Competitive Personalized Pricing with Sophisticated Consumers

Zhijun Chen, Chongwoo Choe, and Noriaki Matsushima
Monash University, Monash University, and Osaka University

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Paris School of Economics
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

By Moran Zhang  On 08/10/12 AT 3:52 PM

Business

Personalized Pricing: Retailers Are Watching Your Every Move

They know who you are. They know where you live. They monitor your every purchase, its time, its place, its amount.

Sweet only at Safeway

Safeway shares were among the biggest pre-open gainers on news of its Canada unit sale.
Evidence of Personalized Pricing

- Orbitz used its knowledge of its customers’ demographics to charge certain customers more for hotels
- 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. Sophisticated 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.
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.
A Game of Sophistication

- Firms and consumers are engaged in a game of sophistication
- Sellers attempt to identify individual consumer 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?
  - How does consumer sophistication affect the equilibrium?
  - Do consumers benefit from being sophisticated?
  - How do regulations affect the equilibrium outcome and welfare?
Common Wisdom

- It is well-recognized that effectiveness of price discrimination depends on consumer sophistication.
- Sophisticated consumers can hide their personal information and protect themselves from price discrimination.
- See for instance Taylor (2004), Montes et. al. (2016), and Contizer et. al. (2015) among others.
- Consumer switch and arbitrage make price discrimination less effective.
- Common Wisdom: consumers benefit from being sophisticated.
- Firms earn less profits due to consumer sophistication.
Common Wisdom does not look at the externalities among consumers. An individual consumer can benefit from being sophisticated. But his sophisticated behavior could impose negative externality on other consumers. Competitive firms are reluctant to offer low prices to the rivals’ customers if their loyal consumers can get such price. As a result, consumers can be collectively worse off. We find that competitive firms can benefit from consumer sophistication. They can earn a higher profit when more consumers become sophisticated.
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

Targeted consumers are aware of being tracked

But they have to incur some transaction costs to bypass the hurdles

In order to get the low price offered to non-targeted consumers
Such transaction costs vary across persons
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
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 \([-0.5, 0.5]\)
Figure 1 illustrates the pricing strategies.
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
Timing of the Pricing Game

- 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 $q_B$. 
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.
Non-Contestable Consumers

- 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.

\[
\begin{align*}
N_B &= [-0.5, \min\{b, 0\}] \\
N_A &= [\max\{a, 0\}, 0.5]
\end{align*}
\]
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 \( l \in \mathbf{N}_B = [-0.5, -\varepsilon] \) are not contestable by firm A

Consumers with \( l \in \mathbf{N}_A = [\varepsilon, 0.5] \) 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 $\varepsilon \to 0$, $\pi_A = \pi_B = \frac{1}{8}$, firms earn the lowest profit.
- Common wisdom: firms are worse off in competitive price discrimination.

\[
p_B(l) = -l + \varepsilon \quad p_A(l) = l + \varepsilon
\]
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 $q_A = \varepsilon$, its profit from non-targeted consumers is equal to $\varepsilon^2$.

It is negligible for arbitrarily small $\varepsilon$.

However the foregone benefit is equal to $\alpha \left(1/8 - \varepsilon\right)$, 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
\[ p^m_A (l) = 1 + l/2 \] and \[ p^m_B (l) = 1 - l/2 \] to targeted consumers
Firms extract full consumer surplus from targeted consumers
Consumers obtain zero surplus
When \( \varepsilon \rightarrow 0 \), 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

\[ p_B^m(l) = 1 - l / 2 \]
\[ p_B(l) = -l + \varepsilon \]
\[ p_A^m(l) = 1 + l / 2 \]
\[ p_A(l) = l + \varepsilon \]
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 the markets where consumers are fully targeted 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 $l = \hat{x}$.
Equilibria with Fully Targeted Consumers

Figure: PPD equilibrium

PPD Equilibrium with $\delta < \bar{\delta}(\alpha)$
Equilibria with Fully Targeted Consumers

- 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

\[
\alpha \int_{\delta}^{0.5} (p^*_A(l) - q_A) \, dl = \alpha (\pi^*_A(\delta) - (0.5 - \delta) q_A)
\]

- 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 \( q_A \)

\[
\hat{q}_A(\alpha) = \hat{x} = \frac{\delta + \alpha (0.5 - \delta)}{2}.
\]
Equilibria with Fully Targeted Consumers

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

- The equilibrium mixes PPD and tough competition

\[ p_B(l) = 1 - l / 2 \]
\[ p_A(l) = 1 + l / 2 \]
\[ a = -\delta \]
\[ b = \delta \]

Zhijun Chen, Chongwoo Choe, and Noriaki Matsushima
Monash University, Monash University, and Osaka University
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)
Equilibria with Non-targeted Consumers

- We now examine the markets where a proportion of customers are not targeted.
- Consider $a = -b = \delta$ 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 $\delta$

- $p_B(l) = 1 - l/2$
- $p_A(l) = 1 + l/2$
Equilibria with Non-targeted Consumers

- 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 $q_A^m = 1 - \delta / 2$ 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 $\alpha (\pi_A^* (\delta) - q_A^m (0.5 - \delta))$.
- 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 $\delta \leq \hat{\delta} (\alpha)$. 
Unilateral PPD Equilibrium

- 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 $\hat{\delta}(\alpha) < \delta < \tilde{\delta}(\alpha)$. 
Competition for Non-targeted Consumers

- 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

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

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

\[ p_B(l) = \tilde{q}(\alpha) + l \]
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
Summary of Main Results

- 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 consumers 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.
The research is related to the recent hot debate on Internet privacy protections.

FCC approved the Internet privacy protections in the final days of 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 Ohlhause, 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.”
We find that 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, which 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.
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) among others.

They consider also 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.


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.