Competitive Personalized Pricing with Sophisticated Consumers

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The Era of Big Data

- We live in the era of big data
- Massive data collection and process on individual-level information:
  - Online search and transactions: Google, Amazon, Alibaba, Netflix,...
  - Social medias: Facebook and Twitter
  - Loyal programs and credit card payments
- Relevant information is also collected and distributed via data brokers
  - Include Acxiom, Bloomberg, Bluekai (Oracle), and Teradata
- The business generates $150 Billion dollars value a year
The availability of massive personal data opens a door for personalized pricing. Firms use personal-level information to target customers and offer personalized deals to consumers. Once a consumer logs into a retailer website, it knows where you are from because of your IP address. The prices are generated by the computer system based on a particular customer’s perceived ability to pay. Personalized prices are offered privately. It is difficult to compare prices across persons.
Evidence of Personalized Pricing

- Orbitz used its knowledge of its customers’ demographics to charge certain customers more for hotels.
- More affluent users are automatically steered to more expensive options.
- It also found that users browsed on Mac devices were willing to pay up to 30 percent more for a hotel than Windows users.
- Delta Airlines charged frequent flyers up to $300 more for a ticket than an infrequent traveler.
- People who travel often are probably doing it for business purposes.
- The Wall Street Journal also reported Staples.com charged different prices according to consumers locations.
Amazon has used personalized pricing strategy most effectively. Amazon changes its prices every 10 minutes based on the data it collects in real time. In 2000 Amazon set personalized prices for consumers purchasing DVD. Registered consumers faced higher prices than new customers. Some consumer discovered this price discrimination and complained in the social media. Amazon was accused widely by consumer protection agencies. Amazon defended it as an "experiment of differential pricing."
On the other hand, consumers are becoming aware of their situations. They know their personal information might be collected and may take actions to protect themselves. Consumers can exert effort to understand sellers’ privacy policy. They can delete browser cookies or use a temporary E-mail address. They may create several online identities and pay with different credit cards. These actions require time, effort, and even money. They are referred to as the *identity management strategies*. 
Firms and consumers are engaged in the game of *Hide and Seek*. Sellers attempt to identify individual consumers for price discrimination. Buyers endeavor to conceal their personal information and bypass the hurdle for price discrimination.

Research questions:

- What is the equilibrium of this game?
- Who is the winner and who is the loser?
- How do regulations affect the equilibrium outcome and welfare?
These questions are related to the recent hot debate on Internet privacy protections.

FCC approved the Internet privacy protections in the final days of the Obama administration.

The privacy rules were intended to give consumers extra control over their personal data.

On March 28, 2017, House of Representatives voted to repeal this regulation.

FTC chair, Maureen Ohlhauser, argued that personalized prices spur competition:

"Information can be used to target some consumers with higher prices, but the same information can be used to target consumers with a better deal."

Key question: Can the massive use of personal data benefit consumers?

To answer this question, we study personalized pricing in competitive markets.

Consider a static duopoly model with Hotelling competition.

Firms are equipped with complete information of preferences for a given target set of consumers.

They can charge personalized prices to their targeted consumers.

But can offer only uniform price for non-targeted consumers.

We solve for the equilibria of the Hide-and-Seek game.
Key modelling feature: consider consumer sophistication
Targeted consumers are aware of being tracked
Firms are becoming very powerful in identifying consumers with big data
They can use multi-dimensional personal data to cross-tracking consumers
They may also impose some hurdles for consumers to conceal their identities
Bypassing these hurdles incurs transaction costs to consumers
Such transaction costs vary across persons
The insurance company Budget Direct offers 35% discount of the home insurance premium to new customers.

One author, Chongwoo, recently renewed his home insurance and found this low price.

He wanted to register as a new customer.

But his unique home address indicates that he is not eligible.

Chongwoo called the insurance company and threatened to cancel the contract.

He managed to get this discount after 30 minutes bargaining, saving about $300 a year!
Some consumers will complain to the sellers when they find a better deal.

Others may value their time highly and/or hate bargaining.

The recent survey of U.S. Consumers Union finds about 33% of consumers negotiated with existing cellphone providers.

Among these, 74% reported being successful at least once, with average saving of US$80 a year.

It also finds 32% of customers for bank cards sought for a better deal.

