Voluntary Disclosure and Personalized Pricing

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The world is awash in consumer data. Firms use this to:

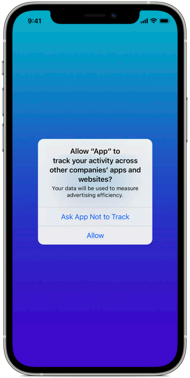
- Assess consumer willingness to pay
- Target particular consumers for marketing campaigns
- Offer discounts (i.e. personalized pricing)

data ecosystem

"Privacy is not the opposite of sharing—rather, it is control over sharing."

– Acquisti, Taylor, and Wagman (2016, JEL)

Given concerns that firms use data to price discriminate, existing policies emphasize consumer control of their data.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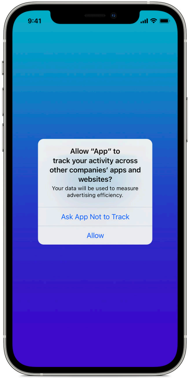
Allow "App" to track your activity across other companies' apps and websites?
Your data will be used to measure advertising efficiency.
Ask App Not to Track
Allow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THE

alternative data ecosystem

I control my data, send a verifiable message to firm

Firm responds with a personalized offer

Generate Data

amazon facebook Google VISA

We study what happens if consumers perfectly control data, and can verifiably disclose evidence about their preferences in monopolistic and competitive markets.

Can consumers benefit from personalized pricing?

Can data be used to improve market efficiency without the additional surplus all going to data owners, brokers and firms?

the motivating concern

Firms draw inferences based both on what is disclosed and what is not.

Classical intuition: Verifiable disclosure $\Rightarrow$ unraveling.

If the market unravels and consumers have no private information, firms can perfectly price discriminate $\Rightarrow$ no consumer surplus.

what we do

Paper considers two kinds of evidence: **simple** and **rich**.

Simple evidence: reveal type perfectly or say nothing at all.

- Speak the whole truth and nothing but the truth.
- Stylized example of track / do-not-track dichotomy.

Rich evidence: partially disclose evidence about one's type.

- Speak ~~the whole truth and~~ nothing but the truth.
- Models partial disclosure possibilities.

what we find

Our results:

- Simple evidence is ineffectual in monopolistic markets, but rich evidence can benefit consumers.
- Both simple and rich evidence help consumers in competitive markets with differentiated products.

Whether these markets work well for consumers depends both on the kinds of disclosures that are permissible and equilibrium selection.

$\Rightarrow$ role for market designers.

classical pricing problem

A single consumer ("she") has unit demand, and value v for a product.

Interacts with a monopolist who incurs no cost of production.

As example: Nature draws v from $[0, 1]$, uniformly.

Consumer observes v, firm does not.

classical benchmark

Consumer purchases product at price p only if $v > p$.

Therefore, "quantity" sold at price p is $Q(p) = 1 - p$.

$$\max_{p \in [0,1]} pQ(p) \Rightarrow p^* = 1/2.$$

Interim consumer surplus is $U^{ND}(v) \equiv \max\left\{v - \frac{1}{2}, 0\right\}$.

Static Monopolist Problem + Verifiable Disclosure.

timeline

Consumer observes valuation v.

Sends message $m \in M(v)$: $M(v)$ is set of messages available for type v.

Monopolist observes message m and sets a price $p(m)$.

Consumer chooses whether to buy product.

Neither party can commit: Perfect Bayesian Equilibria.

Simple evidence: $M(v) = M^S(v) \equiv \Big\{\{v\}, [0,1]\Big\}$.

- Fully revealing: Message $\{v\}$ can be sent only by type v.
- Fully concealing: Message $[0,1]$ can be sent by any type.
- Captures idea that consumer can "certify" her type.
- Stylized model for track / do-not-track dichotomy.
- Speak the whole truth and nothing but the truth.

Rich evidence: $M(v) = M^R(v) \equiv \Big\{[a,b] \subseteq [0,1] : a \leqslant v \leqslant b\Big\}$.

- Enables partial disclosure: any interval that contains true type.
- Geometry embodies an idea: if type v and v' have evidence in common, so does any intermediate type.
- Speak nothing but the truth.

Claim. For both evidence structures, $\exists$ a fully separating equilibrium where every type reveals itself.

