A Model of Product Design & Information Disclosure Investments

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CURRENT ECOMMERCE TRENDS

Trends:

⌘ New ways to invest to reduce consumer uncertainty about product characteristics

⌘ Increasing importance of infomediaries as an independent source of product information

⌘ Increasing importance of reducing consumer uncertainty about one's product

Examples & Evidence

 Warby Parker offers virtual try-ons of prescription eyeglasses

 IKEA uses augmented reality technology to let prospective customers see how the company's products fit in a room

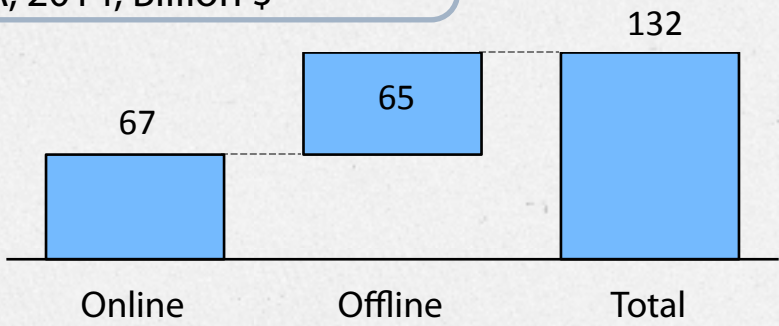*Pinterest* Social commerce site became top 50 web destination while in beta

cnet Expert reviews site is top 90 destination

Digital Photography Review dpreview.com Top 1000 destination by including only camera reviews

Sales involving active online buyer search for product info USA, 2014, Billion $

Online	Offline	Total
67	65	132

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Problem Statement

- *How does product quality influence investments that reduce consumer uncertainty, and vice versa?*
- *How to account for third party information availability when investing in quality or in quality disclosure?*

Example

Printer Manufacturer:

The firm released one high-end and one budget model. It invests heavily to educate buyers on print longevity & color fidelity and explain the printers' performance on those dimensions

- What are optimal information investment levels for the two models?
- A prominent infomediary released a thorough (and fair) expert review. Should the firm adjust investment for the 2 models and how?
- How should the firm account for future information investments when designing new a printer?

Key Message

- ⌘ *"Firms should view **product design** and **investments in reducing consumer uncertainty** as **an integrated process**…"*

- ⌘ *"… that is in turn **heavily influenced by the operation of 3rd party infomediaries**"*

Contribution

- Product quality decisions influence future disclosure costs
- Firms should take this dependence into account to avoid over-investing in quality

- Firms (especially lower quality) can free ride on infomediaries' investments and reduce their own disclosure costs
- Firms can take advantage of the presence of infomediaries, to reduce their quality investments and increase their profitability

Decision Variables

- Target qualities: q_{ri}
- Quality disclosure target: r_i
- Prices: p_i

Model Parameters

- N sellers
- Product value v
- Fit cost parameter t
- Quality preference θ
- Quality production cost $kq_{ri}^2/2$
- Actual quality $q_i=q_{ri}+\varepsilon$, where ε in $[-r,r]$
- Quality uncertainty $[q_{iA},q_{iB}]$, $\alpha_q=q_{iB}-q_{iA}$
- Quality disclosure investment cost c

Buyer behavior

- Uniformly distributed preferences
- Utility $= v+ \theta \cdot q - t \cdot \delta d$

Additional Assumptions

- Infomediaries provide info so that a seller's true location is equiprobable inside the uncertainty interval
- Symmetric product types (sellers are equidistantly positioned in the product type dimension)