73% of these reported being successful at least once, with average saving of $100 a year.
To capture the heterogeneity of consumer sophistication
- We assume there are two types of consumers
  - *Sophisticated* consumers incur zero transaction cost to bypass the hurdle
  - They can negotiate a better deal
  - *Naive* consumers instead face a prohibitively high transaction cost
  - They are unable to get the better deal
There is a growing literature of personalized pricing (or behavioral-based price discrimination) among others.

Taylor (2004), Montes et. al. (2016), and Contizer et. al. (2015) consider consumer sophistication in a different way. They assume consumers can take costly actions *ex ante* to hide personal information. They show that consumers are better off in hiding personal information.

We consider consumers can take actions *ex post* to avoid exploitation. We show that consumers are collectively worse off under personalized pricing.
This paper also contributes to the large literature of competitive price discrimination. Armstrong and Vickers (2001), Fudenberg and Tirole (2000), Thisse and Vives (1988) among others. They show that competitive price discrimination makes firms worse off and consumers better off. Their results rely heavily on the assumption that all consumers are “naive.” We show that competitive price discrimination is anti-competitive with consumer sophistication. Thus, prohibiting price discrimination could improve consumer surplus.
The Model

- Two firms, $A$ and $B$, sell competing brands of a consumer good.
- The good is produced at zero marginal cost.
- A continuum of consumers with unit demand and heterogeneous brand loyalty $l$.
- A consumer with brand loyalty $l$ derives $V_A(l) = 1 + l/2$ from good $A$ and $V_B(l) = 1 - l/2$ from good $B$.
- Consumers prefer Brand $B$ to $A$ if and only if $V_A(l) - p_A < V_B(l) - p_B$.
- This amount to $p_A - p_B > l$.
- Loyalty $l$ is uniformly distributed in $[-0.5, 0.5]$. 
The Model

- Each firm has a target segment of consumers.
- Let \([-0.5, b]\) denote firm B’s target zone and \([a, 0.5]\) be firm A’s target zone.
- Firms know the exact consumer loyalty for their targeted consumers.
- Firm A can offer personalized prices \(p_A(l)\) to its targeted consumers and a uniform price \(q_A\) to other consumers.
- Firm B can charge personalized prices \(p_B(l)\) to its targeted consumers and a uniform price \(q_B\) to other consumers.
Figure 1 illustrates the pricing strategies.
A static model: firms play the game only once

The uniform and personalized prices are set sequentially

Stage 1: Firms set uniform prices $q_A$ and $q_B$ respectively for non-targeted consumers

Stage 2: Observing these prices, firms offer personalized prices $p_A(l)$ and $p_B(l)$ to their targeted consumers

Stage 3: Consumers make purchase decisions

The timing captures the fact that uniform prices are observable while personalized prices are private
Suppose no consumers are targeted, i.e., $a = 0.5 = -b$

- Firms have no information about individual consumer’s loyalty
- They can only charge uniform prices
- Firms compete a la Hotelling with uniform pricing
- Equilibrium Hotelling prices are given by $q_A = q_B = 1/2$
- Each firm earns a profit of $1/4$
Firm A’s targeted consumers will receive $p_A (l)$ from firm A and $q_B$ from firm B.

In addition, a sophisticated consumer can bypass the hurdle and access to $q_A$ as well.

However, a naive consumer is unable to overcome the hurdle and is not eligible to $q_A$.

Likewise, a naive consumer of firm B can compare $p_B (l)$ and $q_A$.

Whereas a sophisticated consumer of firm B can access to $p_B (l)$, $q_A$ and $q_B$. 

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A naive consumer of firm $B$, $l \in [-0.5, b]$, compares two prices $p_B(l)$ and $q_A$.

If firm $A$ aims to poach this customer, it can set the most aggressive price $q_A = 0$.

Firm $B$’s best response: $p_B(l) = q_A - l = -l$ for $l \leq 0$ and $p_B(l) = 0$ if $l \geq 0$.

Firm $B$ offers $p_B(l) = 0$ for the marginal consumer with $l = 0$ if $b \geq 0$.

But the personalized offer is not observable by other consumers.

It does not prevent firm $B$ to charge different prices to others.

Firm $B$ can defend its turf aggressively under personalized pricing.
Firm $B$ can always keep consumers with $l \leq \min\{b, 0\}$ profitably.

That is, firm $B$’s targeted consumers in $N_B \equiv [-0.5, \min\{b, 0\}]$ are non-contestable by firm $A$.

Likewise, firm $A$’s targeted consumers in $N_A \equiv [\max\{a, 0\}, 0.5]$ are non-contestable by firm $B$.