Proof: For every message m, firm believes m is sent by highest type that can send that message. (On and off-path)

$\implies$ firm charges price equal to that valuation.

On path: Every type reveals itself and obtains payoff of 0.

Deviation: Payoff still is 0: every other feasible message induces a weakly higher price.

Neither consumer nor firm has incentive to deviate.

Claim. For both evidence structures, $\exists$ a fully pooling equilibrium where no type reveals itself.

Proof: Every type sends message $[0, 1]$.

After message $[0, 1]$, monopolist charges $\frac{1}{2}$.

For any other message, monopolist believes message is sent by highest type that could send it.

Consumer has no incentive to deviate.

But in this equilibrium, verifiable disclosure does not help the consumer.

can one do better?

simple evidence: no

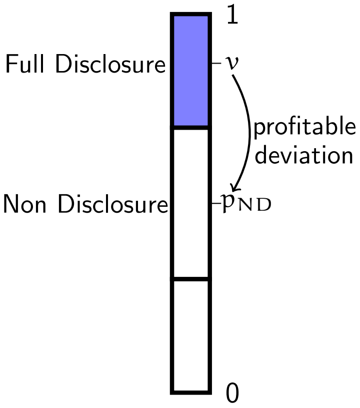
Claim. With simple evidence, for every equilibrium, and for every v, the interim consumer surplus is no more than $\max\left\{v-\frac{1}{2}, 0\right\}$, which is its payoff with no-personalized-pricing.

Proof: Consider an equilibrium. Let p_{ND} be equilibrium price charged after the message $[0,1]$. Will graphically illustrate two observations.

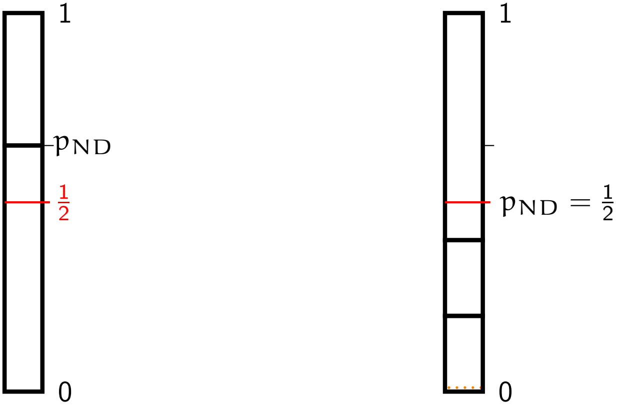
A. High types conceal: $v > p_{\mathrm{ND}} \Rightarrow v$ conceals.

B. Optimal non-disclosure price always exceeds $\frac{1}{2}$.

$$v > p_{\mathrm{ND}} \Rightarrow m^*(v) = [0,1]$$



$p_{\text{ND}} \geqslant 1/2$



simple evidence: no

Simple evidence does not benefit any consumer type in any equilibrium.

Idea generalizes: holds across distributions and for general type spaces ($t \in T$, $v : T \to \mathfrak{R}$).

can one do better?

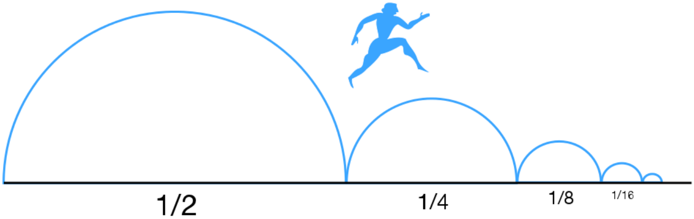
rich evidence: yes

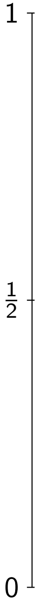
With rich evidence, consumers can do strictly better in some equilibria.

We identify a “greedy algorithm” that is an interim Pareto improvement:

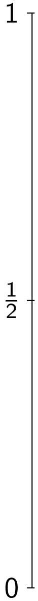
- trade occurs with probability 1.
- no consumer type is worse off.
- almost all consumer types in $\left[0, \frac{1}{2}\right]$ are strictly better off.

