Consumer Reviews and Dynamic Price Signaling

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Question

★★★★★ **Great quality for the price!**

Reviewed in the United States us on January 1, 2022

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Research Question: How do reputational incentives affect prices?

Motivation

(1) Lower prices $\longrightarrow$ better reviews

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Firm's tradeoff

- Lowering price improves reputation and increases future profits
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When do firms ***underprice*** *their product below the myopic optimum?*

Model Overview

Single long-lived firm

- Firm strategically prices its product
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Multiple short-lived consumers

- Rational consumers observe past reviews and the current price
  - Past prices are unobserved
- Reviews depend on the utility of consumption of experience good:
  - Price
  - Product quality (vertical differentiation)
  - IID taste shock (horizontal differentiation)

Results Preview

Main results

(1) Underpricing occurs iff ratio of $\underbrace{\textit{marginal}}_{\text{review if underpriced}}$ to $\underbrace{\textit{inframarginal}}_{\text{review w/o underpricing}}$ reviewers is high.

- **Does not occur** if consumer's tastes are too diverse (uniform case)
- **Occurs** if vertical quality differentiation $>$ horizontal taste differentiation

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- The high-quality firm prices lower than the low-quality firm.

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(2) Underpricing can only happen at low current "reputation".

- The high-quality firm prices lower than the low-quality firm.

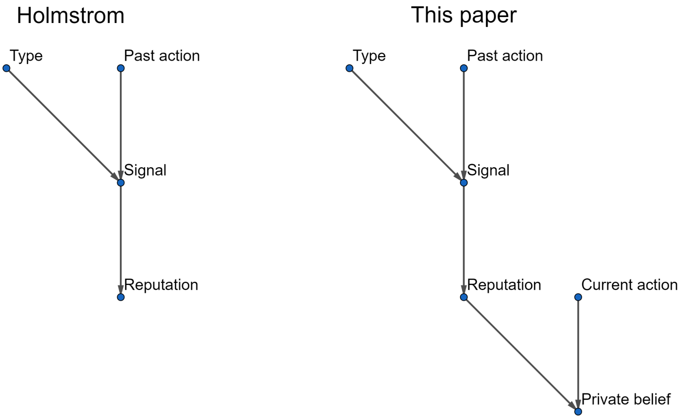
(3) Underpricing increases consumer surplus and speeds up learning.

- Rational consumers are not mislead by UP & they pay less.

Literature

- Consumer Reviews Depending on Prices
  - Static models: Feng, Li, and Zhang (2019); Martin and Shelegia (2021); Huang, Li, and Zuo (2022);
  - Boundedly-rational consumers: He and Chen (2018); Carnehl, Stenzel, and Schmidt (2021);
- Reputation
  - Reputation for quality: Holmström (1999); Mailath and Samuelson (2001); Board and Meyer-ter-Vehn (2013);
  - Dynamic signaling: Fudenberg and Levine (1989); Pei (2020); Ekmekci et al. (2022);
- Signaling by Choosing Info Structure
  - Degan et al. (2021); Rodríguez Barraquer and Tan (2022);

Literature



Reputation model with strategic pricing:

1. Prices affect reviews *(signal jamming)*
2. Price signals quality today *(repeated static signaling)*

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Model

Firm

- **Long-lived Firm** sells a single product
  - Chooses $p_t \in [0, 1]$ over $t \in \mathbb{R}_+$
- Product quality is exogenous: $\theta \in \{L, H\},\ 0 < L < H = 1$
  - $\theta = H$, w/p q_0
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Consumers

- **Short-lived Consumers** arrive at rate λ
  - Unit demand
- Utility of consumption

$$u_t = \theta - p_t + \varepsilon_t$$

  - ε_t is IID ex-post taste shock, w/ $f_\varepsilon(x) = f_\varepsilon(-x)$
  - Outside option is 0

