The Optimal Choice of Pre-Launch Reviewer: How Best to Transmit Information using Tests and Conditional Pricing

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November 2008
Motivation

- Public tests can be powerful in launching new products, standards, careers, ideas
  - Reviews
  - Accreditations
  - References
- Principal discovers whether she is "good" or "bad" type
  - Study the use of a public test by principal to try to convince agents to endorse her
  - Test is passed or failed
  - Information transmission problem
- Principal chooses toughness of test from a continuum of test types
  - Higher probability of passing a softer test
  - Greater impact from passing a tougher test
- And how pricing should respond to outcome of the public test
- Note: not studying problem of optimal test expertise
Outline

A. Introduction
B. Model
C. Choice Problem
D. Wanting to be Tested
E. Extreme Tests are Best
F. Choice of Extreme
G. Importance of Price
H. Conclusion
A. Introduction: Examples

- Beta-testers & magazine "previews" in software industry
- Job market candidates choosing referees
- Premieres at movie festivals
- Students choosing degree program to attempt
- Politicians "selling" a policy seeking support from think tanks
- Technology sponsors using standard setting organizations (SSOs)
  - “Technology sponsors attempt to build standards around their technologies by having them validated by SSOs that range from fully independent to largely captive special interest groups.” (Lerner & Tirole, AER 06)

- "Price" of endorsement can take different forms, e.g.
  - Standard market price
  - Salary
  - Degree of compromise offered on policy position
A. Introduction: Preview of Results

- Model not about signalling through *choice* of test; rather about signalling through *decision* of testing body
  - All equilibria are pooling
- Principal always chooses to be tested
  - Test complements the choice of price
- Choosing toughest or softest available is optimal
  - Ability to condition price on test result crucial in pushing choice to an extreme
- Toughest test possible where precision of agents’ private information is low and prior not too positive
  - Launch innovative product or idea with bang on passing tough test
- Softest test possible where precision of private information is high
  - Well-know product or idea
Lerner & Tirole (AER 06) consider biased SSOs
- Sponsor attempts to receive certification from an SSO
  - Continuum of SSOs which vary in bias for or against sponsor
- Differences compared to our setup
  - Sponsor does not know her quality
  - SSO discovers sponsor’s quality with certainty
  - Users receive no private information
  - Certification rule sensitive to any anticipated price response to decision
- Thus certifiers cannot counter bad private information
- And certification does not enable a rise in price
  - Sponsor happy to commit to price
  - Given certification rule adjusts if price set conditional on decision
- So no role for certifiers biased against the technology
- Choose SSO most biased in favor, subject to users adopting following certification
High initial prices in Taylor (REStud 99) and Bose et al. (RAND 07) play qualitatively similar role to tough reviewers

- Bose et al.: if expensive good becomes successful conveys strong positive information to later buyers
- Taylor: if expensive house not sold quickly, prospective buyers can attribute failure to sell to product being overpriced

Payment structures to certification intermediaries

- Lizzeri (RAND 99) and Albano & Lizzeri (IER 01)
- Ask how intermediaries affect product quality
- Disclosure may be incomplete, but no bias allowed

Ottaviani & Prat (Econometrica 01) consider use of certifier

- Again no bias; neither buyer nor seller fully informed
- Public signal correlated with buyer’s information reduces buyer’s rents given 2nd-degree price discrimination

Gill & Sgroi GEB 08: herding model without prices
B. Model: Timing

- Nature chooses unverifiable principal type $V \in \{0, 1\}$
  - "Good" type: $V = 1$
  - "Bad" type: $V = 0$
  - Prior $q \in (0, 1)$ that principal is good type
  - Type draw observed by principal but not agents

- $N$ agents each receive a private signal about type of principal

- Principal decides whether to face public test
  - If tested, chooses type of test to face, which is public
  - Test is passed or failed

- Principal chooses price $\lambda$
  - Conditioned on chosen test type and test decision