That which is in locomotion must arrive at the half-way stage before it arrives at the goal. - Aristotle

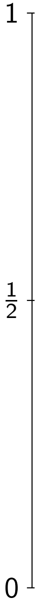



1
$\frac{1}{2}$
0

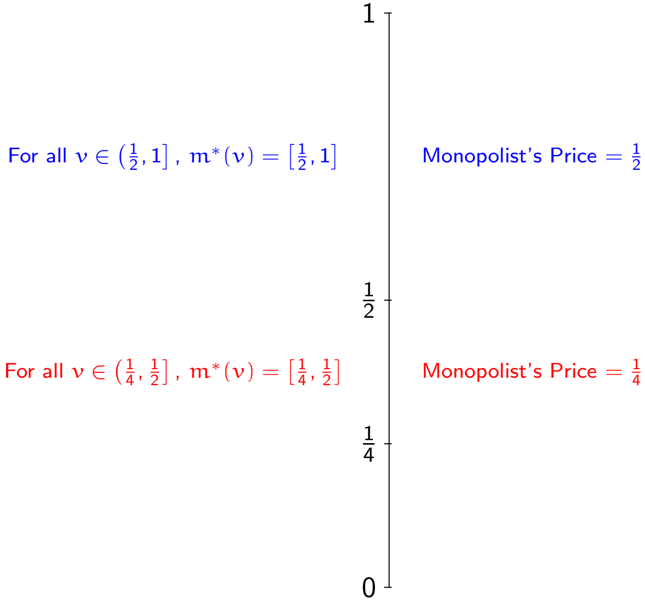
For all $\nu \in \left(\frac{1}{2}, 1\right]$, $m^*(\nu) = \left[\frac{1}{2}, 1\right]$

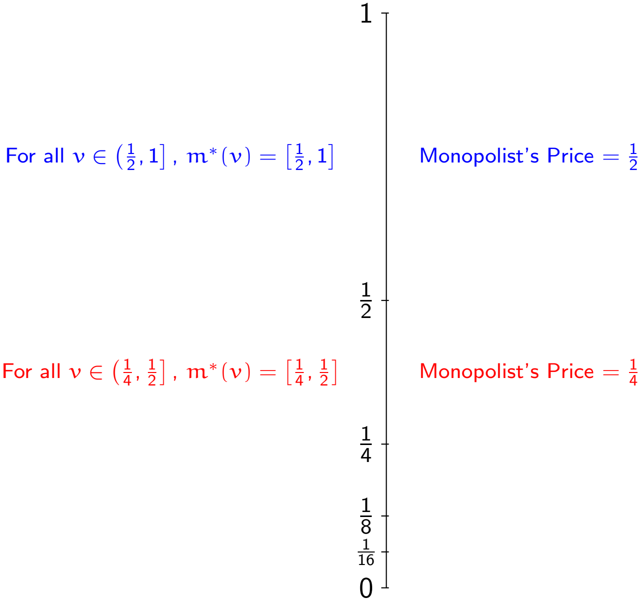


For all $v \in \left(\frac{1}{2}, 1\right]$, $m^*(v) = \left[\frac{1}{2}, 1\right]$



Monopolist's Price $= \frac{1}{2}$


1
For all $v \in \left(\frac{1}{2}, 1\right]$, $m^*(v) = \left[\frac{1}{2}, 1\right]$
Monopolist's Price $= \frac{1}{2}$
$\frac{1}{2}$
For all $v \in \left(\frac{1}{4}, \frac{1}{2}\right]$, $m^*(v) = \left[\frac{1}{4}, \frac{1}{2}\right]$
Monopolist's Price $= \frac{1}{4}$
$\frac{1}{4}$
0


1
For all $v \in \left(\frac{1}{2}, 1\right]$, $m^*(v) = \left[\frac{1}{2}, 1\right]$
Monopolist's Price $= \frac{1}{2}$
$\frac{1}{2}$
For all $v \in \left(\frac{1}{4}, \frac{1}{2}\right]$, $m^*(v) = \left[\frac{1}{4}, \frac{1}{2}\right]$
Monopolist's Price $= \frac{1}{4}$
$\frac{1}{4}$
$\frac{1}{8}$
$\frac{1}{16}$
0

Claim. This scheme generates an equilibrium.

Proof: By construction, each type sends favorite "on-path" message. Monopolist prices at the bottom of each such interval.

Off-path message: Pricing with skeptical beliefs: $p^*(m) = \overline{v}(m)$.

why don't we see unraveling?