Model

Reviews: Perfect Good News

- A consumer leaves a review iff $\theta = H$ AND $u_t > \bar{u}$ $\quad (\bar{u} \geq 1)$
  - $\lambda_g(p_t) := \lambda \cdot \Pr(H - p_t + \varepsilon_t > \bar{u})$

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Information

- $h^{t-} = \langle t, \{\tau_1, ..., \tau_n\} \rangle$ is a **public** history of past reviews
- Firm observes θ and h^{t-}
  - $p_t = p(\theta, h^{t-})$
- Consumer observes p_t and h^{t-}
  - Expectations about firm's quality $\tilde{\theta}(p_t, h^{t-}) \in [L, H]$ (buy iff $\tilde{\theta} - p_t \geq 0$)

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Firm's Problem

- Production is **costless** and payoffs are discounted at rate r

$$\max_{p_t} \mathbb{E}\left[\int_0^{+\infty} e^{-rt} \mathbf{1}_{\{\tilde{\theta}(p_t, h^{t-}) \geq p_t\}} p_t \, \lambda dt\right]$$

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Markov Perfect Bayesian Equilibrium

Markov State and Beliefs

Firm's Reputation is the public belief that the quality is high:

$$q(h^{t-}) := (\tilde{\theta}(h^{t-}) - L)/(H - L) \in [0, 1]$$

Markov Perfect Bayesian Equilibrium

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$$q(h^{t-}) := (\tilde{\theta}(h^{t-}) - L)/(H - L) \in [0, 1]$$

Strategies, beliefs, and values depend on history only via $q(h^{t-})$

- *Firm's prices* $p(\theta, q)$
- *Consumers' beliefs about prices* $\tilde{p}(\theta, q)$
- *Consumers' expectations about firm's quality* $\tilde{\theta}(p, q) \in [L, H]$
- *Firm's value function* $V(\theta, q) \in \mathbb{R}_+$

Markov Perfect Bayesian Equilibrium

MPBE is $\{p(\theta, q),\ V(\theta, q),\ \tilde{p}(\theta, q),\ \tilde{\theta}(p, q)\}$, s.t.

(1) $V(\theta, q)$ and $p_\theta(q)$ solve **HJB** (Static, Reputation)

$$rV(H, q) = \max_{p \in \mathcal{P}_q} \left\{ \lambda p + \lambda_g(p) \cdot [V(H, 1) - V(H, q)] \quad + \text{``}V_q(H, q) \cdot \frac{dq}{dt}\text{''} \right\}$$

$$rV(L, q) = \max_{p \in \mathcal{P}_q} \left\{ \lambda p \quad + \text{``}V_q(L, q) \cdot \frac{dq}{dt}\text{''} \right\}$$

- $\frac{dq}{dt} = -\lambda_g(\tilde{p}(H, q)) \cdot q(1 - q)$ (w/o good news)
- $\mathcal{P}_q := \{p \in [0, 1] | \tilde{\theta}(p, q) \geq p\}$ (*Acceptable Prices*)

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(2) Beliefs about prices are correct

- $\tilde{p}(\theta, q) = p(\theta, q)$

MPBE is $\{p(\theta,q),\ V(\theta,q),\ \tilde{p}(\theta,q),\ \tilde{\theta}(p,q)\}$, s.t.

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(2) Beliefs about prices are correct

- $\tilde{p}(\theta,q) = p(\theta,q)$

(3) Consumer expectations are **Bayesian** on path

- $\tilde{\theta}(p_\theta(q),q) = \mathbb{E}[\theta | p_\theta(q), q]$

Continuity Refinement

Continuity Refinement

Belief function $\tilde{\theta}(p, q)$ is continuous in p.

Equilibrium is an MPBE that satisfies *continuity refinement*.

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No Underpricing & Underpricing

Equilibrium dichotomy:

(1) No UnderPricing (**NUP**) is pricing at the consumers' willingness to pay:

$$\tilde{\theta}(q) := qH + (1-q)L$$

(2) UnderPricing (**UP**) is pricing below the consumers' willingness to pay.

