The paradox of platform recommendations: Harmful in markets they are needed most

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Importance of recommender systems

- In the era of digitalization, recommender systems have become a cornerstone of user engagement on platforms.
- The reason for their widespread use is that they address core frictions in consumer decision-making, such as
  - search costs: Brynjolfsson et al. (2006), Hinz and Eckert (2010),
  - information overload: O'Donovan and Smyth (2005),
  - choice overload: Bollen et al. (2010),

  by narrowing down options and personalizing suggestions.
- Consequences are, i.a., enhanced user satisfaction (Kim et al., 2021), increased user retention and revenue growth (Gomez-Uribe and Hunt, 2015; MacKenzie et al., 2013).

”Frequently bought together” on Amazon

All Today's Deals Registry Prime Video Gift Cards Customer Service Sell

Added to cart

Size: 40-Inch
Style: F6000 Series

Customers who bought items in your cart also bought

Mounting Dream TV Wall Mount for 32-65 Inch

★★★★★ 42,974

18% off Limited time deal

$39.98

SAMSUNG 65-Inch Class 4K Crystal UHD DU8000 Series

★★★★½ 1,483

SAMSUNG 50-Inch Class Crystal UHD 4K DU7200

★★★★☆ 3,675

Pipishell Full Motion TV Monitor Wall Mount Bracket

★★★★½ 130,278

$17.99

List Price: ~~$24.96~~

How recommender systems affect consumer decisions

- Generally, recommender systems can affect consumer decisions by
  - (i) suggesting substitutes or complements,
  - (ii) in various phases during the process.
- Screening phase: consumers compare, e.g., functionality, prices, features, aesthetics, i.e., they browse information.
- Purchasing phase: consumers identify the best alternative and would like to augment valuation of the chosen product.
- Zhang and Bockstedt (2020) empirically find that substitutes are preferred during screening, while complements are favored during purchasing.

Recommender systems and promotion of substitutes

- We focus on the screening phase, where substitute recommendations are most relevant to consumers.
- We abstract from strategic bias by the platforms: recommendations enhance consumer welfare by intensifying seller competition.
- We show that even if platforms do not bias visibility, can consumers be harmed by exposure to alternatives.

Recommender systems and product uncertainty

- We analyze the implications of recommender systems in a setting where product uncertainty is the main friction.
- When consumers consider a product, performance is often unclear due to lack of information/gaps in understanding.
- In offline markets, individuals can physically evaluate products by inspecting or testing them.
- In online markets, individuals suffer from the inability to mitigate product uncertainty by inspecting and testing.

Recommender systems and product uncertainty

- In our setting, the recommender system can help mitigate product uncertainty.
- The reason is that information provided on a different product page serves to fill in information gaps.

$\Rightarrow$ Substitutes share overlapping features that help infer the focal product's performance or reliability either

  - directly from the substitute product's description, or
  - indirectly from user reviews of the substitute product.

Related literature

- Literature on bias in recommender systems:
  - systemic bias: Fleder and Hosanagar (2009), Abdollahpouri et al. (2019), Abdollah and Mansoury (2020), Calvano et al. (2023, WP)
  - design bias: Lee (2023, WP), Fletcher et al. (2023a, WP; 2023b, WP)
  - strategic bias:
    (i) Platform-diverted search: Hagiu and Jullien (2011, RAND), Dinerstein et al. (2018, AER), Bourreau and Godin (2022, JEMS), Teh and Wright (2022, AEJ: Micro), Donnelly et al. (2024, Mark. Sci.), Zhou et al. (2024, Manag. Sci.)
    (ii) Self-preferencing: De Corniere and Taylor (2019, RAND); Aridor and Gonçalves (2022, IJIO), Hagiu et al. (2022, RAND), Raval (2022, WP), Chen and Tsai (2024, RAND)
    (iii) Paying for prominence: Arbatskaya (2007, RAND), Armstrong et al. (2009, RAND), Armstrong and Zhou (2011, EJ), Bar-Isaac and Shelegia (2022, WP)

The basic setting

- Consumers buy a product they derive uncertain utility from and sellers offer their product through a platform.

- Consumer utility is represented by an exponential utility function (Phelps, 2024, JRiskU)

$$U(v) = 1 - e^{-\alpha_p(v - P - \alpha_r \psi)},$$

with

  - v stand alone utility,
  - P price,
  - ψ random variable that captures the uncertainty over the product's valuation ($\psi \sim \mathcal{N}(0, \sigma_H^2)$),
  - α_p and α_r consumers' price and risk sensitivity, respectively.