In most disclosure models, sender's payoff is strictly monotone in the belief induced in the receiver.

By contrast: monopolist charges same price when she knows $v = 1/2$ with probability 1 as when she believes that $v \sim \mathcal{U}[1/2, 1]$.

$\Rightarrow$ can pool types with $1/2$ without giving it an incentive to separate.

general results

Construction generalizes to arbitrary distributions.

Basic idea for the "greedy" algorithm, proceeding iteratively:

- Identify optimal posted price, p^*.
- Highest market segment $= (p^*, \overline{v}]$.
- Truncate distribution, and repeat on $[\underline{v}, p^*]$.

other equilibria

This is not the only equilibrium (e.g., fully revealing equilibrium exists).

From the perspective of consumer surplus, suffices to look at only those equilibria that are efficient and partitional.

Within such equilibria, the greedy construction is interim Pareto efficient (cannot make some type better off without hurting another type).

But is the greedy construction ex ante optimal? Not necessarily.

- Yes: $F(v) = v^k$ for $k > 0$
- No: Have counterexample for other distributions.
- Log-concave: Good question!

Competition

heuristic argument for uniform distribution

Across efficient equilibria: Maximizing CS $\Leftrightarrow$ Minimizing Average Price.

Let $\overline{P}(\kappa)$ be lowest avg price achieved for a uniform distribution on $[0, \kappa]$.

$$\begin{aligned}
\overline{P}(1) &= \min_{\kappa \geqslant \frac{1}{2}} \left\{(1-\kappa)\kappa + \kappa\overline{P}(\kappa)\right\} \\
&= \min_{\kappa \geqslant \frac{1}{2}} \left\{(1-\kappa)\kappa + \kappa^2\overline{P}(1)\right\} \\
&= \min_{\kappa \geqslant \frac{1}{2}} \left\{\frac{\kappa}{1+\kappa}\right\} \\
&= \frac{1}{3}
\end{aligned}$$

which is the average price achieved by Zeno's Partition.

example where greedy fails

Consider the following distribution:

$$\Pr(v = 1) = \frac{1}{6}, \ \Pr(v = 2/3) = \frac{1}{3} + \epsilon, \ \Pr(v = 1/3) = \frac{1}{2} - \epsilon.$$

The greedy segmentation sets the highest segment as $\{2/3, 1\}$ and the next segment as $\{1/3\}$, resulting in an average price of $\approx 1/2$.

But a better segmentation is $\{1\}$ and $\{1/3, 2/3\}$, which reduces the average price to $4/9$.

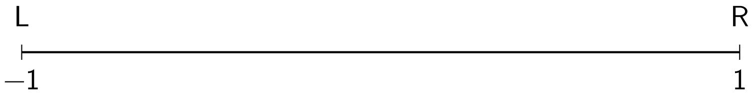
Paper studies competition with $n \geqslant 2$ firms and general product differentiation.

But the economic point emerges already in Bertrand duopoly with horizontal differentiation.

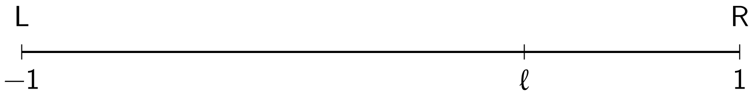
Why think about differentiation? Without differentiation, disclosure doesn't matter, because the firms earn zero markups (Bertrand competition)

Key Force: voluntary disclosure amplifies competitive forces.

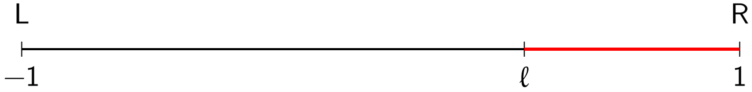
example



example

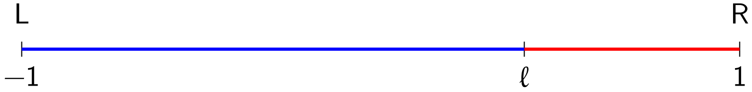


example



Transportation Cost of buying from firm $R = 1 - \ell$.

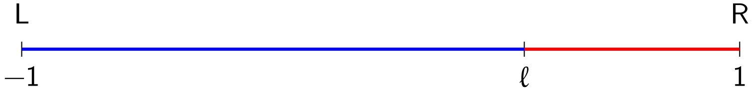
example



Transportation Cost of buying from firm $R = 1 - \ell$.