*Remark: there is **NUP** in the myopic benchmark; $\tilde{\theta}(q)$ is the standard price in reputation models.*

Main Result

Theorem 1

An equilibrium exists.

1. If $h_\varepsilon < \frac{1}{1-L}$, then **no underpricing** is the unique equilibrium ($\forall q \; p(\theta, q) = \tilde{\theta}(q)$).

2. If $h_\varepsilon > \frac{1}{1-L}$, then $\exists \; 0 < q^* < q^{**} \leq 1$, s.t. in every equilibrium

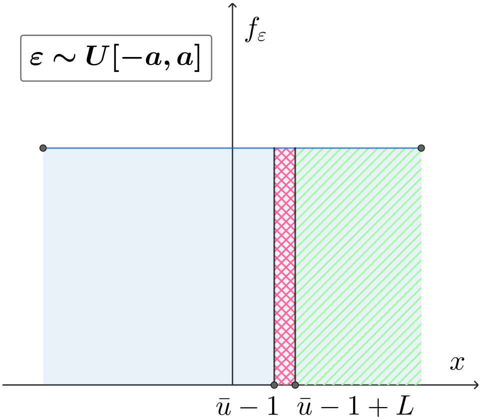
   (a) there is **underpricing** $\forall q \leq q^*$: $p(H, q) = 0, \;\; p(L, q) = L$

   (b) there is **no underpricing** $\forall q \geq q^{**}$.

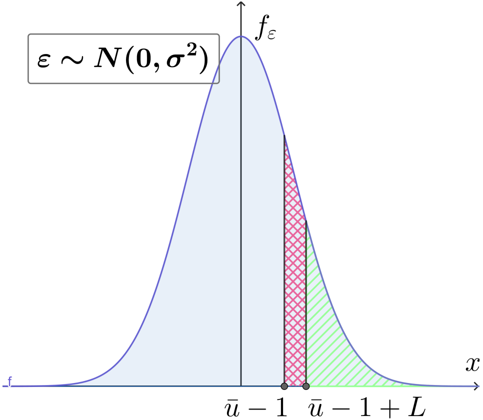
Adjusted hazard rate (of taste shock distribution) is

$$h_\varepsilon := \frac{(F_\varepsilon(\bar{u} - 1 + L) - F_\varepsilon(\bar{u} - 1))/L}{1 - F_\varepsilon(\bar{u} - 1 + L) + r/\lambda}$$

Adjusted Hazard Rate



(a) Low adjusted hazard rate



(b) High adjusted hazard rate

Inframarginal reviewers (NUP: $p = L$) v.s. Marginal reviewers (from UP $\rightarrow$ $p = 0$) at $q = 0$

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No-Underpricing Example: Uniform Case

Assumption

$\varepsilon \sim U[-a, a]$, *for* $a \geq \max\{\bar{u}, 1 - \bar{u}\}$

$$\lambda_g(p) = \lambda \Pr(1 - p + \varepsilon \geq \bar{u}) = -\frac{\lambda}{2a} \cdot p + \frac{\lambda(1 + a - \bar{u})}{2a}$$

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- **Pricing incentives for H**

$$\frac{\partial}{\partial p}\left\{\lambda p + \lambda_g(p)[V(H,1) - V(H,q)]\right\} = \underbrace{\lambda}_{\text{static incentives}} - \underbrace{\frac{\lambda}{2a}[V(H,1) - V(H,q)]}_{\text{reputational incentives}}$$

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- **Optimal pricing**

$$p_H^*(q) = \mathbf{1}_{\{\lambda - \frac{\lambda}{2a}[V(H,1) - V(H,q)] > 0\}} \cdot \max \mathcal{P}_q$$
$$p_L^*(q) = \max \mathcal{P}_q$$

Uniform Case: Optimal Pricing

Lemma

The high-quality firm always prefers choosing the highest acceptable price, $\max \mathcal{P}_q$.