- Agents simultaneously decide whether to endorse
B. Model: Test Technology

- Testing body receives one signal from \( \{H, U, L\} \)
- \( p^z_V \) is probability test receives signal \( z \) given principal of type \( V \)
  - \( p^H_1 > p^H_0 \), so \( H \) is a high signal
  - \( p^L_1 < p^L_0 \), so \( L \) is a low signal
  - \( p^U_1 = p^U_0 \), so \( U \) is an uninformative signal
  - \( p^z_V > 0 \), so no signal is fully informative
  - When \( p^H_1 = p^L_0 \), we call signal structure "symmetric"
- Testing body makes a decision \( d \in D = \{P, F\} \)
- \( \phi^z_P \) is probability test is passed on receiving signal \( z \)
- Principal chooses test type \( \phi = \{\phi^H_P, \phi^U_P, \phi^L_P\} \)
  - W.l.o.g. \( \phi^H_P \geq \phi^L_P \), so \( P \) is good news and \( F \) bad news
  - Call tests with lower \( \phi^U_P \) "tougher"
  - Call tests with higher \( \phi^U_P \) "softer"
- Coarseness of binary report relative to trinary information is key
B. Model: Agents

- Each agent draws one signal from finite set $\mathcal{X} = \{0, 1, 2, ..., M\}$
  - Draws are i.i.d. conditional on $V$
  - And conditionally independent of test’s signal

- $p^m_V$ is probability agent receives signal $m$ given principal of type $V$
  - $p^m_V > 0$, so no signal is fully informative
  - If $p^m_V = p^0_V$ for all $m$, agents receive no private information

- $\mu = \Pr[V = 1|m, \phi, d, \lambda]$ is an agent’s posterior belief

- Agent endorses iff his $\mu \geq \lambda$
  - If agent endorses, $u = V - \lambda$
  - If doesn’t endorse, $u = 0$
  - Endorse at indifference is w.l.o.g.

- $\mu^m = \Pr[V = 1|m]$ is an agent’s posterior having observed only his private signal
Principal aims to maximize expected revenue $R$

Complicated choice problem

- For every possible test and decision, $M + 1$ possible prices
- Anticipated price choices feed back into choice of test
- And principal needs to worry about inferences from choice of test and price

First, we rule out inference from choices per se
- All equilibria are pooling

Then we show that principal will always choose
- $\phi_H^P = 1$, $\phi_L^P = 0$ and $\phi_U^P \in \{0, 1\}$
- Toughest or softest test available

Finally, we compare the toughest and softest tests
- Analytical results
- And some numerical analysis
C. Choice Problem: Ruling out Separation 1/2

- Throughout we restrict principal to pure strategies
- Perfect Bayesian Equilibrium is the solution concept
- Separating equilibria are impossible
- At node where actions differed, action would fully reveal type
  - Bad principal could costlessly copy the choice of good principal
  - Would then be believed to be good for sure by all agents
  - And agents would ignore test
- So in equilibrium choice of test and price uninformative
C. Choice Problem: Ruling out Separation 2/2

- Equilibrium selection issue among pooling equilibria
  - Any pooled strategies form a PBE
- Conditional on pooling, let \( \Omega \) be good type of principal’s set of optimal strategies
- We restrict attention to pooling equilibria with strategies in \( \Omega \)
  - Good type of principal chooses test and pricing rule
- Justified if, starting from a pooling equilibrium with strategies outside of \( \Omega \)
  - Deviations to \( \Omega \) weakly increase beliefs that principal is good type
In equilibrium, an agent’s posterior belief given by

\[ \mu_d^m = \frac{\Pr [d| V = 1, \phi] \mu^m}{\Pr [d| V = 1, \phi] \mu^m + \Pr [d| V = 0, \phi] (1 - \mu^m)} \]

Principal chooses price \( \lambda \in \{ \mu_0^d, \mu_1^d, ..., \mu_M^d \} \)

Setting \( \lambda = \mu_d^m \) results in endorsements from agents with signals

\[ k : \mu_k^d \geq \mu^m \]

Standard price-quantity trade-off

If \( \lambda \) outside this set, could increase price a little with no loss of endorsements

