Personalized Pricing and Competitive Dispersion

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1 Motivation

- Companies today have access to huge amount of consumer data
- Personalized (or discriminatory) pricing has become more prevalent
- May be hidden: e.g. could appear as personalized discounts

What is welfare effect of personalized pricing?

- Generally, personalized pricing assumed harmful to consumers
- Often described as "transfer of value" from consumers to firms
- However, some theoretical results suggest otherwise

2 Existing results

- Classic result in Thisse and Vives (1988):
  - With one firm, personalized pricing harms consumers
  - With two firms, **personalized pricing benefits consumers**
- Personalized pricing and competition in Rhodes and Zhou (2022):
  - Environment more general (partial coverage, non-i.i.d. valuations etc)
  - With **full coverage**, **personalized pricing benefits consumers**
  - Welfare effect of personalized pricing depends on market coverage

Question

- In these models, all consumers face same number of firms
- All firms know the degree of competition (no. firms) they face
- What happens if we allow for **competitive dispersion**?
    - Dispersion in the degree of competition for a consumer
    - Different consumers "meet" a different number of firms
    - Can think of these firms as consumer's "consideration set"
    - Dispersion may be due to search frictions or otherwise
- **Does personalized pricing still benefit consumers?**

Environment

- Consider a single product market with large no. consumers
- Each consumer "meets" $n \geq 2$ firms ("consideration set")
- "Meet" $=$ the consumer has opportunity to trade with firm
- No. firms consumer meets is random and given by $\mathbb{P}$
- The "meeting technology" $\mathbb{P}$ captures **competitive dispersion**
- Expected no. firms each consumer meets is $\mathbb{E}_{\mathbb{P}}(n) = \theta$

How are prices determined?

- Two discrete choice models with random utility shocks
- Consumers draw i.i.d. utility shocks $(x_1, ..., x_n)$ from distbn G
- Assume that distbn G has log-concave density $g > 0$

Uniform pricing

- Firms choose prices **before** observing utility shocks and no. firms
- Extension of Perloff-Salop (1985) model to uncertain no. firms

Personalized pricing

- Firms choose prices **after** observing utility shocks and no. firms
- Essentially, this is asymmetric Bertrand competition

6 Equilibrium markup with uniform pricing

- Consider standard case: every consumer "meets" $n \geq 2$ firms
- Firms set prices p_i **before observing shocks** $(x_1, ..., x_n)$
- In symmetric equilibrium, all firms set same price, $p_i = p$
- Consumer purchases from firm with highest x_i
- For $n \geq 2$ firms, markup $p - c$ is

$$\mu^U(n) = \frac{1}{n\mathbb{E}_{H_n}(g(x))}$$

where exp value is wrt distribn of max, $H_n(x) \equiv G(x)^n$

7 Equilibrium markup with personalized pricing

- Consider standard case: every consumer "meets" $n \geq 2$ firms
- Prices p_i set by firms **after observing shocks** $(x_1, ..., x_n)$
- Consumer purchases from firm with highest x_i
- Markup equals highest shock minus second-highest, $\mu_n = M_n - S_n$
- For $n \geq 2$ firms, average markup $\mathbb{E}(M_n - S_n)$ is

$$\mu^D(n) = \mathbb{E}_{H_n}\left(\frac{1 - G(x)}{g(x)}\right)$$

where exp value is wrt distribn of max, $H_n(x) \equiv G(x)^n$

8 Uniform pricing with competitive dispersion

- Firms choose prices **before observing shocks and no. firms**
- The average markup with uniform pricing is

$$\mu^U_{\mathbb{P}}(\theta) = \frac{1}{\theta \mathbb{E}_{H_{\mathbb{P}}}(g(x))}$$

where exp value is wrt distribn of max,

$$H_{\mathbb{P}}(x;\theta) = \sum_{n=2}^{\infty} \mathbb{P}(n;\theta) G(x)^n$$

Personalized pricing with competitive dispersion

- Firms choose prices **after observing shocks and no. firms**
- The average markup with personalized pricing is

$$\mu_{\mathbb{P}}^{D}(\theta) = \mathbb{E}_{H_{\mathbb{P}}}\left(\frac{1 - G(x)}{g(x)}\right)$$

where exp value is wrt distribn of max,

$$H_{\mathbb{P}}(x; \theta) = \sum_{n=2}^{\infty} \mathbb{P}(n; \theta) G(x)^{n}$$

Simple example (no dispersion)

- Let distbn of shocks G be uniform with support $[1, 2]$
- For $n \geq 2$ firms, the uniform markup is

$$\mu^U(n) = \frac{1}{n}$$

and the average personalized markup is

$$\mu^D(n) = \frac{1}{n+1}$$

- Therefore, we have

$$\frac{\mu^U(n)}{\mu^D(n)} = 1 + \frac{1}{n} > 1$$

- **Personalized pricing always benefits consumers**

- **Uniform pricing:** prices set before observing shocks and no. firms
- If G is uniform, the uniform markup is

$$\mu_{\mathbb{P}}^{U}(\theta) = \frac{1}{\theta}$$

- **Personalized pricing:** prices set after observing shocks and no. firms
- If G is uniform, the average personalized markup is

$$\mu_{\mathbb{P}}^{D}(\theta) = \sum_{n=2}^{\infty} \mathbb{P}(n;\theta) \frac{1}{n+1}$$