The basic setting

- Exponential utility: risk aversion plus diminishing marginal utility, but is more complex than the linear utility (Pratt, 1964 Econ, Arrow, 1965, Phelps, 2024, JRiskU).

- The assumption of the normal distribution allows us to separate risk and express expected utility as

$$\mathbb{E}[U] = 1 - e^{-\alpha_p(v-P)} e^{\alpha_\sigma \sigma_H^2}.$$

- There are two producers (Firm 1 and Firm 2) whose products are only available through the platform.

- Firms engage in quantity competition, but we generalize the standard quantity competition model to allow for awareness of only one product.

The basic setting

- We assume that consumers are exogenously divided into three masses ($\phi_i = 0$ is the standard Cournot model):
  - a mass ϕ_1 (ϕ_2) only observe Firm 1's (2's) product,
  - a mass $1 - \phi_1 - \phi_2$ observe both so that $\phi_1, \phi_2, \phi_1 + \phi_2 \in [0, 1]$,
  - Interpretation: ϕ_i arrival rate to Firm i's product.
- The platform can distinguish between consumer types and use recommendations on product pages.
- Platform chooses to recommend to a fraction $(1 - \lambda_i)$, where $\lambda_i \in [0, 1]$.
- This increases the number of consumers that see both products such that the three groups amass to
  - $\lambda_1\phi_1$ [$\lambda_2\phi_2$] who only observe Firm 1's [Firm 2's] product,
  - $(1 - \lambda_1\phi_1 - \lambda_2\phi_2)$ who observe both firms, where $\lambda_1\phi_1 + \lambda_2\phi_2 \in [0, 1]$.

The basic setting

- A lower λ_i implies a higher exposure of consumers to recommendations of substitute product j.
- A recommendation is directly beneficial to consumers because it reduces uncertainty from σ_H^2 to $\sigma_L^2 \leq \sigma_H^2$.
- The reason is that information provided on a different product page serves to fill in information gaps.

The basic setting

- Consumers differ in their stand-alone value, which is distributed according to a cdf $G(v)$ with density $g(v)$ on the support $[\underline{v}, \bar{v}]$.
- Consumers purchase the product if their expected utility is non-negative, i.e., $E(U(v)) \geq 0$.
- Hence, the marginal consumers are determined by

$$1-e^{-\alpha_p(v_i^*-P)}e^{\alpha_\sigma\sigma_i^2} = 1-e^0 \quad \Leftrightarrow \quad v_i^* = P+\frac{\alpha_\sigma}{\alpha_p}\sigma_i^2, \quad i = H, L$$

- Market demand is therefore given by

$$Q = (\lambda_i\phi_i + \lambda_j\phi_j)[1 - G(v_H^*)] + (1 - \lambda_i\phi_i - \lambda_j\phi_j)[1 - G(v_L^*)]$$

The basic setting

- Firms are symmetric in their marginal costs, c, and face the same ad valorem fee charged by the platform, f.
- Firm i maximizes profit with respect q_i where profit is

$$\pi_i = [(1 - f)P - c] \cdot q_i.$$

- The platform maximizes profits from the sale of the two products by choosing λ_1 and λ_2 where profit reads

$$\Pi = f \cdot PQ - \kappa(\lambda_i, \lambda_j),$$

where $\kappa(\lambda_i, \lambda_j)$ is a convex cost related to providing recommendations.

Recommendations and equilibrium quantity

- How does greater exposure to recommendations of a substitute product affect equilibrium quantity?

$$\frac{dQ}{d\lambda_i} = \Omega \left[g\left(v_H^*\right) - 2g\left(v_L^*\right) \right],$$

where $\Omega > 0$ if $g(v)$ is not too log-concave.

- Generally, the effect is ambiguous and depends on the shape of $g(v)$.

- Intuition: A higher exposure of consumers to recommendations of a substitute product
  1. increases competition between firms, which reduces the equilibrium price,
  2. reduces uncertainty and raises consumers' willingness to pay which increases the equilibrium price.

Recommendations and equilibrium quantity

- To see that this ambiguity arises from the reduction in uncertainty, assume that $\sigma_L^2 = \sigma_H^2$, which implies

$$\frac{dQ}{d\lambda_i}|_{v_L^*=v_H^*} = \Omega\left[g\left(v_H^*\right) - 2g\left(v_H^*\right)\right] = -\Omega g\left(v_H^*\right) < 0,$$

  i.e., more recommendations (a lower λ_i) lead to a higher output.

