Consumer Reviews and Dynamic Price Signaling

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Motivation

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

Reviewed in the United States us on January 1, 2022

Luca and Reshef (2021); Cabral and Li (2015)

Firm's tradeoff

- Lowering price improves reviews and helps to build reputation
- Lowering price decreases profit
- Price signals quality today

Research Question: How do reputational and signaling incentives affect prices?

Underpricing is pricing the product below the myopic optimum.

This Paper

Main features:

- Reviews depend on the quality of the product and its price
  - Signals depend on the state and actions
- Fully rational consumers observe past reviews and the current price
  - Past prices are unobserved
  - Consumers only care to "guess" the state
- Infinite horizon model
  - Pricing incentives depend on the continuation value

Price effects on beliefs:

- Prices affect the rating tomorrow (managing reputation)
- Prices signal quality today (static signaling)

Literature

- Models with reviews depending on quality and prices
  Acemoglu et al. (2017); He and Chen (2018); Carnehl, Stenzel, and Schmidt (2021); Martin and Shelegia (2021); Huang, Li, and Zuo (2022);
- Reputation models
  Fudenberg and Levine (1989); Holmström (1999); Mailath and Samuelson (2001); Board and Meyer-ter-Vehn (2013,2022); Pei (2020);
- Signaling and learning
  Degan et al. (2021); Rodríguez Barraquer and Tan (2022);

Results Preview

Main results

(1) Underpricing does not always occur.
Uniform case

(2) Underpricing occurs iff the ratio of marginal to inframarginal consumers is high.
Consumers' tastes are not too diverse

(3) Reputational incentives can induce underpricing only at lower ratings.

(4) The high-quality firm underprices more than the low-quality firm.

Table of Contents

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
  - In the paper, θ is redrawn at rate $\chi \geq 0$

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 if $\theta = H$ AND $u_t > \bar{u}$
  - $\lambda_g(p_t) := \lambda \cdot \Pr(H - p_t + \varepsilon_t > \bar{u})$

Information

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

Firm's Problem

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

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

Table of Contents

Markov Perfect Bayesian Equilibrium

Markov State and Beliefs

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

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

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

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*)

(2) Beliefs about prices are correct

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

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

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

Table of Contents

Equilibrium Characterization: Underpricing

Equilibrium dichotomy:

(1) No UnderPricing: $p_\theta(q) = \tilde{\theta}(q) := qH + (1-q)L$

(2) UnderPricing: $p(H, q) = 0,\ p(L, q) = L$

Main Result

Theorem 1

An equilibrium exists.

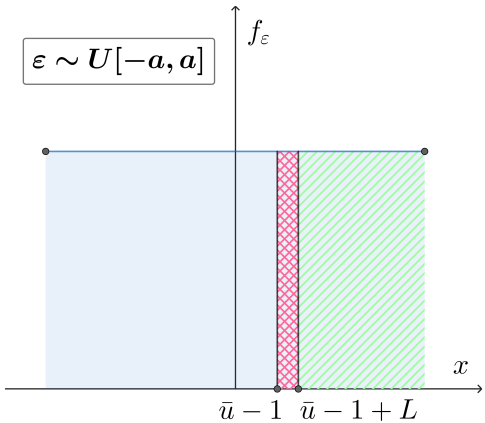
1. If $h_\varepsilon < \frac{1}{1-L}$, then **NUP** is a unique equilibrium ($\forall q$).

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

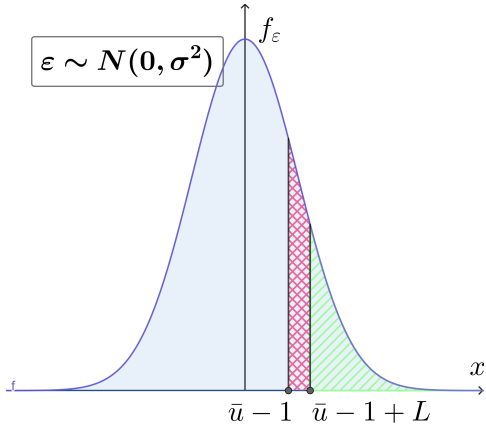
Adjusted hazard rate is

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

Adjusted Hazard Rate



(a) Low adjusted hazard rate



(b) High adjusted hazard rate

Table of Contents

NUP Example: Uniform Case

Assumption

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

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

- **Pricing incentives for H**

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

- **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-type firm always prefers choosing the highest acceptable price, $\max \mathcal{P}_q$.

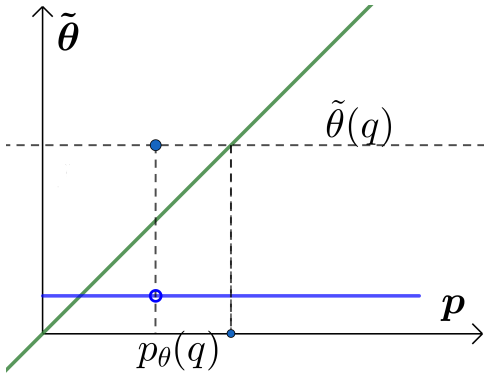
Corollary: every equilibrium is pooling, $\forall q \; p(L,q) = p(H,q) = \max \mathcal{P}_q$.

Proof intuition.

