Asymmetrically informed firms
  - Alternative information structure

Thank you!

Proof of Proposition 1

- Note that $H_c(x) = H_p(x)$ because full market coverage implies $c < p \leq \underline{v}$
- Therefore using logconcavity in Assumption 1 we can write

$$\underbrace{\int_0^\infty [1 - H_c(x)]dx}_{\text{“personalized” profit}} = \int_0^\infty \frac{1 - H_c(x)}{h_c(x)} dH_c(x)$$

$$\leq \frac{[1 - H_c(0)]^2}{h_c(0)}$$

$$= \underbrace{\frac{[1 - H_p(0)]^2}{h_p(0)}}_{\text{“uniform” profit}}$$

Back