- If $g(v)$ is not too log-convex, .i.e, $\frac{g'(v)}{g(v)}$ not too positive, then $g(v_H^*) < 2g(v_L^*)$, which implies $\frac{dQ}{d\lambda_i} < 0$.

- If $g(v)$ is sufficiently log-convex, .i.e, $\frac{g'(v)}{g(v)}$ sufficiently positive, then $g(v_H^*) > 2g(v_L^*)$, which implies $\frac{dQ}{d\lambda_i} > 0$.

Recommendations and consumer surplus

- The effects on equilibrium quantity is a stepping stone for the effects on consumer surplus.

- A higher exposure of recommendations of a substitute product is beneficial to consumers if
  1. the reduction in uncertainty is negligible, or
  2. $g(v)$ is log-concave.
- A higher exposure of recommendations of a substitute product is harmful to consumers if
  (i) $g(v)$ is sufficiently log-convex,
  (ii) product visibility is sufficiently low either because recommendations are sufficiently costly (convexity of $\kappa(\cdot)$) or arrival rates are low (ϕ_i, ϕ_j)

Interpretation of the results: Mature markets

- Log-concave demand is commonly associated with mature or mass markets where preferences are well-established.
- Such preferences are often seen in short-tail markets where demand is concentrated around generic products.
- In addition, the informational value of recommendations is often minimal in short-tail, mature or mass markets.
- This is because products are either already well-known or product descriptions and reviews are very informative.
- Hence, recommendations function as competitive force, which drives down prices and increase consumer surplus.

$\Rightarrow$ Recommendations are beneficial for consumers in mature markets.

Interpretation of the results: Niche markets

- Young or niche markets tend to exhibit a wide dispersion of willingness to pay across consumers.
- Diverse preferences are often seen in long-tail markets that the literature has described by power-law sales distributions.
- Power-law sales distributions strongly suggest log-convex demand as they reflect a heavy-tailed demand distribution.
- In addition, niche markets face significant challenges to generate accurate recommendations due to data scarcity.
- Moreover, arrival rates are scattered across a large number of niche products and are therefore low for each product.

$\Rightarrow$ Recommendations are harmful for consumers in niche markets.

Recommendations in niche markets

- Conventional wisdom suggests that recommender systems are particularly valuable in niche markets.
- Reason: Limited information makes informed purchases costly, while recommendations reduce decision costs.
- We challenge this presumption because under these very conditions, recommendations can harm consumers.

$\Rightarrow$ This paradox highlights the need to meticulously consider market characteristics when evaluating consumer welfare.

Optimal platform policy

- Whether the platform increases consumers' exposure to recommendations of a substitute product depends on:
  - (i) the shape of the market demand,
  - (ii) sellers' production costs, and
  - (iii) arrival rates.
- Our results show that fostering recommendations can be either beneficial or detrimental under similar demand structures.
- It is therefore useful to highlight practically relevant cases to draw meaningful implications.

Optimal platform policy: Mature markets

- As mentioned before, mature and short-tail markets are characterized by log-concave demand.
- Due to the high concentration of demand across a few generic products, arrival rates are arguably high.
- Moreover, although some counter examples exist, these markets are typically characterized by low-to-intermediate marginal production costs due to economies of scale.
- Our analysis shows that the platform will
  - not recommend a substitute product in low-cost markets,
  - make recommendations in intermediate-cost markets.

$\Rightarrow$ The recommender system does not provide benefits to consumers in low-cost segments.

Optimal platform policy: Niche markets

- Niche/long-tail markets are characterized by log-convex demand.
- Due to the widespread demand across a large range of products, arrival rates are arguably low.
- Long-tail products often rely on digital or on-demand production, meaning that marginal production costs are typically low-to-intermediate.

$\Rightarrow$ Our analysis shows that it is beneficial for the platform to recommend a substitute product under these conditions.

$\Rightarrow$ This result rounds off the paradox as the interests of the platform and the consumers are not aligned.

Extensions

- A Hybrid Platform: The Platform as a Seller.
- Within Page Recommendations as Ads.
- Endogenous fees, f.
- More competitors: n-firms.

Conclusions

- Recommender systems can be positive for consumers in mature markets under specific conditions.
- Recommender systems are harmful for consumers in niche markets.
- This seems paradoxical as conventional wisdom suggests that recommender systems are particularly valuable in niche markets.
- Our analysis highlights that it is important to consider the market characteristics when evaluating whether platform and consumers preferences are misaligned.