Connection to classic literature

- Model reduces to Economides (1993) for $r=0$ and $\alpha_q=0$
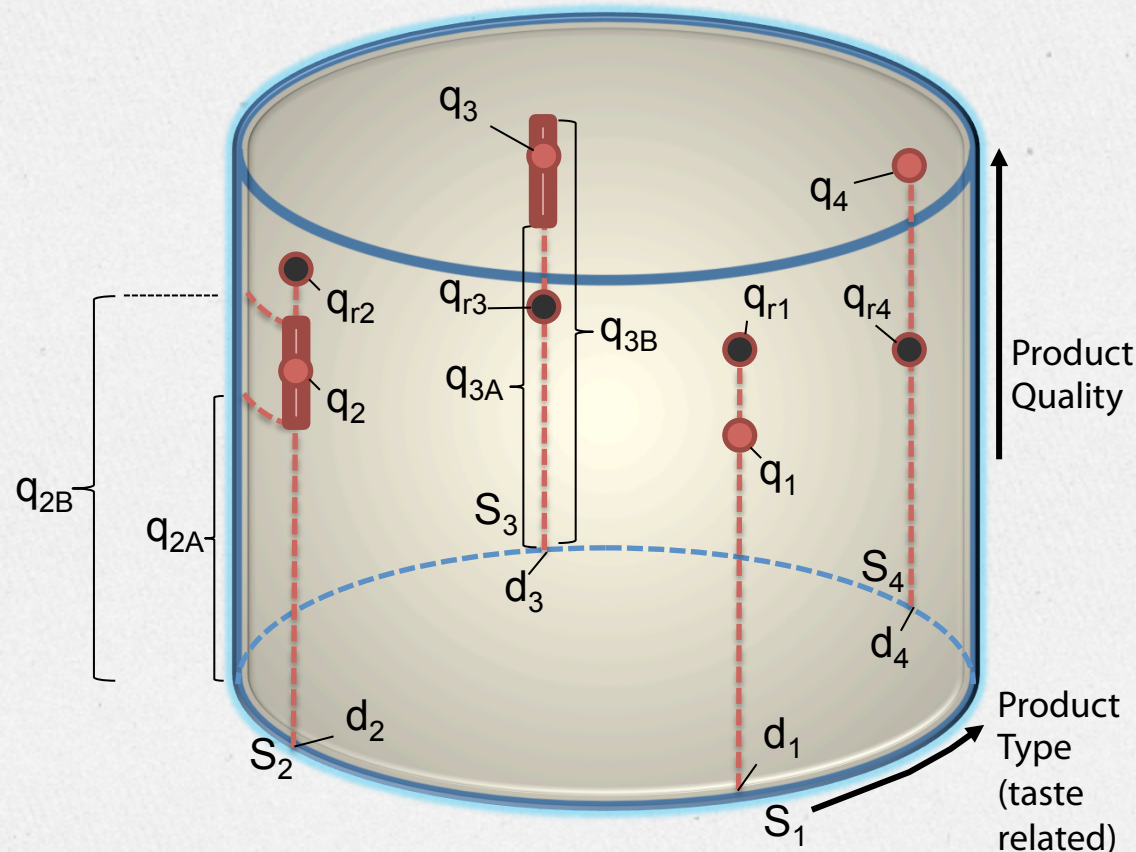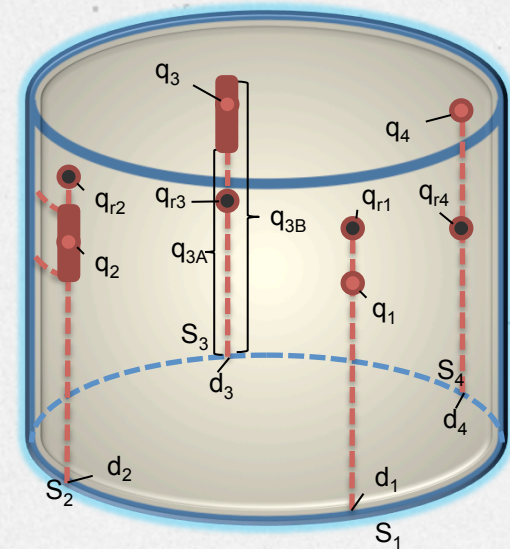
Firms' objective function (Profit)