Transportation Cost of buying from firm $L = 1 + \ell$.

example



Transportation Cost of buying from firm $R = 1 - \ell$.

Transportation Cost of buying from firm $L = 1 + \ell$.

Consumer compares $V - p_L - (1 + \ell)$ with $V - p_R - (1 - \ell)$.

We assume that V is sufficiently high that consumer buys from one of these two firms; for analysis here, $V \geqslant 2$.

no disclosure

Suppose ℓ is drawn uniformly from $[-1, 1]$.

An equilibrium (p_L, p_R) solves:

$$p_L^* \in \arg\max_{p \in \mathfrak{R}_+} pQ_L(p, p_R^*).$$

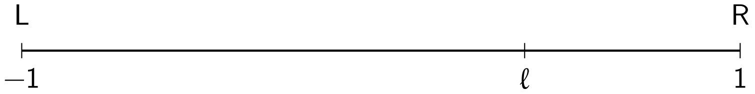
$$p_R^* \in \arg\max_{p \in \mathfrak{R}_+} pQ_R(p_L^*, p).$$

which implies that $p_L^* = p_R^* = 2$.

Therefore, the total cost incurred by type ℓ is $2 + \min\{1 - \ell, \ell + 1\}$.

unraveling $\to$ competition for the middle

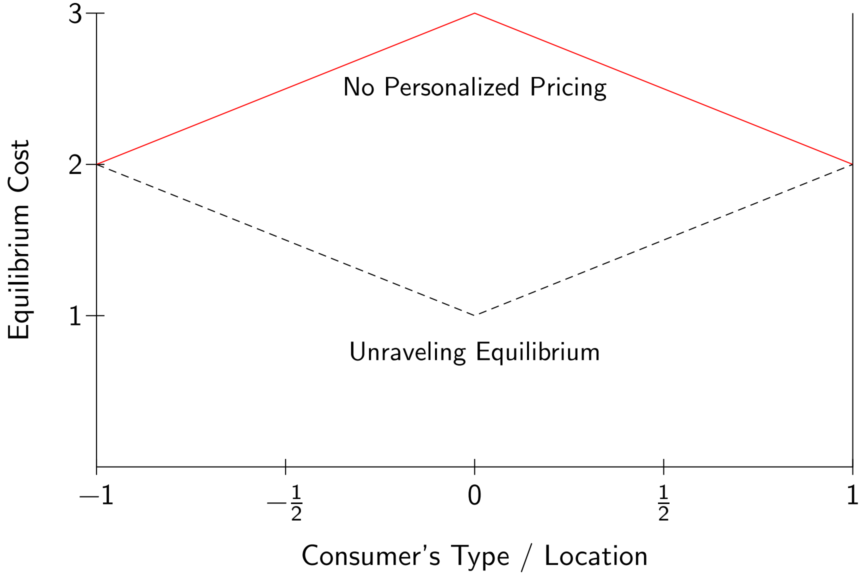
Suppose that the consumer's location were disclosed or commonly known.



Consider eqm where $p_L = 0$ and p_R satisfies an indifference condition:

$$\ell + 1 = p_R + (1 - \ell) \Rightarrow p_R = 2\ell.$$

Therefore, the total cost incurred by type ℓ is $\max\{1 + \ell, 1 - \ell\}$.



3
2
1
Equilibrium Cost
No Personalized Pricing
Unraveling Equilibrium
−1
−1/2
0
1/2
1
Consumer's Type / Location

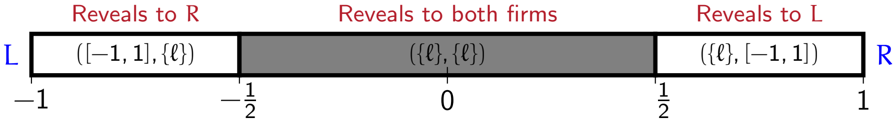
But one can do even better with simple evidence.

