# 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

# Big Data and Personalized Pricing

- 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

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.

BY **MORAN ZHANG** ON 08/10/12 AT 3:52 PM


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"

# Consumer Sophistication

- 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

# Consumer Sophistication: A Story

- 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!

# Evidence of Consumer Sophistication

- 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 Is Wrong

- 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

# Modelling Consumer Sophistication

- 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

# Modelling Consumer Sophistication

- 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 $[-0.5, 0.5]$

# The Model

- Figure 1 illustrates the pricing strategies

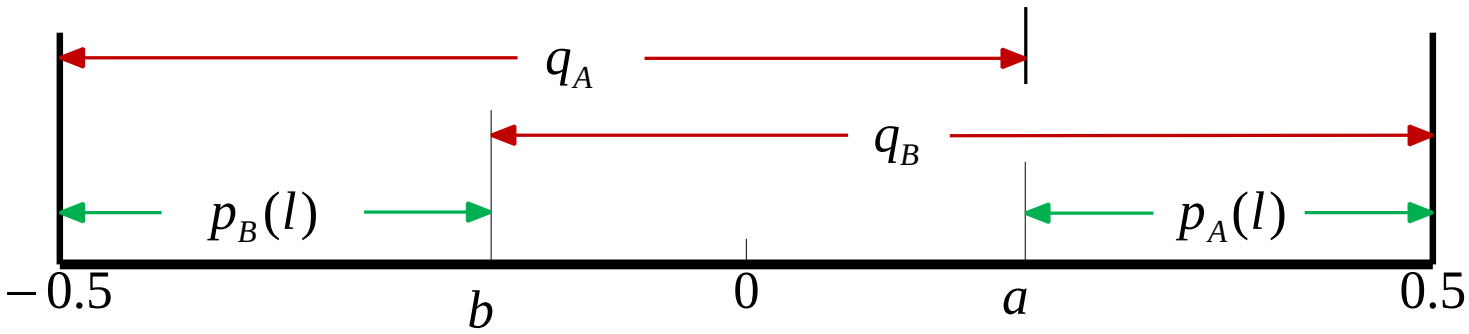



Figure 1

# 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

# Hotelling Competition with Uniform Pricing

- 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 $1/4$

# Naive v. Sophisticated Consumers

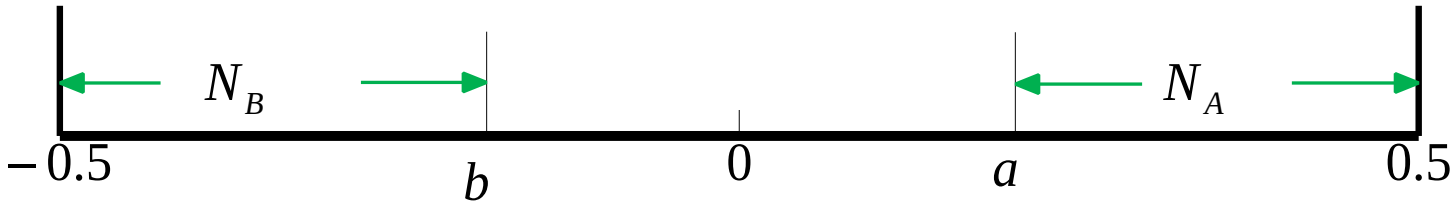
- Firm $A$'s targeted consumers will receive $p_A(I)$ from firm $A$ and $q_B$ from firm $B$
- In addition, a sophisticated consumer can bypass the hurdle and access to $q_A$ as well
- However, a naive consumer is unable to overcome the hurdle and is not eligible to $q_A$
- Likewise, a naive consumer of firm $B$ can compare $p_B(I)$ and $q_A$
- Whereas a sophisticated consumer of firm $B$ can access to $p_B(I)$, $q_A$ and $q_B$

# Non-Contestable Consumers

- 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 $\mathbf{N}_B \equiv [-0.5, \min\{b, 0\}]$ are non-contestable by firm $A$
- Likewise, firm $A$'s targeted consumers in $\mathbf{N}_A \equiv [\max\{a, 0\}, 0.5]$ are non-contestable by firm $B$
- The sets of non-contestable consumers are illustrated as follows