Corollary: every equilibrium is pooling, $\forall q \; p(L, q) = p(H, q) = \max \mathcal{P}_q$.

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Proof intuition (by contradiction)

$$\frac{\partial}{\partial p} = \lambda - \frac{\lambda}{2a}[V(H, 1) - V(H, q)]$$

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- $[V(H,1) - V(H,q)]$ is largest when $q = 0$
- W/o underpricing: $V(H,0) = \frac{\lambda_g(L) \cdot V(H,1) + \lambda L}{\lambda_g(L) + r}$

$$\Rightarrow \; V(H,1) - V(H,0) \leq \frac{rV(H,1) - \lambda L}{\lambda_g(L) + r} = \frac{1 - L}{1 - F_\varepsilon(\bar{u} - 1 + L) + r/\lambda}$$

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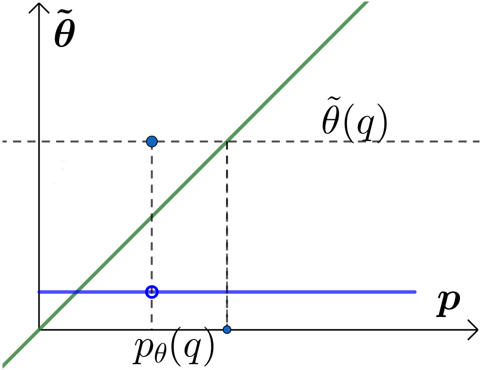
- **Good news arrives very soon with or without underpricing at q=0.**

Unreasonable Underpricing

Both types underprice: $p(H, q) = p(L, q) < \tilde{\theta}(q)$



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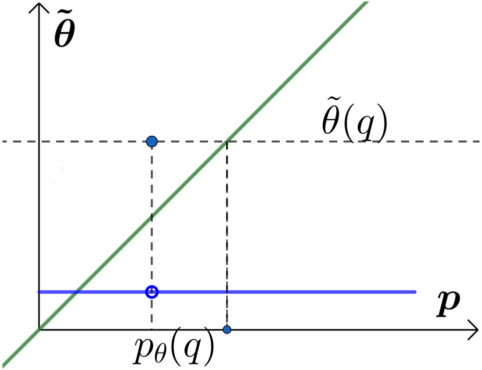

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Belief function $\tilde{\theta}(p, q)$ is continuous in p.

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If ε is distributed uniformly, ***NUP*** *is the unique equilibrium.*

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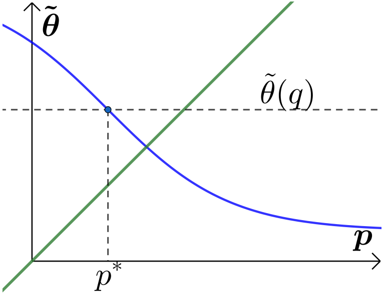

Both types can increase their prices.

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Proof: Part 1

UP Condition

Theorem 1 *(restated)*

1. $h_\varepsilon < \frac{1}{1-L} \;\Rightarrow\;$ **NUP** is the unique equilibrium ($\forall q$).
2. $h_\varepsilon > \frac{1}{1-L} \;\Rightarrow\;$ there is **UP** in every equilibrium:

   $\exists\, 0 < q^* < q^{**} \leq 1$, s.t.

   (a) **UP** $\forall q \leq q^*$: $p(H, q) = 0,\; p(L, q) = L$

   (b) **NUP** $\forall q \geq q^{**}$.