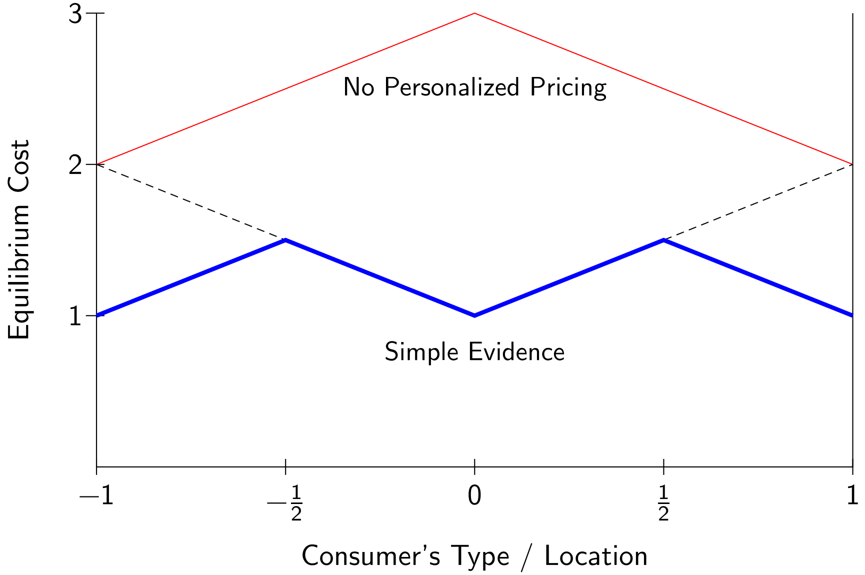
Disclosure strategy:

$$m_L^*(\ell), m_R^*(\ell) = \begin{cases} \big([-1,1], \{\ell\}\big) & \text{if } -1 \leqslant \ell \leqslant -1/2, \\ \big(\{\ell\}, \{\ell\}\big) & \text{if } -1/2 < \ell < 1/2, \\ \big(\{\ell\}, [-1,1]\big) & \text{if } 1/2 \leqslant \ell \leqslant 1, \end{cases}$$

On-path: distant firm charges 0, and closer firm charges optimal price.

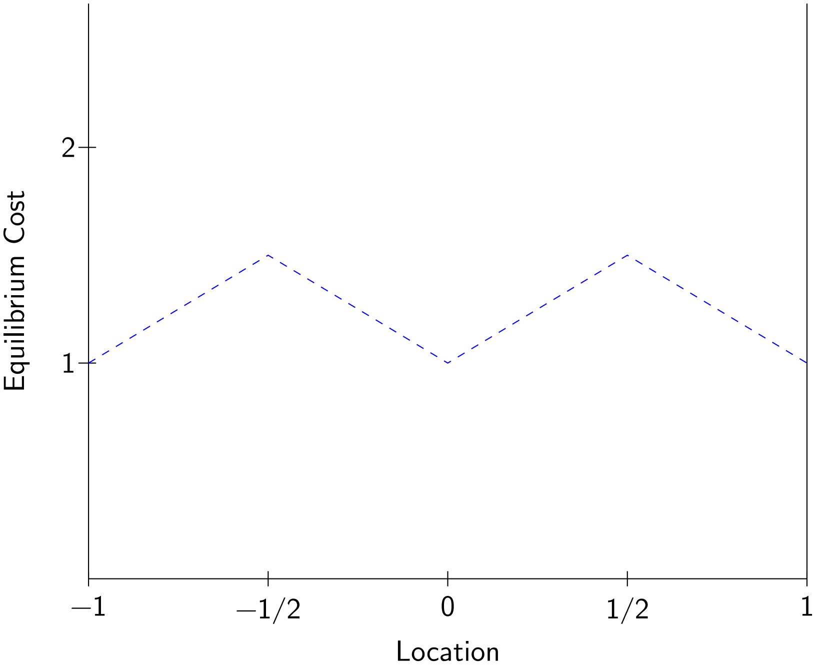
Construction uses simple evidence ("track / do not track") that sends messages privately.