Demand | Expected value of type | Expected value of quality

$$D_i = \frac{1}{N} + \frac{p_{i+1} + p_{i-1} - 2p_i}{2t} + \frac{\theta\left(2E(\overline{q_i}) - E(\overline{q_{i+1}}) - E(\overline{q_{i-1}})\right)}{2t}$$

$$\Pi_i(\mathbf{p}, \mathbf{q}, \mathbf{d}) = p_i \cdot D_i(\mathbf{p}, \mathbf{q}, \mathbf{d}) - C(q_i) - r_i \quad , \quad d\Pi_i/dp_i = 0$$

$$\Pi_i^*(p_i^*, \mathbf{q}, \mathbf{d}) = p_i^{*2}/t - C(q_i) - r_i$$

Game stages & timing

Stages 1: All sellers choose their quality investment

Sellers learn the quality level that they achieved, and also learn how their own products are perceived by early users in pre-market trials. They thus learn the uncertainty intervals (chosen by nature) that will be associated with their products if they do not invest in information disclosure

Stage 2: All seller decide on whether to invest in quality disclosure

All sellers and buyers learn the quality of sellers who invested in disclosure and learn from infomediaries the uncertainty intervals of sellers who have not invested in disclosure.

Stage 3: All sellers choose their price

Key literature

⌘ Discovery of the quality unraveling mechanism

⌘ First study of the unraveling mechanism under costly disclosure investments

⌘ First analytical model with endogenous vertical <u>and</u> horizontal differentiation

⌘ First uncertainty model that includes endogenous quality production (for monopoly)

⌘ First non-monopoly model to study quality uncertainty in the presence of infomediaries

⌘ First uncertainty model of a competitive market that includes endogenous vertical differentiation.

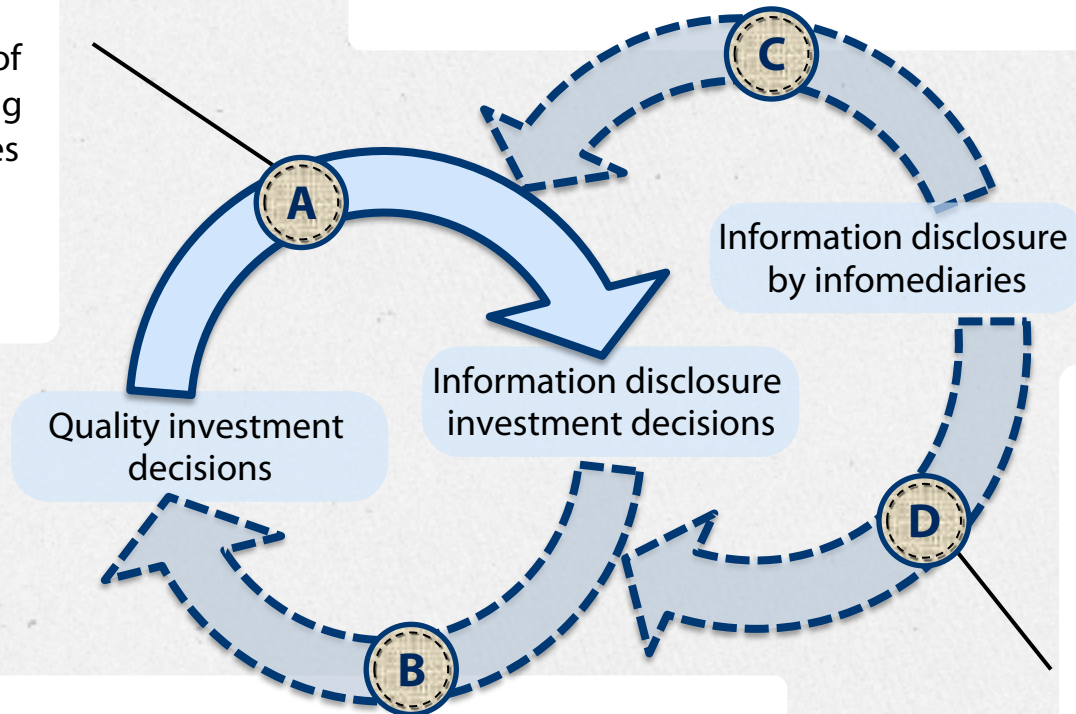| Authors	Year	Number of Sellers	Endogenous Quality?	Quality Uncertainty?	Info-mediaries?
Grossman and Hart	1980	$N, 1$	No	Yes	No
Grossman	1981	1	No	Yes	No
Milgrom	1981	$N, 1$	No	Yes	No
Jovanovic	1982	N Large	No	Yes	No
Verrecchia	1983	1	No	Yes	No
Matthews and Postlewaite	1985	1	No	Yes	No
Dye	1986	1	No	Yes	No
Milgrom and Roberts	1986b	$N, 1$	No	Yes	No
Okuno-Fujiwara et al.	1990	N	No	Yes	No
Economides	1993	N	Yes	No	No
Shavell	1994	N	No	Yes	No
Dye and Sridhar	1995	N	No	Yes	No
Albano and Lizzeri	2001	1	Yes	Yes	Yes
Fishman and Hagerty	2003	1	No	Yes	No
Stivers	2004	$N, 1$	No	Yes	No
Cheong and Kim	2004	N Large	No	Yes	No
Chen and Xie	2005	2	No	Yes	Yes
Board	2009	2	No	Yes	No
Levin et al.	2009	$1, 2$	No	Yes	No
Hotz and Xiao	2010	2	No	Yes	No
Sun	2011	1	No	Yes	No
Present Model	**2013**	N	**Yes**	**Yes**	**Yes**