Adjusted hazard rate (of taste shock distribution) is

$$h_\varepsilon = \frac{(F_\varepsilon(\bar{u} - 1 + L) - F_\varepsilon(\bar{u} - 1))/L}{1 - F_\varepsilon(\bar{u} - 1 + L) + r/\lambda}$$

Pricing Incentives

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$\lambda_g(p)$ *and H's objective function* $(\lambda p + \lambda_g(p)(V(H,1) - V(H,q)))$ *are* ***convex*** *and*

$$p(H,q) \in \{0, \max \mathcal{P}(q)\}$$

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$$p(H,q) \in \{0, \max \mathcal{P}(q)\}$$

Recall: Reviews are sufficiently selective: $\bar{u} \geq 1$

Motivation: Only 1 out of 1000 consumers leaves a review (Hu, Pavlou, and Zhang 2017).

Empirical Evidence

Equilibrium Dichotomy

1. If $h_\varepsilon > \frac{1}{1-L}$, then there is some **UP** in every equilibrium.
2. If $h_\varepsilon < \frac{1}{1-L}$, then **NUP** is the unique equilibrium.

Equilibrium Dichotomy

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Sketch of the proof:

- Assume that **NUP** ($\forall q$) is an equilibrium

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Sketch of the proof:

- Assume that **NUP** ($\forall q$) is an equilibrium
- We need to check underpricing incentives only at $q = 0$
- $h_\varepsilon < \frac{1}{1-L} \Rightarrow$ there are no underpricing incentives $\Rightarrow$ **NUP** ($\forall q$) is an equilibrium and it is unique (because it yields the largest underpricing incentives).

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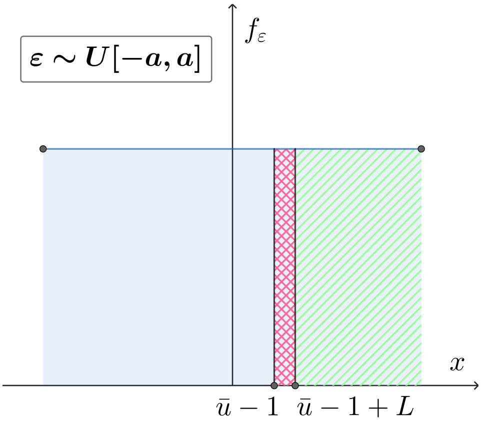
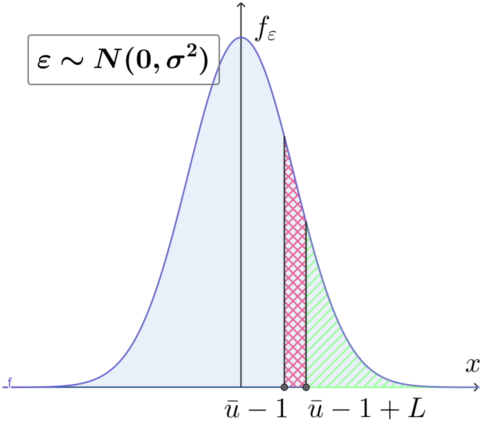
- Assume that **NUP** ($\forall q$) is an equilibrium
- We need to check underpricing incentives only at $q = 0$
- $h_\varepsilon < \frac{1}{1-L} \Rightarrow$ there are no underpricing incentives $\Rightarrow$ **NUP** ($\forall q$) is an equilibrium and it is unique (because it yields the largest underpricing incentives).
- If $h_\varepsilon > \frac{1}{1-L} \Rightarrow$ there are underpricing incentives $\Rightarrow$ **NUP** ($\forall q$) is NOT an equilibrium $\Rightarrow$ there must be **UP** in every equilibrium. ∎

Adjusted Hazard Rate



(a) Low adjusted hazard rate $\Rightarrow$ **NUP**



(b) High adjusted hazard rate $\Rightarrow$ **UP**

Comparative Statics

Corollary

Take a set of primitives $L, q_0, \lambda, r, F_\varepsilon$. Then

(1) $\exists\, \alpha^* < +\infty$, *s.t.* $\forall\, \alpha > \alpha^*$ *and* $\varepsilon' = \alpha\varepsilon$ *NUP is the unique equilibrium.*