The sets of non-contestable consumers are illustrated as follows:

\[ N_B \equiv [-0.5, \min\{b, 0\}] \]
\[ N_A \equiv [\max\{a, 0\}, 0.5] \]
Assume all consumers are naive

Consider the case with almost fully targeted consumers

That is, \( a = \varepsilon = -b \), where \( \varepsilon \) is arbitrarily close to zero

Consumers with \( l \in N_B = [-0.5, -\varepsilon] \) are not contestable by firm A

Consumers with \( l \in N_A = [\varepsilon, 0.5] \) are not contestable by firm B

But consumers with \( l \in [-\varepsilon, \varepsilon] \) are contestable by both firms

Competition for this tiny portion of consumers leads to \( q_A = q_B = \varepsilon \)

A firm’s aggressive poaching price limits the rival’s personalized price

As best response, firms charge \( p_A (l) = l + \varepsilon \) and \( p_B (l) = -l + \varepsilon \) for targeted consumers
Equilibrium with Naive Consumers

- Each firm earns strictly less profit than in Hotelling competition
- When $\varepsilon \rightarrow 0$, $\pi_A = \pi_B = 1/8$, firms earn the lowest profit
- Common wisdom: firms are worse off in competitive price discrimination
The above conclusion begs two questions.

Q1: How reasonable is this outcome?

Would firms set aggressive poaching prices to compete for a tiny portion of consumers?

Expect that they will be trapped into a prisoners’ dilemma

Q2: How robust is the above equilibrium?

When a tiny proportion of consumers are sophisticated

This equilibrium outcome is flipped over
Suppose a non-trivial proportion \( \alpha \) of consumers are sophisticated. These consumers can access to the low poaching price as well. If firm \( A \) sets poaching price \( q_A = \epsilon \), its profit from non-targeted consumers is equal to \( \epsilon^2 \). It is negligible for arbitrarily small \( \epsilon \). However, the foregone benefit is equal to \( \alpha \left( \frac{1}{8} - \epsilon \right) \), is non-trivial. Thus, firms will deviate from the prisoners’ dilemma when a small proportion of consumers are sophisticated. The presence of sophisticated consumers discourages firms from poaching.
There exists a unique NE in which both firms do not poach.

Firms set prohibitively high uniform prices.

This allows to charge the maximum personalized prices
\[ p^m_A(l) = 1 + l/2 \text{ and } p^m_B(l) = 1 - l/2 \]
to targeted consumers.

Firms extract full consumer surplus from targeted consumers.

Consumers obtain zero surplus.

When \( \varepsilon \to 0 \), firms earn \( \pi^*_A = \pi^*_B = 9/16 \), the highest profit.

The equilibrium replicates the outcome of Perfect Price Discrimination (PPD).

But in a competitive market without tacit collusion!
Equilibrium with Sophisticated Consumers

Figure: the PPD equilibrium

\[ p_B^m(l) = 1 - l/2 \]
\[ p_A^m(l) = 1 + l/2 \]
\[ p_B(l) = -l + \varepsilon \]
\[ p_A(l) = l + \varepsilon \]
Equilibrium with Sophisticated Consumers

- How robust is this PPD equilibrium?
- When $a = b = 0$, this PPD equilibrium arises for any $\alpha > 0$
- As long as a tiny proportion of consumers are sophisticated
- Because both firms’ target sets are non-contestable by the rival
- Consumers are targeted by either firm $A$ or firm $B$
- A small proportion of sophisticated consumers is sufficient to prevent firms from setting aggressive prices
We first examine established markets where consumers are targeted by at least one firm.

Consider the fully targeted market with $a = b = \delta > 0$.

Firm $A$’s targeted consumers in $[\delta, 0.5]$ are not contestable; firm $B$ does not gain from poaching.

Firm $B$’s targeted consumers in $[-0.5, 0]$ are not contestable as well.

But its targeted consumers in $[0, \delta]$ are contestable by firm $A$.

Suppose firm $A$ sets $q_A$ to poach the rival unilaterally.

Firm $B$ will defend in personalized pricing.

It will set $p_B(\hat{x}) = q_A - \hat{x} = 0$ for marginal consumer $l = \hat{x}$.
Firm $A$ can attract consumers with $l \in [\hat{x}, \delta]$, and earns an extra profit $q_A (\delta - \hat{x}) = q_A (\delta - q_A)$.

But sophisticated consumers in target zone can take $q_A$ as well.