OVERVIEW OF KEY RESULTS

⌘ The expected (ex-ante) **probability of quality disclosure increases smoothly with equilibrium quality**

⌘ This is a refinement of the quality unraveling argument that argues that disclosures will only occur beyond a fixed quality level

⌘ **Infomediaries enable firms to free ride** on the info that they provide and firms find that they can reduce their own disclosure investments. Free riding is **more attractive at lower product quality levels**

A — Quality investment decisions

B

C

D — Information disclosure by infomediaries

Information disclosure investment decisions

⌘ **Infomediaries enable firms to reduce product quality**, as more & more firms choose to free ride

⌘ **Infomediaries can have an outsized impact to quality investments** as they make profits less elastic on quality

⌘ Considering the impact of their quality choices to the probability of subsequent quality disclosure investments, rational **firms should invest less in quality**, as compared to the perfect information case

EQUILIBRIUM SOLUTION

Stage 1 *Sellers set quality targets:*

$$q_{ri}^* = \begin{cases} \dfrac{b \cdot \theta}{k \cdot N} & \text{if } c > c' \\[2ex] \dfrac{b \cdot \theta}{k \cdot N} + \dfrac{2c}{\alpha_q \cdot k} - c \dfrac{\sqrt{-4c \cdot t + (2t/N + b \cdot r \cdot \theta)^2} - \sqrt{-4c \cdot t + (-2t/N + b \cdot r \cdot \theta)^2}}{\alpha_q \cdot b \cdot k \cdot r \cdot \theta} & \text{if } c < c' \end{cases}$$

where c' *is the information disclosure cost beyond which sellers always withhold information, and is given in Lemma 6 in the Appendix.*

Stage 2 *Seller* S_i *will disclose quality if and only if his quality exceeds the lower limit of his quality uncertainty interval by*
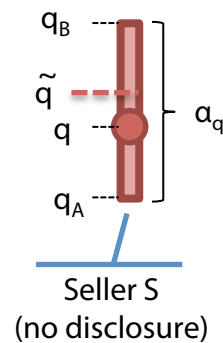
$$\varphi = \frac{4}{\theta \cdot b \cdot \alpha_q} \left(\frac{t}{N} + \frac{\epsilon \cdot \theta \cdot b}{2} - \sqrt{\left(\frac{t}{N} + \frac{\epsilon \cdot \theta \cdot b}{2} \right)^2 - t \cdot c} \right).$$

where $\epsilon \in [-r, r]$ *is the uniformly distributed error term that measures the Seller's deviation from his quality target (see Section 3.1).*