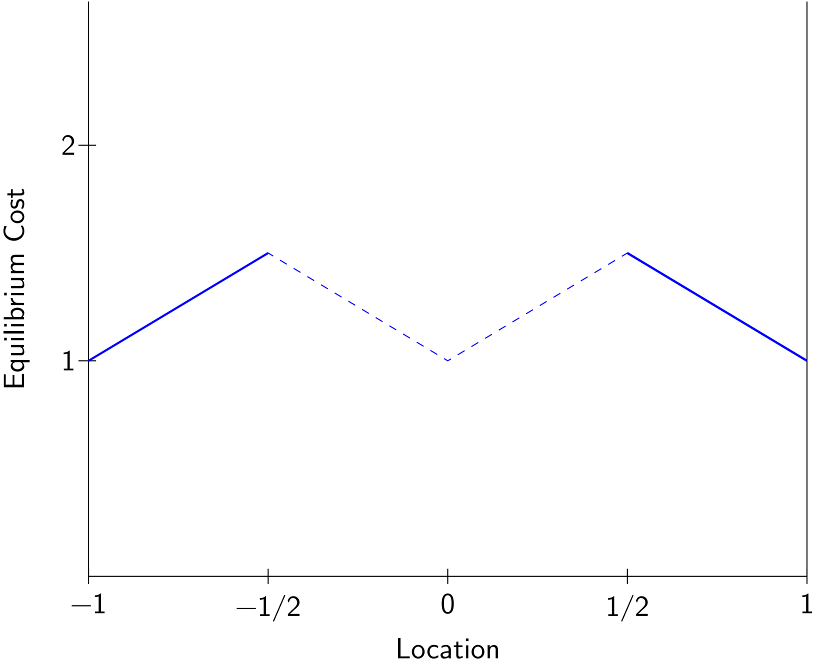

Reveals to R
Reveals to both firms
Reveals to L
L
([−1, 1], {ℓ})
({ℓ}, {ℓ})
({ℓ}, [−1, 1])
R
−1
−1/2
0
1/2
1