Its foregone benefit from sophisticated consumers is

$$\alpha \int_{\delta}^{0.5} (p_A^m (l) - q_A) \, dl = \alpha (\pi^*_A (\delta) - (0.5 - \delta) q_A)$$

Its net benefit from deviation is

$$\Gamma = q_A (\delta - q_A) + \alpha (0.5 - \delta) q_A - \alpha \pi^*_A (\delta)$$

Maximizing the above gives the optimal $q_A$

$$\hat{q}_A (\alpha) = \hat{x} = \frac{\delta + \alpha (0.5 - \delta)}{2}.$$
Firm A will not poach if the maximum net benefit
\[ \Gamma(\delta) = (\hat{x})^2 - \alpha \pi_A^*(\delta) \leq 0 \]
\[ \Gamma(\delta) \text{ increases with } \delta, \text{ satisfying } \Gamma(0) < 0 \text{ and } \Gamma(0.5) > 0 \]
There exists a cut-off threshold \( \tilde{\delta}(\alpha) \) such that \( \Gamma(\delta) \leq 0 \) if and only if \( \delta \leq \tilde{\delta}(\alpha) \)
Thus, PPD equilibrium can sustain if \( \delta \leq \tilde{\delta}(\alpha) \)
Intuitively \( \tilde{\delta}(\alpha) \) increases with \( \alpha \)
When \( \alpha = 0.5 \), \( \tilde{\delta}(0.5) = 0.41 \)
PPD equilibrium arises with roughly 80% of the parameter range
Figure: PPD equilibrium

PPD Equilibrium with $\delta < \bar{\delta}(\alpha)$

$p_B^m(l) = 1 - l/2$

$p_A^m(l) = 1 + l/2$

$N_B$

$N_A$

$0.5$

$1 + \delta/2$

$-0.5$

$1.25$

$0$

$1.25$
Equilibrium in Established Markets

- When $\delta > \bar{\delta}(\alpha)$, firm $A$ will poach by setting $\hat{q}_A$
- The poaching limits firm $B$’s personalized pricing
- Firm $B$’s best response is $p_B(l) = \hat{q}_A - l$ for the remaining targeted consumers
- It earns less profit than in PPD equilibrium with $\delta = 0$
- Firm $B$ is strictly worse-off in this situation
- It does not pay for firm $B$ to target too many consumers!
Equilibrium in Established Markets

- Figure: One-way Poaching

PPD Equilibrium with $\delta > \bar{\delta}(\alpha)$

$\hat{q_A} = 0.5 - \hat{q_A}$

$p_B(l) = \hat{q_A} - l$

$a = b = \delta$

$1 + \delta / 2$

$1.25$
Overlapping Target Zones

- Suppose firms’ target zones are overlapped: $a = -\delta$ and $b = \delta$
- Firms compete for commonly targeted consumers in $[-\delta, \delta]$ through personalized pricing
- Consumers in $[-\delta, 0]$ are non-contestable by firm A
- But firm A can set $p_A(l) = 0$ for these consumers, and firm B responds by $p_B(l) = -l$
- Likewise, firm B sets $p_B(l) = 0$ for $l \in [0, \delta]$ and firm A defends with $p_A(l) = l$
- Each firm earns lowest profit from commonly targeted consumers
- However, firms can still charge maximum personalized prices for non-overlapping consumers
- Firm A charges $p_A^m(l)$ for $l \in [\delta, 0.5]$ and firm B charges $p_B^m(l)$ for $l \in [-0.5, -\delta]$
The equilibrium mixes PPD and tough competition.
Overlapping Target Zones

- Firms will not use uniform price to poach the rival
- Because consumers in \([-0.5, -\delta]\) are not contestable by firm A
- Likewise, those in \([\delta, 0.5]\) are not contestable by firm B
- Firms are worse-off with overlapping target zones
- In the extreme case when the whole market is overlapped
- Firm A sets \(p_A(l) = 0\) for \(l \in [0, 0.5]\) and firm B sets \(p_B(l) = -l\) for \(l \in [-0.5, 0]\)
- The equilibrium yields the same lowest profit as if all consumers are naive
- Both firms are trapped into the Prisoners’ Dilemma
- This case coincides with Thisse and Vives (1988 AER)
In growing markets, new customers are not targeted

Consider now \( a = -b = \delta \) such that consumers in \([-\delta, \delta]\) are not targeted by either firm

Firm \( B \)'s target zone \([-0.5, -\delta]\) is non-contestable by firm \( A \)

Firm \( A \)'s target zone \([\delta, 0.5]\) is non-contestable by firm \( B \)

Intuitively, PPD equilibrium arises when \( \delta \) is sufficiently small

Firms make PPD profit from targeted consumers

They serve only targeted consumers and leave them zero surplus

However, consumers with \( l \in [-\delta, \delta] \) are not served by either firm!