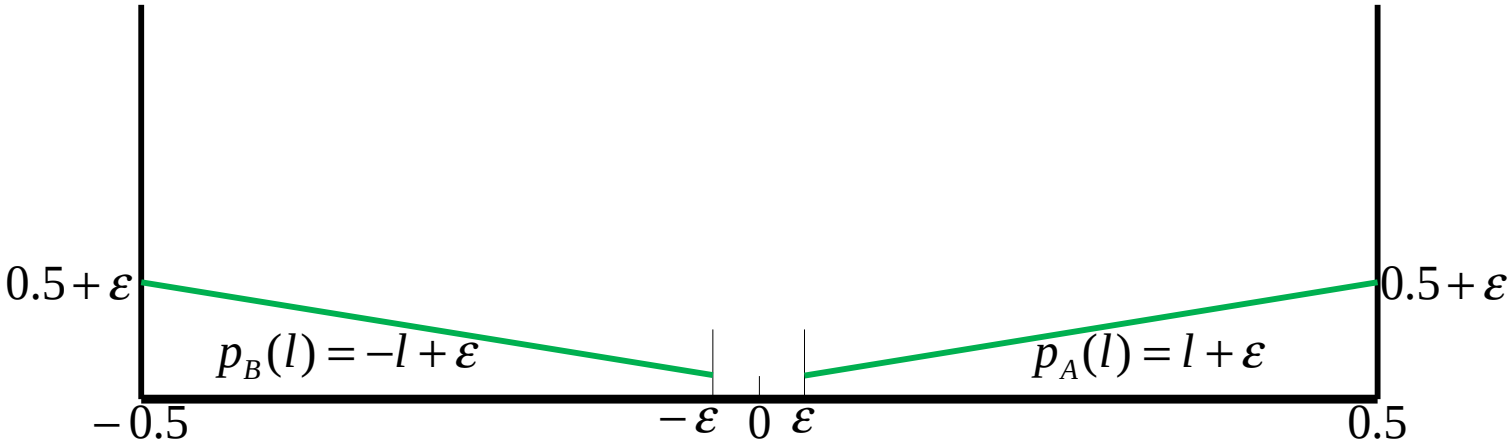


# Equilibrium with Naive Consumers: A Benchmark

- 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 $\varepsilon \to 0$, $\pi_A = \pi_B = 1/8$, firms earn the lowest profit
- Common wisdom: firms are worse off in competitive price discrimination



# Equilibrium with Sophisticated Consumers: Sharp Contrast

- 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

# Equilibrium with Sophisticated Consumers: Sharp Contrast

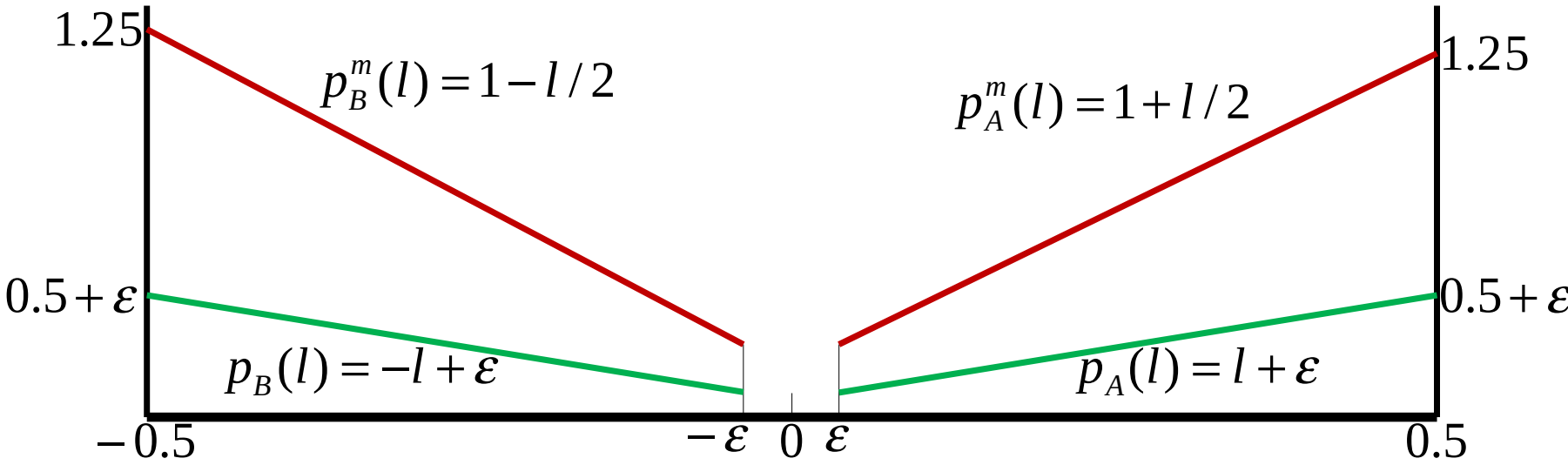
- Suppose a non-trivial proportion $\alpha$ of consumers are sophisticated
- These consumers can access to the low poaching price as well
- If firm $A$ sets poaching price $q_A = \varepsilon$, its profit from non-targeted consumers is equal to $\varepsilon^2$
- It is negligible for arbitrarily small $\varepsilon$
- 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