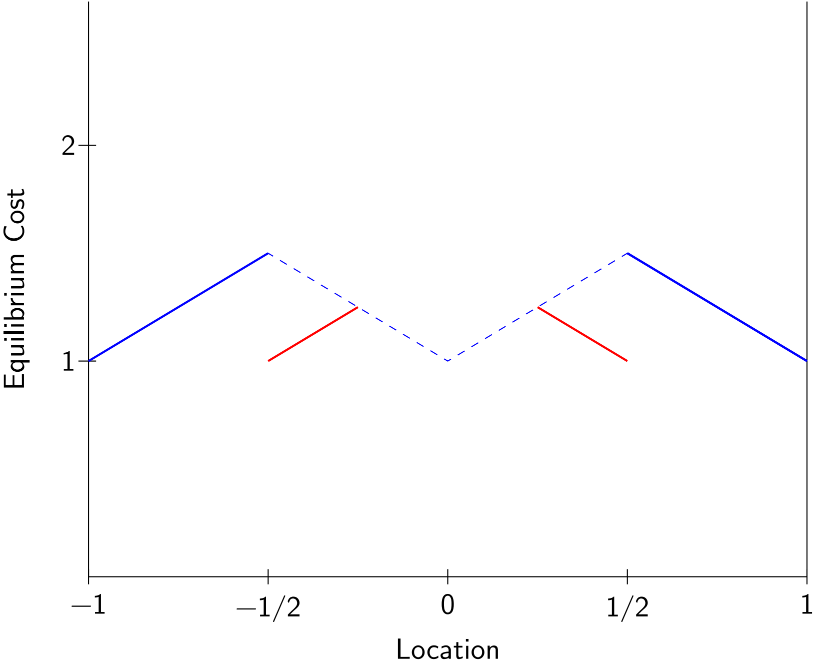


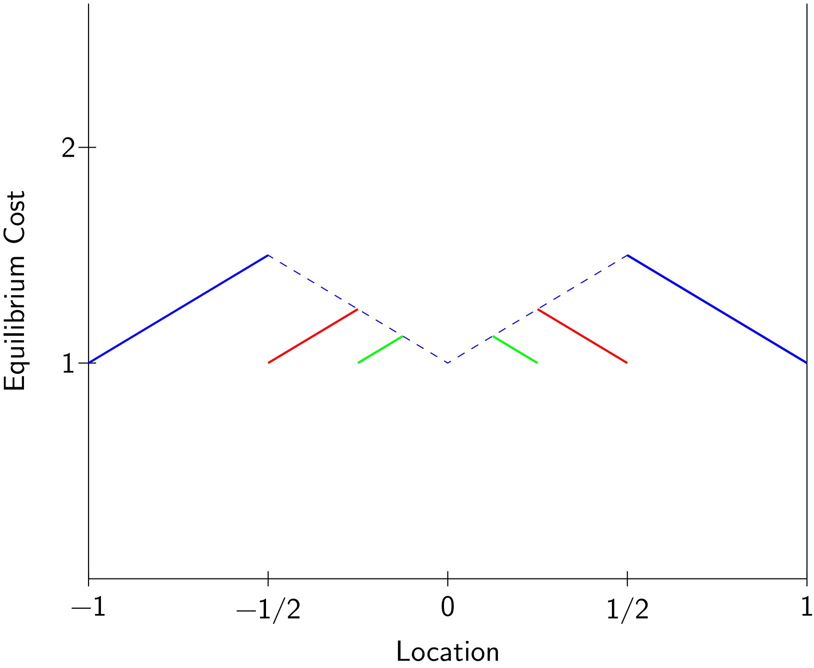
Equilibrium Cost
3
2
1
No Personalized Pricing
Simple Evidence
−1
−½
0
½
1
Consumer's Type / Location

Can do even better with rich evidence by using a greedy construction.


Equilibrium Cost
2
1
−1
−1/2
0
1/2
1
Location


Equilibrium Cost
2
1
−1
−1/2
0
1/2
1
Location


Equilibrium Cost
2
1
−1
−1/2
0
1/2
1
Location


Equilibrium Cost
2
1
−1
−1/2
0
1/2
1
Location

observations

Every type gains relative to both no personalized pricing and full unraveling.

Allocation is fully efficient.

Extreme types benefit from pooling with interior types, and interior types have no incentive to separate.

general results for duopoly

We assume that the location is distributed symmetrically around 0 and has a log-concave density.

$\Rightarrow$ pure strategy eqm exists in benchmark model (Caplin & Nalebuff) and is unique.

Under these conditions, the simple evidence equilibrium always does better than no-personalized-pricing for every type.

even more general results...

Suppose that there are $n \geqslant 2$ firms, and each consumer's valuation for the products are $v = (v_1, \ldots, v_n)$, drawn from some set $[\underline{v}, \overline{v}]^n$.

Previous analysis applies where we think of a consumer's two favorite firms i and j, and treat her "location" as $v_i - v_j$.

Paper extends all of our prior results to this general domain.

worst case scenario

What is the worst equilibrium for consumers with competition?

- No pure-strategy equilibrium can result in payoffs below that of the unraveling equilibrium.
- In terms of average payoffs, this is still better than the uniform prices in the benchmark game.
- Highlights that equilibrium coordination may be more vital in the monopolistic setting than when there is horizontal differentiation.

key ideas of our paper

Personalized pricing can benefit consumers when consumers can control the flow of info.

- The price that a firm charges is not strictly monotone in its beliefs.
- Extreme types do not have an incentive to separate themselves from the crowd.

Partial disclosure possibilities are essential for monopolistic markets: track / do-not-track does not suffice.

Voluntary disclosure amplifies competitive forces in Bertrand duopoly with horizontal differentiation.

broader outlook

Discussions of communication + personalized pricing often hint at a tradeoff between *product customization* and *price discrimination*.

Our work highlights how verifiable information can potentially lead to consumer gain without any product customization.

Separately, there is a powerful competitive effect in being able to induce "distant firms" to charge low poaching prices so that one's home firm reduces prices.

relevant literatures

Growing literatures on privacy, price discrimination, and hard information.

- Competitive Markets + Targeting: Thisse & Vives (1988).
- Group Pricing: Belleflamme & Peitz (2010).
- Privacy and dynamic choices: Taylor ('04); Acquisti & Varian ('05); Calzolari & Pavan ('06); Bhaskar & Roketskiy ('19); Acquisti, Taylor, and Wagman ('16).
- Disclosure Games: Hagenbach, Koessler, & Perez-Richet ('14); Sher & Vohra ('15); Hart, Kremer, & Perry ('17); BDL ('18,'19); Koessler & Skreta ('18); Glode, Opp, & Zhang ('18); Hidir & Vellodi ('20); Pram ('20).
- Information Design: BBM ('15), Ichihashi ('18), Elliot, Galeotti, & Koh ('20), Armstrong & Zhou ('20), Li ('20).

Thank you!