Stage 3 *Firms' ex-ante expected price is* $p^* = t/N$. *Actual prices depend on the realization of qualities and quality uncertainty intervals, and are given by Equation 7:*

$$p_i^* = \sum_{j=-N/2}^{N/2} b_j e_{j+i}(\mathbf{q})$$
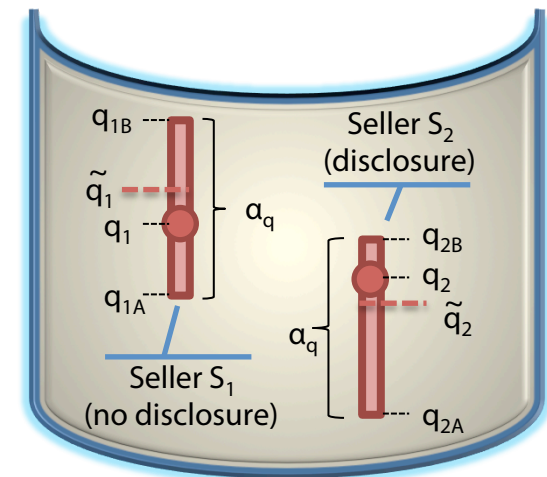
Classic Literature

Current Model

⌘ **Mechanism**

The *unraveling* result states that there exists a threshold $\tilde{q}$ such that sellers disclose *iff* their quality exceeds $\tilde{q}$
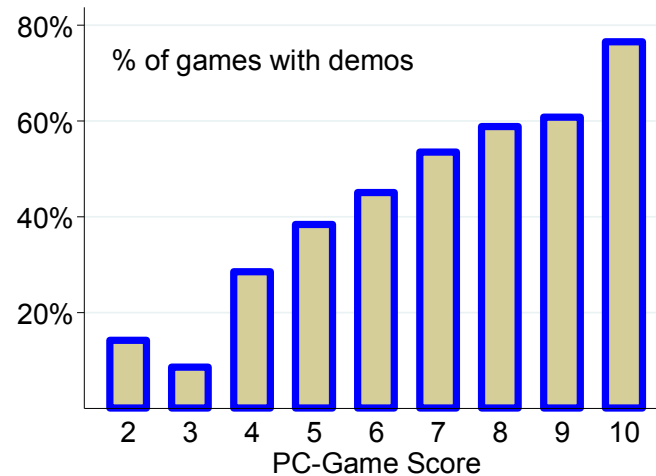
A seller discloses *iff* his quality exceeds a quality threshold $\tilde{q}_i$ inside his uncertainty interval. This threshold decreases with higher quality

⌘ **Impact of quality to quality disclosure investments**

A quality increase does not increase the probability of disclosure
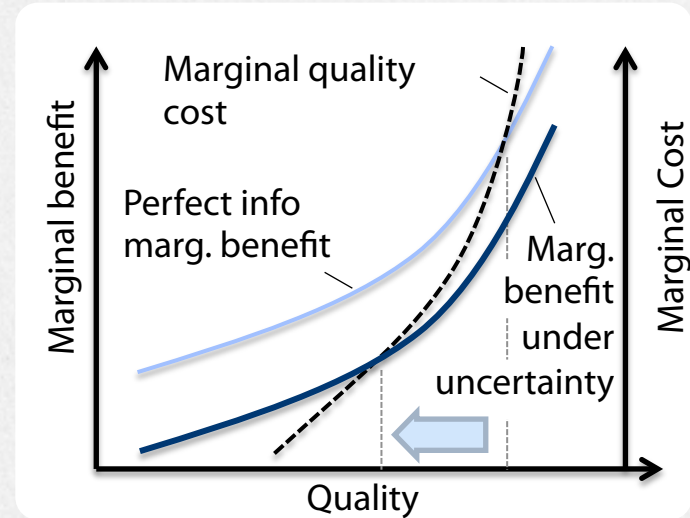
A quality increase increases the probability of disclosure

⌘ Data on 1848 PC-Games released between 1993-2003, collected from Gamespot.com

⌘ % of games that released a demo version, against the score that the game received from professional reviewers employed by Gamespot