W.l.o.g. normalize number of agents to 1
C. Choice Problem: Revenue Function 2/2

- Given $\phi$ and $d$, optimal pricing results in expected revenue

$$\max_{m \in X} \mu_d^m \sum_{k: \mu^k \geq \mu^m} p^k$$

- So given $\phi$, but before test decision is known, expected revenue is

$$R = \sum_d \Pr[d \mid V = 1, \phi] \max_{m \in X} \mu_d^m \sum_{k: \mu^k \geq \mu^m} p^k$$

$$= \sum_d \max_{m \in X} \Pr[d \mid V = 1, \phi] \mu_d^m \sum_{k: \mu^k \geq \mu^m} p^k$$

- Principal chooses $\phi$ to maximize this
Theorem 1:
The principal strictly prefers any test to not being tested at all

Let’s compare any test $\phi$ to not being tested

In absence of a test

$$R = \max_{m \in \mathcal{X}} \mu^m \sum_{k: \mu^k \geq \mu^m} p^k_1$$

Let $\hat{m}$ be the maximizing $m$

- Principal sets $\lambda = \mu^{\hat{m}}$
- To target agents with signals at least as strong as $\hat{m}$
Now suppose

- Principal starts with belief $\mu^m$ about her type
- After the test, principal must set $\lambda = \mu_d^m$

Then test of no use as

$$\Pr[P|\Phi] \left( \mu_P^m - \mu^m \right) = \Pr[F|\Phi] \left( \mu^m - \mu_F^m \right)$$

However

- Principal knows she is a good type
- And can choose how many agents to target conditional on $d$
E. Extreme Tests are Best: Test Toughness

**Definition:** *(For fixed $\phi^H_P$ and $\phi^L_P$)*

(i) Test "toughness" is decreasing in $\phi^U_P$
(ii) Test "softness" is increasing in $\phi^U_P$

- A pass raises beliefs while a fail lowers them
  - $\mu^m_P > \mu^m > \mu^m_F$
- The softer the test
  - The smaller the positive impact of a pass: $\frac{\partial \mu^m_P}{\partial \phi^U_P} < 0$
  - And the bigger the negative impact of a fail: $\frac{\partial \mu^m_F}{\partial \phi^U_P} < 0$
  - But the greater the chance of passing
- The tougher the test
  - The bigger the positive impact of a pass
  - And the smaller the negative impact of a fail
  - But the smaller the chance of passing
E. Extreme Tests are Best: Convexity

- Remember

\[ R = \sum_{D} \max_{m \in X} \Pr [d \mid V = 1, \phi] \mu_d^m \sum_{k : \mu_k \geq \mu^m} p_k^1 \]

- Can prove that \( \Pr [d \mid V = 1, \phi] \mu_d^m \) is strictly convex in \( \phi_U \)
  - For any \( \phi_H^P \) and \( \phi_L^P \)

- Convex analysis then makes life easy
  - Maximum of strictly convex functions is strictly convex
  - As is sum of strictly convex functions

- Thus \( R \) is strictly convex in \( \phi_U^P \)
  - So maximized at \( \phi_U^P = 1 \) or \( \phi_U^P = 0 \), for any \( \phi_H^P \) and \( \phi_L^P \)

- Always choose toughest or softest test
- Clearly, result extends to any finite set of toughness levels
E. Extreme Tests are Best: Intuition 1/2

- We’ve seen that all prices are decreasing in $\phi_P^U$
  - Pass raises beliefs more the tougher the test
  - Fail not so damaging if test is tougher
- In fact, $\mu^m_P$ strictly convex in $\phi_P^U$
  - Conditional on a pass, increasing toughness more powerful the tougher the test already is
- But probability of pass is linear in $\phi_P^U$
  - To maximize $\Pr [P|V = 1, \phi] \mu^m_P$ principal chooses extreme $\phi_P^U$
  - Toughest test
    - Benefit from a steep increase in prices as $\phi_P^U \to 0$
    - While probability of pass falls linearly
  - Softest test
    - Linear increase in probability of pass
    - While prices do not fall much as $\phi_P^U \to 1$
Pr\[F|V = 1, \phi\] \mu^m_F \text{ maximized at } \phi^U_P = 0