This causes a dead-weight loss in social welfare
The PPD equilibrium with sufficiently small $\delta$
Equilibrium in Growing Markets

- When $\delta$ is sufficiently large, firms have incentives to serve non-targeted consumers.
- If firm $A$ deviates from PPD unilaterally, it becomes the monopoly for non-targeted consumers.
- It charges the monopoly uniform price $q^m_A = 1 - \delta/2$ for consumers in $[-\delta, \delta]$.
- The extra profit from deviation is equal to $2\delta (1 - \delta/2)$.
- However, a proportion $\alpha$ of sophisticated consumers in $[\delta, 0.5]$ can access to this price as well.
- The foregone benefit from each consumer is $\alpha (\pi^*_A (\delta) - q^m_A (0.5 - \delta))$.
- There exists a cut-off level $\hat{\delta} (\alpha)$ such that firm $A$ will not deviate if $\delta \leq \hat{\delta} (\alpha)$.
- PPD equilibrium can be sustained when $\delta \leq \hat{\delta} (\alpha)$. 
When $\delta > \hat{\delta}(\alpha)$, one firm, say firm A, will deviate unilaterally from PPD.

Firm A serves non-targeted consumers as the monopoly.

The price $q^m_A$ is not attractive to consumers with $l < -\delta$.

Thus, firm B can still make PPD profit from its targeted consumers.

If firm B undercuts the rival in serving non-targeted consumers.

It must charge a price less than the monopoly price.

It has less incentives to deviate than firm A.

This equilibrium with unilateral PPD arises when $\hat{\delta}(\alpha) < \delta < \tilde{\delta}(\alpha)$. 
• If $\delta > \tilde{\delta} (\alpha)$, both firms have incentives to compete for non-targeted consumers
• However, competition is softened due to consumer sophistication
• Firms must take into account the foregone benefit in such competition
• The equilibrium uniform prices are then given by

\[ q_A = q_B = \tilde{q} (\alpha) = \delta + (0.5 - \delta) \alpha \]

• It exceeds the Hotelling price $\delta$ with the amount of $(0.5 - \delta) \alpha$
• This reflects the “marginal benefit” due to consumer sophistication
• This allows firms to charge higher personalized prices:

\[ p_A (l) = \tilde{q} (\alpha) + l \text{ and } p_B (l) = \tilde{q} (\alpha) - l \]

• These prices increase with $\alpha$
Figure: Competition for non-targeted consumers

\[ \tilde{q} + 0.5 \]

\[ p_B(l) = \tilde{q}(\alpha) - l \]

\[ q_A = q_B = \tilde{q}(\alpha) \]

\[ \tilde{q} + 0.5 \]

\[ p_B(l) = \tilde{q}(\alpha) + l \]
Endogenous Target Zones

- When firms can choose target zones before the pricing game
- The situation with overlapping target zones will not arise
- Suppose firms can purchase consumer information from a data broker
- If the marginal cost of acquiring information is sufficiently small
- The unique equilibrium is $a = b = \delta < \tilde{\delta}(\alpha)$
- The market is fully segmented and firms make PPD profits
- Without regulation, the industry will evolve to the PPD equilibrium
We consider competitive personalized pricing with consumer sophistication.

PPD equilibrium arises when firms have sufficiently large size of non-overlapping target zone.

Firms’ profit increases with the size of target zone, but then decreases when target zones are overlapped.

An individual consumer can gain from sophistication.

But they lose from being sophisticated collectively.

When target zones are sufficiently small, firms will compete for non-targeted consumers.

Consumers are better off without personalized pricing.

Consumers are the loser and firms are the winner of the Hide-and-Seek game.
Policy Implications

- Consumers are better off at two ends: no consumers are targeted or all consumers are targeted by both firms
- When price discrimination is not banned
- Collecting personal data should be regulated
- High barriers of data collection shrinks firms’ target zone
- This facilitates competition for non-targeted consumers
- In contrast, if data collection is not regulated
- Then price discrimination should be prohibited
- Competition in uniform pricing improves consumer surplus and social welfare