⌘ Similar results when corrected for game genre and year
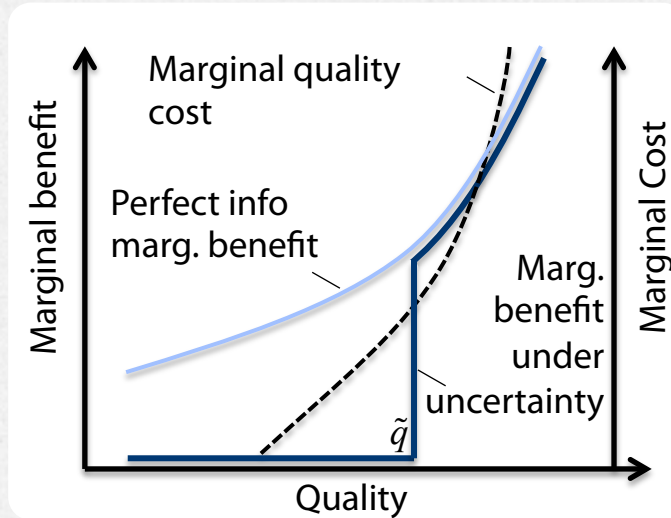
Classic Quality Unraveling

Current Model

⌘ **Impact of uncertainty to optimal product quality**

⌘ The mechanism implies that firms who face imperfectly informed consumers, should **either produce at the lowest possible quality, or they should ignore the impact of buyer uncertainty**, depending on quality production cost

⌘ All firms should **account for uncertainty** when they estimate the **ROI of an investment in quality** improvement

⌘ Doing so, will lead firms to **moderate investments in product quality** (as shown by the arrow)
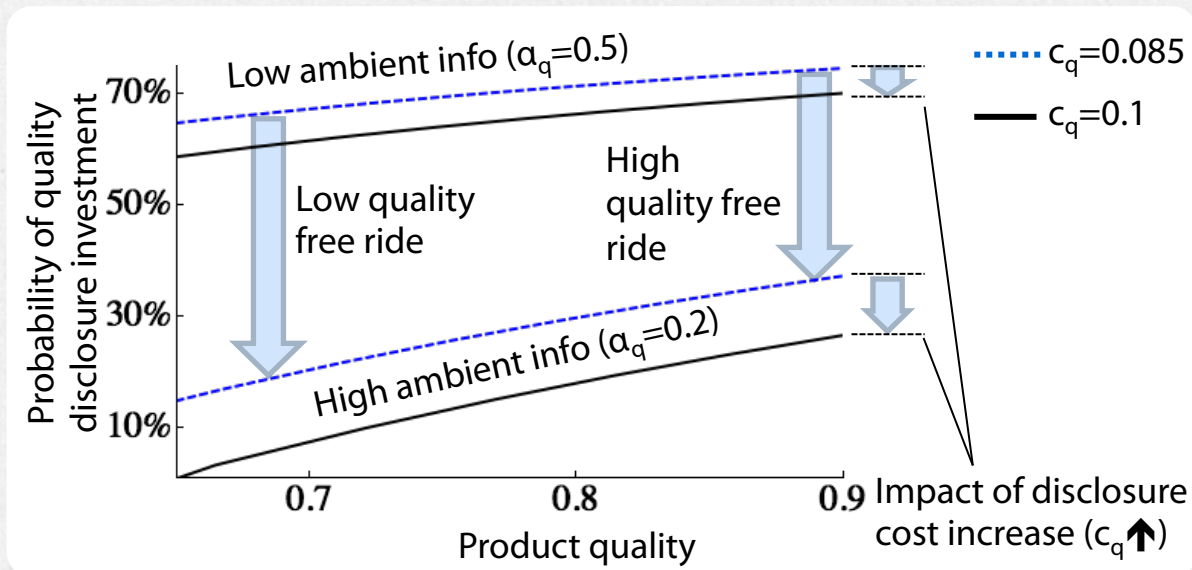
Intuition

⌘ **A quality increase reduces** the firm's **disclosure threshold** (inside the uncertainty interval)

⌘ When the **uncertainty interval is relatively small, even a small decrease in the position of the disclosure threshold can significantly affect the probability** that a firm's quality will be below (or above) the threshold.