# Equilibrium with Sophisticated Consumers: Sharp Contrast

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



# Equilibrium with Sophisticated Consumers

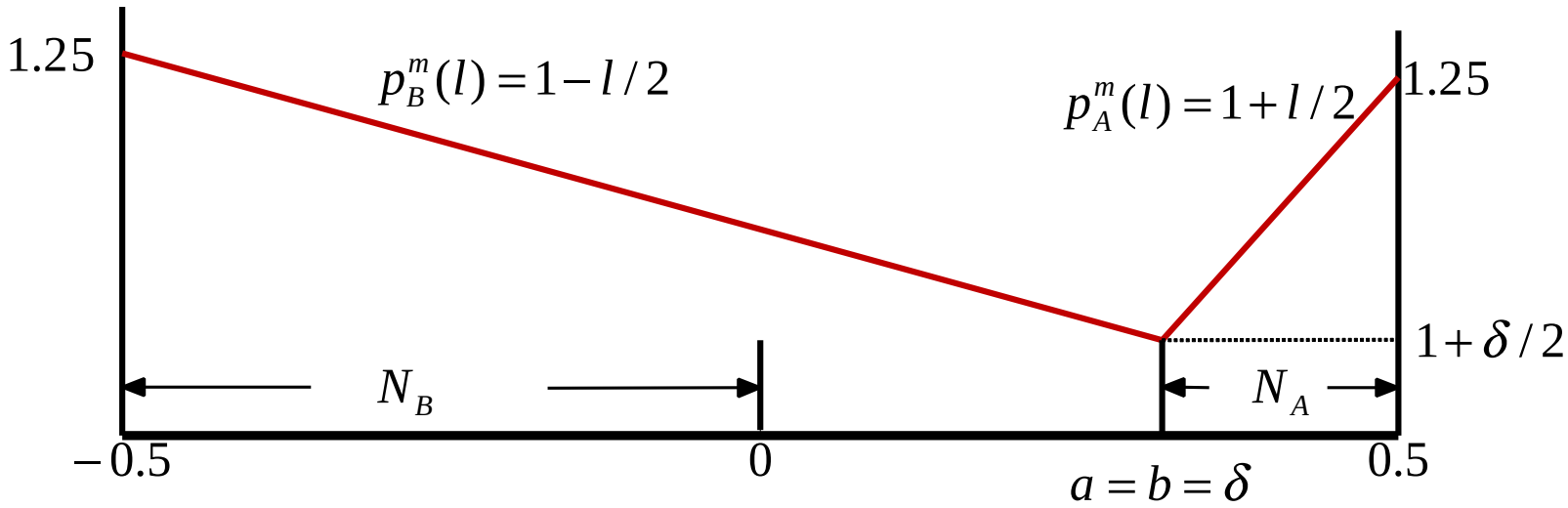
- How robust is this PPD equilibrium?
- When $a = b = 0$, this PPD equilibrium arises for any $\alpha > 0$
- As long as a tiny proportion of consumers are sophisticated
- Because both firms' target sets are non-contestable by the rival
- Consumers are targeted by either firm $A$ or firm $B$
- A small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

# Equilibria with Fully Targeted Consumers

- 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

$$\alpha \int_{\delta}^{0.5} \left(p_A^m(l) - q_A\right) dl = \alpha\left(\pi_A^*(\delta) - (0.5 - \delta) q_A\right)$$