- Therefore, we have

$$\frac{\mu_{\mathbb{P}}^{U}(\theta)}{\mu_{\mathbb{P}}^{D}(\theta)} = \frac{1}{\theta \sum_{n=2}^{\infty} \mathbb{P}(n;\theta) \frac{1}{n+1}}$$

- **Does personalized pricing still benefit consumers?**

Simple example

- Suppose expected no. firms a consumer "meets" is $\theta = 5$
- E.g., if $n = 5$ firms with probability one, then $\frac{\mu_{\mathbb{P}}^{U}(\theta)}{\mu_{\mathbb{P}}^{D}(\theta)} = 1 + \frac{1}{5} > 1$
  - **personalized pricing benefits consumers**
- If $n = 4$ or $n = 6$ with equal probability, then $\frac{\mu_{\mathbb{P}}^{U}(\theta)}{\mu_{\mathbb{P}}^{D}(\theta)} = 1 + \frac{1}{6} > 1$
  - **personalized pricing benefits consumers (by less)**
- If $n = 2$ or $n = 8$ with equal probability, then $\frac{\mu_{\mathbb{P}}^{U}(\theta)}{\mu_{\mathbb{P}}^{D}(\theta)} = \frac{9}{10} < 1$
  - **personalized pricing now harms consumers!**

13 Effect of competitive dispersion

Proposition

If G has a log-concave density, then a mean-preserving spread of the distribution $\mathbb{P}$ (i.e. an increase in the degree of competitive dispersion)

1. *Decreases the average trade surplus $S_{\mathbb{P}}(\theta)$*
2. *Increases the average personalized markup $\mu^D_{\mathbb{P}}(\theta)$*
3. *Weakly decreases the uniform markup $\mu^U_{\mathbb{P}}(\theta)$ if $G'' < 0$*
4. *Decreases the uniform-personalized markup ratio $\frac{\mu^U_{\mathbb{P}}(\theta)}{\mu^D_{\mathbb{P}}(\theta)}$ if $G'' < 0$*

- Greater dispersion in no. firms each consumer "meets"
  - $\Rightarrow$ personalized pricing relatively **more** attractive for firms
  - $\Rightarrow$ personalized pricing relatively **less** attractive for consumers

14 Competitive limit: large number of firms

- Suppose every consumer "meets" large number of firms
- Consider asymptotic behavior of markups as $\theta \to \infty$
- To do this, we restrict attention to class of distbns $\mathbb{P}$
- Class of distbns called invariant in Lester, Visschers, Wolthoff (2015)
- An "approximation" for relatively competitive markets

Asymptotic behavior of markups

- Therefore, the asymptotic ratio of uniform to personalized markups is

$$\frac{\mu_{\mathbb{P}}^{U}(\theta)}{\mu_{\mathbb{P}}^{D}(\theta)} \sim_{\theta\to\infty} \frac{1}{\Gamma(1-\gamma)\Gamma(2+\gamma)} \underbrace{\frac{1}{\varphi_{\mathbb{P}}(\gamma)\varphi_{\mathbb{P}}(-1-\gamma)}}_{\textit{effect of comp dispersion}}$$

- Here γ is **tail index** of the distbn of utility shocks G
- Generalizes results in Gabaix et al (2016) to incorporate dispersion

16 Asymptotic behavior of markups

- Define **measure of dispersion** by

$$d_{\mathbb{P}}(k;\theta) \equiv \left| \frac{E_{\mathbb{P}}(X^k) - E_{\mathbb{P}}(X)^k}{E_{\mathbb{P}}(X)^k} \right| \text{ for } k \in \mathbb{R}$$

- Define **asymptotic dispersion** of $\mathbb{P}$ by

$$d_{\mathbb{P}}(k) \equiv \lim_{\theta\to\infty} d_{\mathbb{P}}(k;\theta) \text{ for } k \in \mathbb{R}$$

- The asymptotic ratio of uniform to personalized markups is

$$\frac{\mu^U_{\mathbb{P}}(\theta)}{\mu^D_{\mathbb{P}}(\theta)} \sim_{\theta\to\infty} \frac{1}{\Gamma(1-\gamma)\Gamma(2+\gamma)} \underbrace{\frac{1}{(1+d_{\mathbb{P}}(\gamma))(1+d_{\mathbb{P}}(-1-\gamma))}}_{\textit{effect of comp dispersion}}$$

