Product Line Design with Frictions

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Motivating picture

Motivation

- Current marketplaces characterized by having many products available

    e.g. searching for computer on Amazon: over 100,000 results!

- Impossible for consumers to consider all those options

    (even if many of them irrelevant or redundant)

- Seller's profits are impacted by this behavior

    $\Rightarrow$ it could influence her product mix decisions

Question:

How does limited consideration impact product line design decisions?

Preview: Model

Mixes random search and price discrimination

- From **Mussa & Rosen (1978)** import **screening & price discrimination**
- From **Burdett & Judd (1983)** import **random simultaneous search**

Key ingredients:

- A monopolist producing a vertically differentiated good,
- Free to choose number of products to offer and their characteristics
- Heterogeneous consumers
- Operating in a within-firm simultaneous search environment

Preview: Results

- Optimal product line is **unbalanced**:
  $\Rightarrow$ some products are made more likely to enter consumers' consideration sets than others

- Product quality may increase or decrease relative to full-consideration

- "Premium" items get no quality distortions, while "non-premium" do

Related Literature

- **Screening + Search:** Garrett et al. (2018), Lester et al. (2019), Fabra & Montero (2022), Nocke & Rey (2023)

    ⇒ **This paper: within-firm search by a monopolist with endogenous products**

- **Limited/partial consideration:** Ursu et al (2021), Safonov (2022), Fershtman & Pavan (2022)

    ⇒ **This paper: focuses on the seller's problem**

- **Revenue maximization with limited information:** Dhangwatnotai et al (2015), Hart & Nisan (2017, 2019), Babaioff et al (2018), Daskalakis & Zampetakis (2020), Fu et al. (2021), Bergemann et al (2021)

    ⇒ **This paper: consumers using samples rather than seller**

Model

A monopolist and a unit-measure of consumers in a vertically differentiated market

- Monopolist produces good of quality $q \in [0, \overline{Q}]$
- Cost of producing a good of quality q is $\varphi(q)$, increasing and convex
- The monopolist designs a finite **product line** over a unit-measure of slots:
  - A product $i = (q_i, p_i, s_i)$:
    - q_i - quality of product i
    - p_i - price of product i
    - s_i - fraction of slots allocated to product i
  - Slots allocated to product i determine how often product i enters consumers' consideration sets

Model: slots

- Interpretation of slots:
  - Shelf space for offline stores
  - Product placement on a website
  - Allocation of a fixed advertising budget across different products
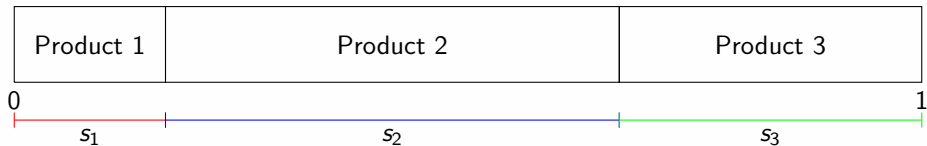
Model: consumers

- Consumers have single-unit demands
- Private valuations
  - Fraction $\mu_\ell > 0$ has low valuation θ_ℓ
  - Fraction $\mu_h = 1 - \mu_\ell$ has high valuation $\theta_h > \theta_\ell$
- Utility from product i: $\theta q_i - p_i$
- **Limited consideration**:
  - Consumers do not observe the full menu
  - Each consumer inspects **two randomly drawn slots**
  - Can choose only among these products (or walk away)

Model: timing

① Monopolist designs her product line

② Consumers learn their valuation and inspect 2 slots at random

③ Consumers choose the best inspected product or walk away

t = 1	**t = 2**	**t = 3**
Monopolist designs product line	Consumers inspect two slots	Consumers decide what to purchase
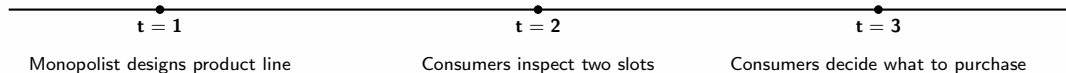
Model: consideration sets

- Frictions lead to the formation of consideration sets
- Slot allocation determines the probability of different consideration sets
- These sets could contain either
  - two different products i and j with probability $2s_i s_j$
  - only one product i with probability $(s_i)^2$
- Random inspection capture attention or processing capacity limitations

Some Remarks

- **No targeting**: same product line for both types of consumers
- **No tracking**: product line is fixed, no conditioning on observed products
- **No uncertainty on the value of a product**: once inspected, real value is learned
- **Fixed search intensity**: sample size is exogenous and fixed

Two Benchmarks

1. Full-information product line:
   - Maximize surplus for each type and charge their exact valuation

   $$q_i^* : \varphi'(q) = \theta_i \qquad p_i = \theta_i \cdot q_i^*$$

2. Optimal product line under asymmetric information (and full-consideration)

   $$q_\ell : \varphi'(q_\ell) = \theta_\ell - \frac{\mu_h}{\mu_l}(\theta_h - \theta_\ell) \qquad q_h = q_h^*$$

   $$p_\ell = \theta_\ell q_\ell \qquad\qquad p_h = \theta_h q_h^* - (\theta_h - \theta_\ell) q_\ell$$

   - Classic no-distortion at the top, high types having informational rents, and low quality distorted
   - Any distribution of slots in which each product receives a positive fraction is equivalent in this case

- In both cases, matching between products and types is perfect

Limited Consideration: what changes?

- Under search frictions, matching between consumers and products is imperfect

- Therefore, the classic tradeoff behind quality distortions also changes

- Seller has an additional lever to adjust her product line: the allocation of slots or "salience" for each product

Main result

Theorem 1

The optimal product line is unbalanced: the fraction of slots used across products cannot be the same.

- Some products are made more salient than others.
- Salience and distortions reinforce each other, which alter the characteristics of the product line

Main result: intuition

- Consider two products: A and B
- Let V_M be the profits of a menu M under full-consideration
- Suppose $V_{AB} > V_A \geq V_B$

Main result: intuition

- Start from a menu containing only product A
  $\Rightarrow$ profits V_A

- Adding a small fraction of B creates:

$$\text{Gain:} \quad V_A \rightarrow V_{AB}$$
$$\text{Loss:} \quad V_A \rightarrow V_B$$

- If $V_A = V_B$: no loss in including B, better to maximize probability of $\{A, B\}$
  $$\Rightarrow \text{balanced menu is optimal}$$

- If $V_A > V_B$: optimal menu must balance cost and benefits of including B
  $$\Rightarrow \text{optimal menu is biased towards } A$$

Main result: intuition

- If products were fixed analysis ends there
- Flexibility allows to adjust the own characteristics of products A and B
- Bias toward A increases incentives to reduce distortions (either in price or quality) in A (and increasing distortions in B)
- With more than two products, a similar argument follows

Also in the paper

- Some intermediate results
  - Products always come in pairs: premium and standard versions
  - No distortion at the top: premium items all have quality $q = q_h^*$
  - Low quality distortions: non-premium items have quality $q < q_\ell^*$

- Optimal product line if consumers inspect a single slot

- Challenge: no revelation principle

Concluding Remarks

- I proposed a model of price discrimination under information and search frictions
- Search frictions **change** the optimal product line
- Optimal menus are always **unbalanced**: firms bias salience toward more profitable products
- Salience becomes an extra tool for the monopolist alongside price and quality

Thanks!

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