- 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

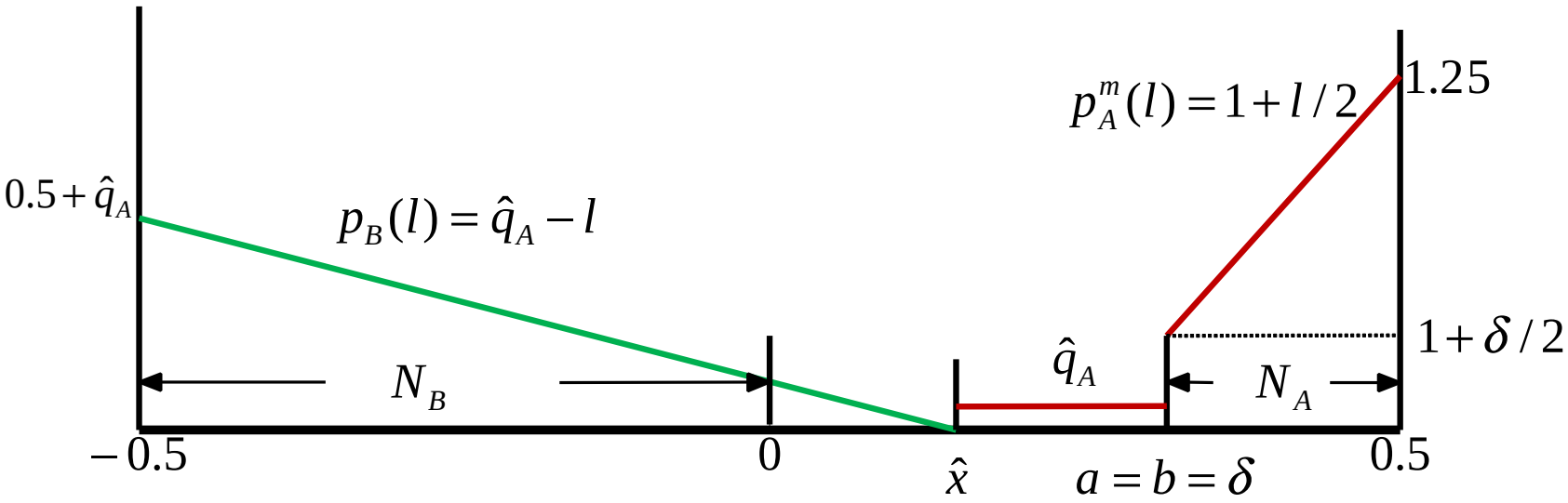
- Firm $A$ will not poach if the maximum net benefit $\Gamma(\delta) = (\hat{x})^2 - \alpha\pi_A^*(\delta) \leq 0$
- $\Gamma(\delta)$ increases with $\delta$, satisfying $\Gamma(0) < 0$ and $\Gamma(0.5) > 0$
- There exists a cut-off threshold $\bar{\delta}(\alpha)$ such that $\Gamma(\delta) \leq 0$ if 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