(2) $\exists\, L^* < 1$, *s.t.* $\forall\, L > L^*$ *NUP is the unique equilibrium.*

(3) $\exists\, (\lambda/r)^* > 0$, *s.t.* $\forall\, (\lambda/r) < (\lambda/r)^*$ *NUP is the unique equilibrium.*

Adjusted hazard rate (of taste shock distribution) is

$$h_\varepsilon = \frac{(F_\varepsilon(\bar{u} - 1 + L) - F_\varepsilon(\bar{u} - 1))/L}{1 - F_\varepsilon(\bar{u} - 1 + L) + r/\lambda}$$

Proof: Part 2

Theorem 1 *(restated)*

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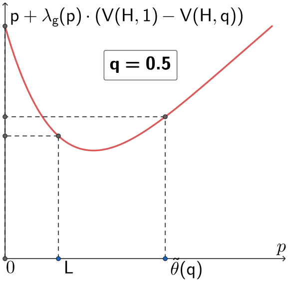
   (a) **UP** $\forall q \leq q^*$: $p(H, q) = 0,\ p(L, q) = L$

   (b) **NUP** $\forall q \geq q^{**}$.

Adjusted hazard rate (of taste shock distribution) is

$$h_\varepsilon = \frac{(F_\varepsilon(\bar{u} - 1 + L) - F_\varepsilon(\bar{u} - 1))/L}{1 - F_\varepsilon(\bar{u} - 1 + L) + r/\lambda}$$

Underpricing Equilibrium Structure



Unique signaling equilibrium is **UP** ($\forall q \leq q^*$)

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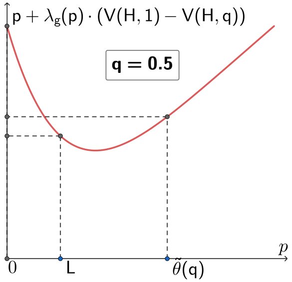

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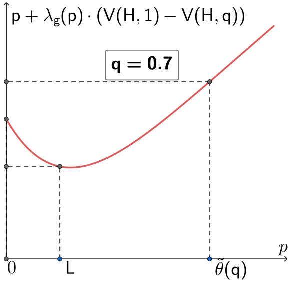
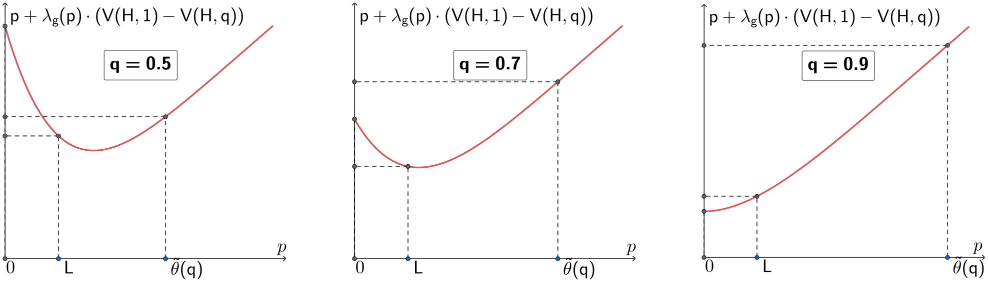


Multiple signaling equilibria ($\forall q^* < q < q^{**}$)

Underpricing Equilibrium Structure



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Bad News

Consumers leave BAD reviews iff $\theta = L$ *and* $u_t < \underline{u}$.

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Proposition

If ε is distributed uniformly, **NUP** is the unique equilibrium.

Popularity-based Demand

Consumer arrival rate $\lambda(q)$ is increasing in the firm's reputation q.

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Proposition

An equilibrium exists.

1. If $h_\varepsilon < \frac{1}{\frac{\lambda(1)}{\lambda(0)} - L}$, then **NUP** is the unique equilibrium ($\forall q$).
2. If $h_\varepsilon > \frac{1}{\frac{\lambda(1)}{\lambda(0)} - L}$, then $\exists\, 0 < q^* < q^{**} \leq 1$, s.t. in every equilibrium there is **UP** $\forall q \leq q^*$ and **NUP** $\forall q \geq q^{**}$.