⌘ Thus, the **probability of a disclosure investment becomes more sensitive on quality when α_q is low** (bottom pair of lines in the graph is steeper)

⌘ Thus, the two sets of **lines of the graph converge: low quality firms adjust their disclosure probability more prominently** than higher quality firms

AN EXAMPLE OF LOWER QUALITY PRODUCTS FREE RIDING MORE THAN THEIR HIGH QUALITY COMPETITORS
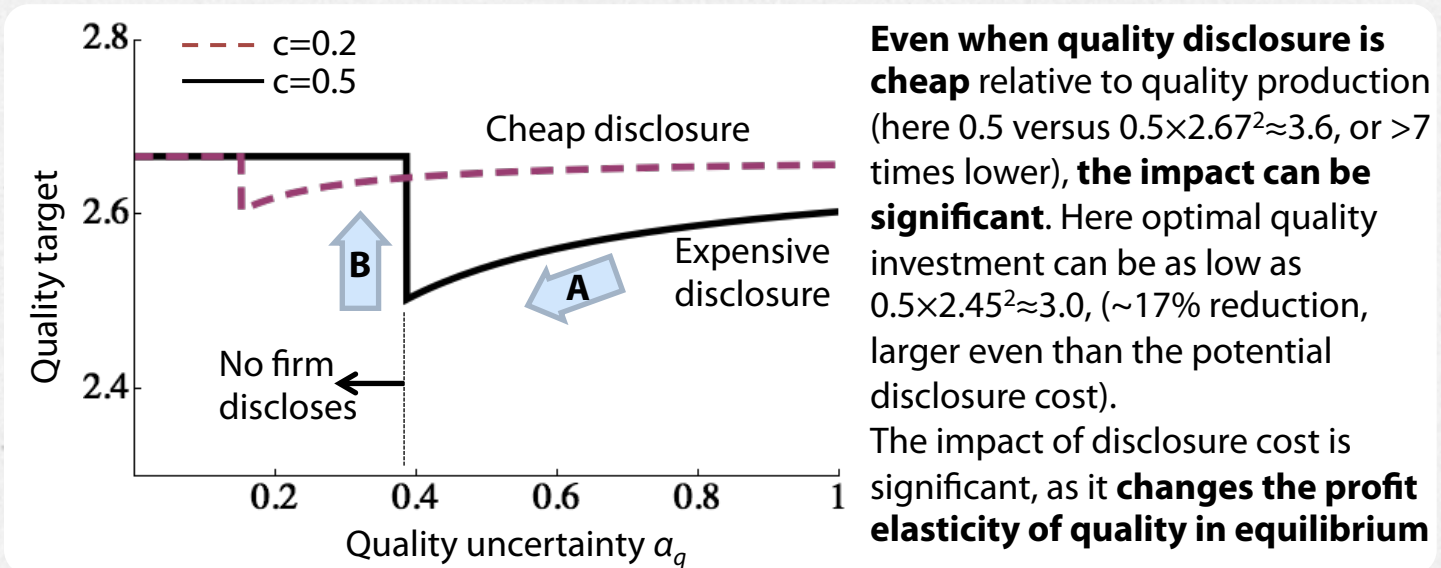
Quality Information by Third Parties

⌘ Chen & Xie (2005) looked at how firms adjust their advertising spend as a response to an independent product review published in a magazine

⌘ 2 review formats:
- **(Shown in graph):** A recommendation format that, in the end, either results on a recommendation or not. This is considered akin to quality disclosure
- **(Not Shown in graph):** General description format, avoiding clear pronouncements on quality, considered akin to taste disclosure

Impact to Firms Own Info Investments

No statistically significant difference

Advertising level (# of ad pages) in magazine, before and after the magazine published an independent product review

1.91 | 2.58

0.67 **-78%** 0.15

0.92 **-30%** 0.64

0.48 **-71%** 0.14

High Quality Printers | Low Quality Printers | High Quality Running Shoes | Low Quality Running Shoes

Source: Chen & Xie (2005) "3rd-Party Product Review & Firm Marketing Strategy" Marketing Science 24(2), pp.218-240

Even when quality disclosure is cheap relative to quality production (here 0.5 versus $0.5 \times 2.67^2 \approx 3.6$, or >7 times lower), **the impact can be significant**. Here optimal quality investment can be as low as $0.5 \times 2.45^2 \approx 3.0$, (~17% reduction, larger even than the potential disclosure cost).