# Equilibria with Fully Targeted Consumers

- 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



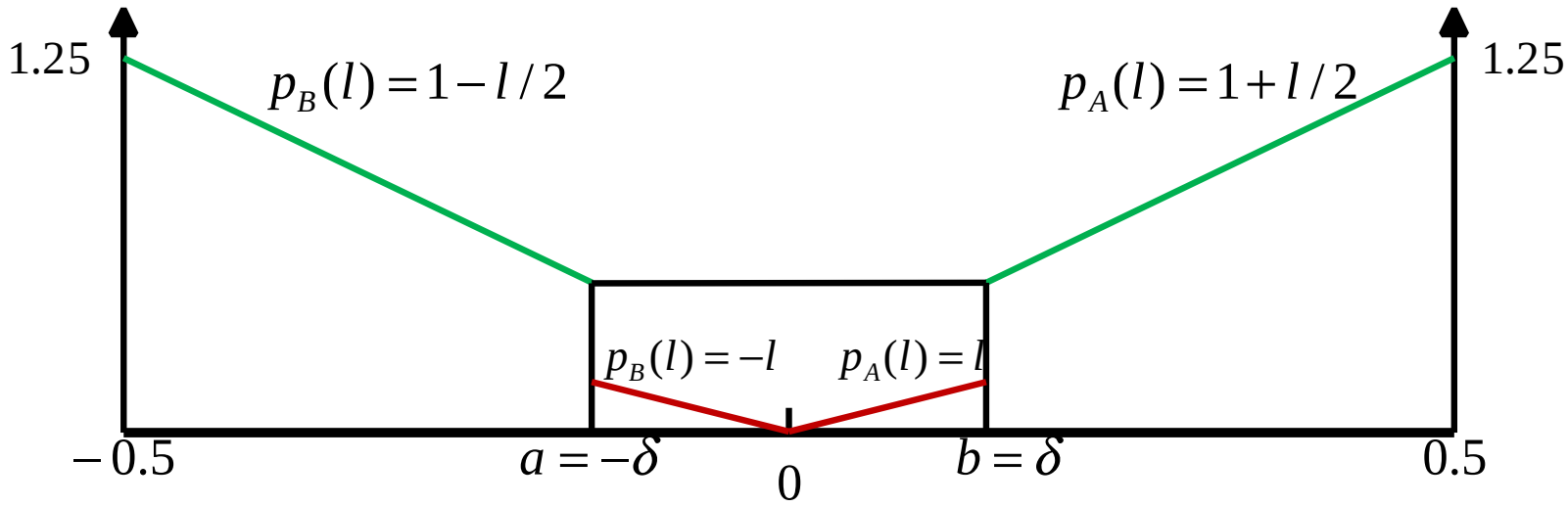

PPD Equilibrium with $\delta > \bar{\delta}(\alpha)$

# 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 $l \in [-0.5, -\delta]$

# Overlapping Target Zones

- The equilibrium mixes PPD and tough competition



# Overlapping Target Zones

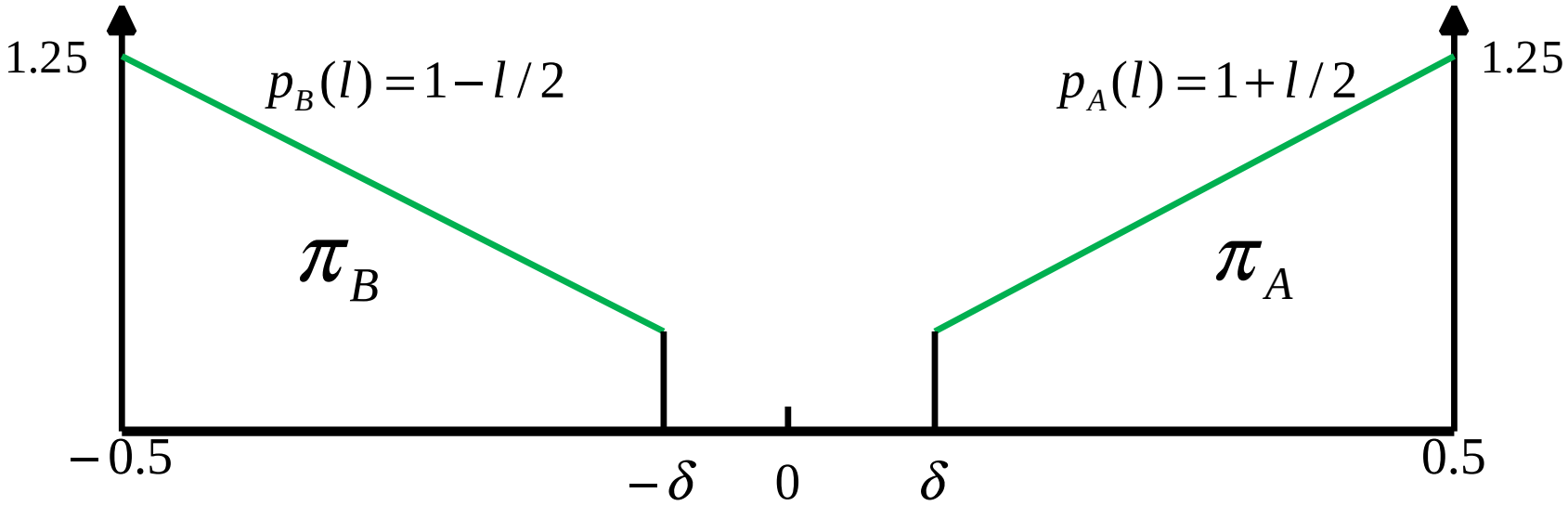
- Firms will not use uniform price to poach the rival
- Because consumers in $[-0.5, -\delta]$ are not contestable by firm $A$
- Likewise, those in $[\delta, 0.5]$ are not contestable by firm $B$
- Firms are worse-off with overlapping target zones
- In the extreme case when the whole market is overlapped
- 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)