- Reputation incentives $\frac{\lambda}{2a}[V(H,1) - V(H,q)]$ are largest when $q = 0$
- At $q \approx 0$, p_H is low
- If $\frac{\lambda}{2a}$ is high, good news arrives very soon with or without underpricing at q=0
- Increasing $\frac{\lambda}{2a}$ increases $\lambda_g(0) \geq \frac{\lambda}{2a}$, which decreases the value gap $V(H,1) - V(H,0)$

Unreasonable Underpricing

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



Assumption

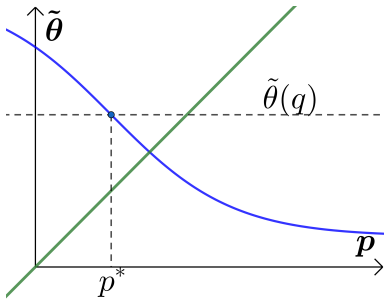
Continuity refinement. *Belief function $\tilde{\theta}(p,q)$ is continuous in p.*

NUP Equilibrium

Proposition

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

Proof by contradiction:



Both types can increase their prices.

Table of Contents

General Characterization Lemma

Lemma

If pooling at $p = \tilde{\theta}(q)$ at any q is an MPBE, it maximizes $V(H, 1)$ and $V(H, 1) - V(H, 0)$ among all MPBE.

Corollary

The following cases are mutually exclusive and collectively exhaustive:

(1) *Pooling at $p = \tilde{\theta}(q)$ at any q is a unique MPBE.*

(2) *There must be separation and underpricing at low reputation levels in any MPBE.*

Table of Contents

General Case

Reviews Selection and Convexity

Assumption

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

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

Lemma

$\lambda_g(p)$ *is* ***convex*** *if* ε *has a uni-modal distribution and* $\bar{u} \geq 1$.

Empirical Evidence

Pricing Incentives: Convexity

H's Pricing Incentives

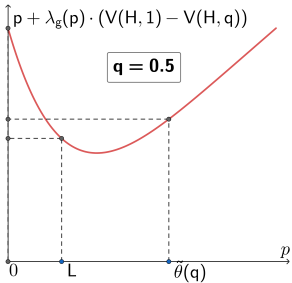
$$p(H,q) = \arg \max_{p \in \mathcal{P}(q)} \{\lambda p + \lambda_g(p)(V(H,1) - V(H,q))\} \in \{0, \max \mathcal{P}(q)\}$$

since $\lambda_g(p)$ and therefore the objective function are convex

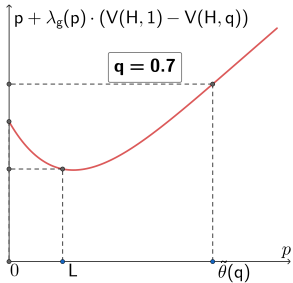
L's Pricing Incentives

$$p(L,q) = \max \mathcal{P}(q)$$

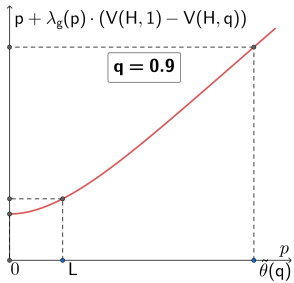
Equilibrium Structure



Unique signaling equilibrium is **NUP**



Unique signaling equilibrium is **UP**



Multiple signaling equilibria

Table of Contents

Welfare and Learning Effects of Underpricing

- If the firm is myopic, each type prefers the highest price in any equilibrium and there is no underpricing.
- Underpricing increases consumer surplus.
- Underpricing speeds up learning and makes ratings more informative.
- High-type firm underprices more, but the low-type firm loses the surplus.

Summary

- Price-dependent reviews can induce underpricing, but underpricing need not happen
- Underpricing depends on the proportion of the density of marginal reviewers to the mass of the inframarginal ones, who leave reviews without underpricing
- If underpricing happens, must occur at low-reputation levels in every equilibrium
- High-quality firm underprices more than low-quality firm
- Underpricing hurts low-quality firm, increases consumer surplus, 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 Sorokin (2021); Carnehl et al. (2021); Feng, Li, and Zhang (2019)

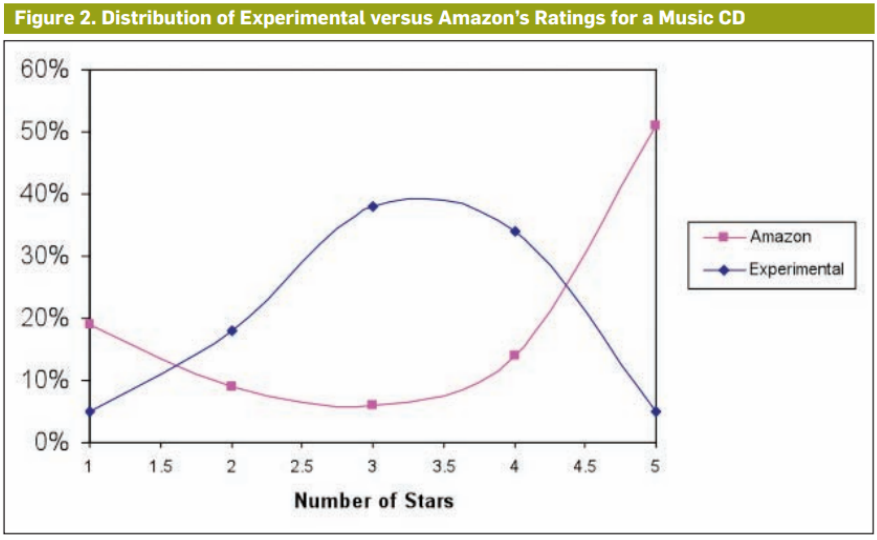
Back

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)

Back

Extreme Reviews



Source: Hu, Zhang, and Pavlou (2009)