- Uniform-personalized ratio is **decreasing** in asymptotic dispersion

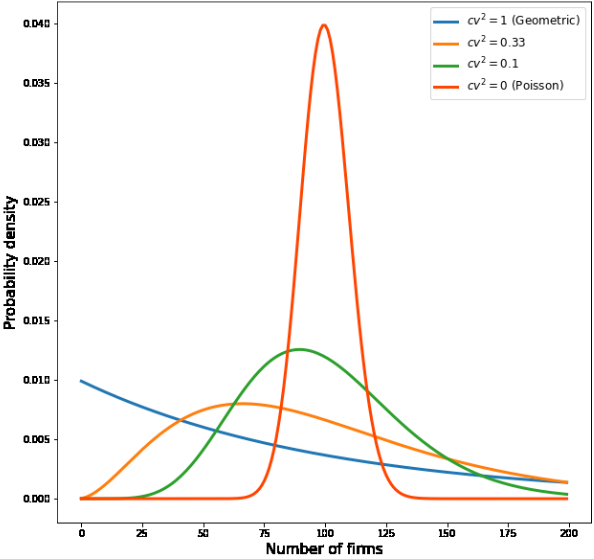
Negative binomial family

- If $\mathbb{P}$ is negative binomial with parameter $r \in \mathbb{N}$, then

$$\lim_{\theta \to \infty} cv^2_{\mathbb{P}}(\theta) = cv^2_{\mathbb{P}} = \frac{1}{r}$$

- Measure of asymptotic dispersion is $1/r \in (0, 1]$
- **Geometric.** In the special case $r = 1$, we have $cv^2_{\mathbb{P}} = 1$
- **Poisson.** In the limit as $r \to \infty$, we have $cv^2_{\mathbb{P}} = 0$
- No asymptotic effect of competitive dispersion for Poisson

Negative binomial family



When does personalized pricing benefit consumers?

Proposition

Suppose that $\mathbb{P}$ is negative binomial and G has a log-concave density. There exists a unique cut-off degree of asymptotic dispersion $c(\gamma)$ such that, if the expected number of firms θ is sufficiently high, then

1. **Personalized pricing benefits consumers** *if degree of asymptotic dispersion is suff. low, i.e.* $cv_{\mathbb{P}}^2 < c(\gamma)$
2. **Personalized pricing harms consumers** *if degree of asympototic dispersion is suff. high, i.e.* $cv_{\mathbb{P}}^2 > c(\gamma)$

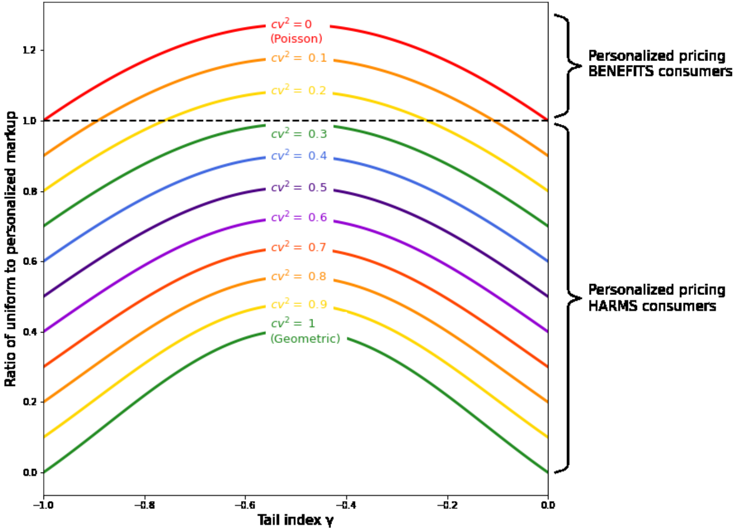
When does personalized pricing benefit consumers?

Proposition

Suppose that $\mathbb{P}$ is negative binomial and G has a log-concave density. If the expected number of firms θ is sufficiently high, then **personalized pricing harms consumers** *if the degree of asympototic dispersion is sufficiently high, i.e.* $cv_{\mathbb{P}}^2 > 1/3$.

- Compare to Rhodes and Zhou (2022), full coverage + no dispersion:
  - For any $\gamma \in (-1, 0)$, if the exp. number of firms θ is sufficiently high, then **personalized pricing benefits consumers**

Uniform-personalized markup ratio



Conclusion

- Welfare effects of personalizing pricing depend on comp dispersion
- **Personalized pricing benefits firms and harms consumers if the degree of competitive dispersion is sufficiently “high”**

A1 Literature

- Rhodes and Zhou (2022)
  - Personalized versus uniform pricing (no comp dispersion)
  - Environment more general (partial coverage, non-i.i.d. valuations)
- Gabaix, Laibson, Li, Li, Resnick, and de Vries (2016)
  - Considers broad class of random utility models
  - Asymptotic results regarding markups for large no. firms
- Lester, Visschers, and Wolthoff (2015)
  - Class of meeting technologies called "invariant"
  - Meeting technology captures search frictions
- Mangin (2022)
  - Personalized pricing with random no. competing firms
  - What is effect of greater competition (more firms) on prices?