The impact of disclosure cost is significant, as it **changes the profit elasticity of quality in equilibrium**

Intuition

⌘ As infomediaries provide **more information**, the **probability of disclosure** reduces and becomes **more sensitive on quality**

⌘ Thus, **at low α_q , profits are less elastic on quality**, as even a small quality increase can significantly raise the probability of a future information disclosure cost

⌘ Thus, **as infomediaries provide more info, firms compete less & less in quality** (arrow A)

⌘ When infomediaries provided **enough information so that no vendor wants to disclose** more (disclosure probability is zero) **quality increases no longer increase future disclosure costs** and firms **compete on quality as if under perfect information**. Thus the return to the perfect-info quality level occurs **before α_q drops to zero** (arrow B)

PUTTING IT ALL TOGETHER: INFOMEDIARIES' IMPACT ON FIRM PROFITABILITY

Parameter values used: (N=3, α_q=0.4, k=1.5, θ=5, t=10, r=1)
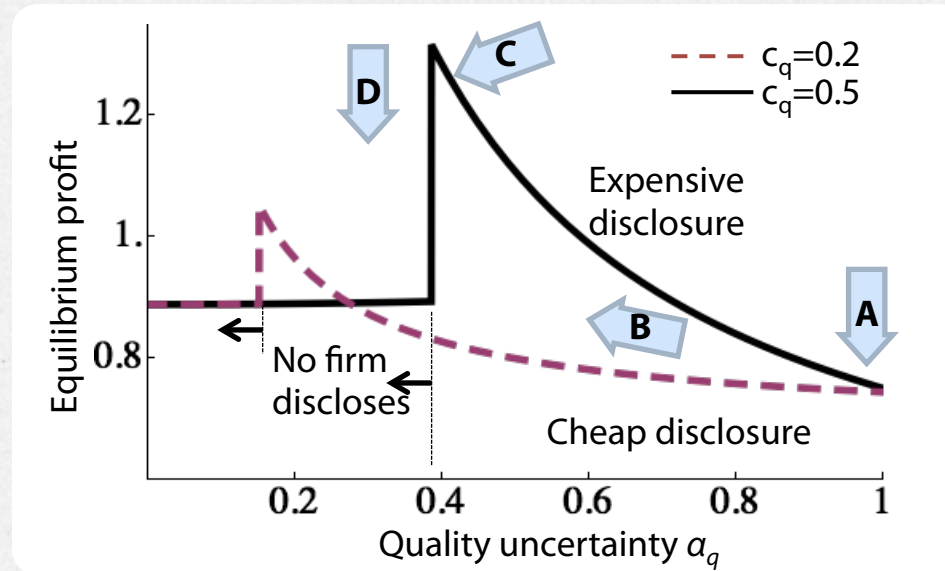
Managerial Implications

⌘ (Arrow A) Without infomediaries, uncertainty reduces firms' profits

⌘ (Arrow B) As infomediaries provide more information, firm profitability improves

⌘ (Arrow C) Firms maximize profit when only few vendors invest in quality disclosure

⌘ (Arrow D) The return to perfect-info profitability occurs before α_q drops to 0

Justification/ Intuition

⌘ Without free-riding, disclosure costs are high and firms' quality is close to the perfect info case. Thus their profitability approaches profitability under perfect information minus the disclosure investment

⌘ Firms begin to free ride and invest less in quality as the pressure for high quality is blunted (profits become less elastic in quality as α_q reduces)

⌘ Both disclosure costs and quality production costs are minimal

⌘ When firms stop incurring information disclosure costs, quality investments return to their perfect information level