# 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

# Equilibria with Non-targeted Consumers

- The PPD equilibrium with sufficiently small $\delta$



# 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 $2\delta\left(1 - \delta/2\right)$
- 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 $\alpha\left(\pi_A^*\left(\delta\right) - q_A^m\left(0.5 - \delta\right)\right)$
- There exists a cut-off level $\hat{\delta}\left(\alpha\right)$ such that firm $A$ will not deviate if $\delta \leq \hat{\delta}\left(\alpha\right)$
- PPD equilibrium can be sustained when $\delta \leq \hat{\delta}\left(\alpha\right)$

# 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 $q_A^m$ 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

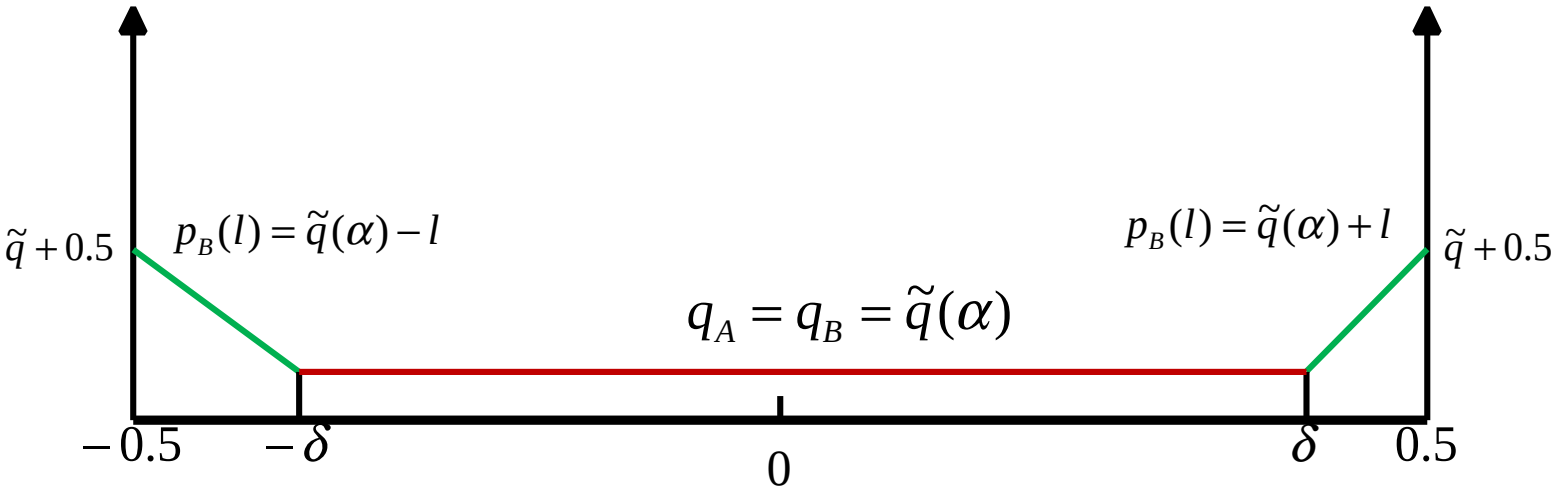
- If $\delta > \tilde{\delta}(\alpha)$, both firms have incentives to compete for non-targeted consumers
- However, competition is softened due to consumer sophistication
- Firms must take into account the foregone benefit in such competition
- The equilibrium uniform prices are then given by

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

- 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: $p_A(l) = \tilde{q}(\alpha) + l$ and $p_B(l) = \tilde{q}(\alpha) - l$
- These prices increase with $\alpha$

# Competition for Non-targeted Consumers

- Figure: Competition for non-targeted consumers



# 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 $a = b = \delta < \bar{\delta}(\alpha)$
- 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

# Policy Debate on Internet Privacy

- 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"

# Policy Implications

- 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
- 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

# Literature Review

- There is a growing literature of personalized pricing (or behavioral-based price discrimination)
- 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

# Literature Review

- 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