Adjusted hazard rate (of taste shock distribution) is

$$h_\varepsilon = \frac{\lambda(0) \cdot (F_\varepsilon(\bar{u} - 1 + L) - F_\varepsilon(\bar{u} - 1))/L}{\lambda(0) \cdot (1 - F_\varepsilon(\bar{u} - 1 + L)) + r}$$

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Welfare and Learning Effects of Underpricing

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- If the firm is myopic, L and H prefer the highest price $\Rightarrow$ **NUP** $\Rightarrow CS = 0$
- **UP** $\Rightarrow CS > 0$.
- High-quality firm underprices more, but the low-quality firm loses the surplus.
- Underpricing speeds up learning and makes both ratings and prices more informative.
- Platform transparency and observable past prices may harm consumers.

Summary

- Price-dependent reviews can but need not induce underpricing.
  - Underpricing depends on the ratio of the density of marginal reviewers to the mass of the inframarginal ones, who leave reviews without underpricing.
- If underpricing happens, it must occur at low-reputation levels in every equilibrium.
  - High-quality firm underprices more than low-quality firm.
- Underpricing hurts low-quality firm, increases CS, and speeds up social learning.

Thank you!

Empirical Motivation

- Firms' ratings affect their revenue
  Luca (2011); Chevalier and Mayzlin (2006)
- Higher prices negatively affect product reviews/ratings
  Luca and Reshef (2021); Cabral and Li (2015)
- Firms take these reputational incentives into account when setting prices
  "...firms close to upgrading their tier are 4-9% more likely to discount." Sorokin (2021)

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Extreme Reviews Empirical Evidence

- Across 25 platforms and 280 million reviews, there are extreme or polarized reviews (Schoenmüller, Netzer, and Stahl 2019)
- But experimental reviews are uni-modal (Hu, Zhang, and Pavlou 2009, Schoenmüller, Netzer, and Stahl 2019)
- Medium quality products are not rated possibly due to a cost of leaving a rating (Lafky 2014)
- Compensated reviews on Glassdoor are less extreme (Marinescu et al. 2021)

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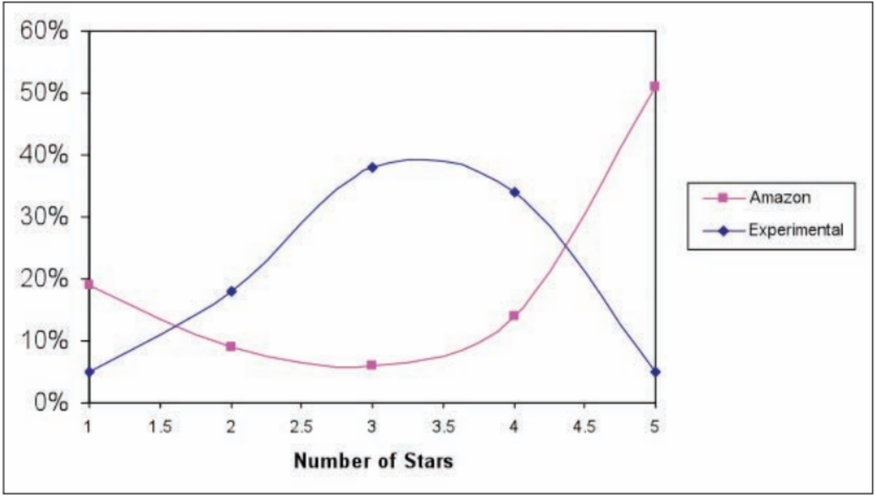
Extreme Reviews

Figure 2. Distribution of Experimental versus Amazon's Ratings for a Music CD



Source: Hu, Zhang, and Pavlou (2009)