Both Pr\[F|V = 1, \phi\] and \mu^m_F \text{ are decreasing in } \phi^U_P

Pr\[F|V = 1, \phi\] \mu^m_F \text{ also convex}

Summing over the 2 cases, principal always prefers extreme \phi^U_P

Chooses either extreme tough type
  - To maximize prices
  - At cost of lower probability of passing

Or extreme soft type
  - To maximize probability of passing
  - At cost of lower prices
E. Extreme Tests are Best: High & Low Signals

- No comparable notion of toughness for $\phi^H_P$ and $\phi^L_P$
- Higher $\phi^H_P$
  - Raises beliefs more after a pass
  - And lowers them more after a fail ($\phi^H_F \downarrow$)
- Lower $\phi^L_P$ does same

  *For any $\phi^U_P$, $R$ maximized at $\phi^H_P = 1$ and $\phi^L_P = 0$*
  - Maximize $\mu^m_F$ and minimize $\mu^m_F$

- Makes pass and fail signals as informative as possible
  - Principal knows her type to be good
  - So wants to transmit information as clearly as possible
  - If $\phi^H_P < 1$, so $\phi^H_F > 0$, some chance fail followed a high signal
  - If $\phi^L_P > 0$, some chance pass followed a low signal

- As $\phi^H_P \to \phi^L_P$, the test becomes uninformative
E. Extreme Tests are Best: Formal Results

Theorem 2:

Principal always selects $\phi^H_P = 1$, $\phi^L_P = 0$ and $\phi^U_P \in \{0, 1\}$, i.e., principal chooses a test which is as tough or as soft as possible on receiving an uninformative signal, and which always returns a pass on receiving a high signal and a fail on receiving a low signal.

Furthermore:

For any finite set of $\phi^U_P$ values such that $\phi^U_{P1} > \phi^U_{P2} > \ldots > \phi^U_{PS}$, $\phi^U_{P1}$ or $\phi^U_{PS}$ strictly preferred by principal to any intermediate test with $\phi^U_{PS} \notin \{\phi^U_{P1}, \phi^U_{PS}\}$.
F. Choice of Extreme: Analytical Results

Does principal prefer toughest ($\phi_P^U = 0$) or softest ($\phi_P^U = 1$) test?

- When $\phi_P^H = 1$ and $\phi_P^L = 0$

Suppose test’s signals are symmetric

- $p_1^H = p_0^L$

Theorem 3:

For sufficiently informative agent signals:

- Principal strictly prefers softest test

For sufficiently uninformative agent signals and $q > \frac{1}{2}$:

- Principal strictly prefers softest test

For sufficiently uninformative agent signals and $q \leq \frac{1}{2}$:

- Principal strictly prefers toughest test
F. Choice of Extreme: Intuition

- When agent signals are very uninformative
  - Principal expects agents to start with beliefs close to prior $q$
  - So when $q$ is high, limited scope to raise price using the test
    - Choose softest test, which is likely to be passed
    - (Even though failing a soft test is quite damaging)
  - And when $q$ is low, bigger scope to raise price using the test
    - Choose toughest test, which gives big upward impact if passed
    - Low initial agent beliefs encourages risk-taking
- When agent signals are very informative
  - Principal expects agents to start with good beliefs
  - Little upside from risking toughest test
  - So choose softest test
F. Choice of Extreme: Numerical Example 1/5

- For intermediate precision of agent information
  - Can’t provide general description of test choice
  - Although a given principal can calculate optimal test
- Suppose $q = \frac{1}{2}$
- Agents signal set is binary
  - $p^1_1 = p^0_0 = p_A$
  - $p^1_0 = p^0_1 = 1 - p_A$
  - $p_A \in \left[\frac{1}{2}, 1\right)$ measures informativeness of agents’ signals
- Test signals
  - $p^H_1 = p^L_0 = (p_T)^2$
  - $p^U_1 = p^U_0 = 2p_T(1 - p_T)$
  - $p^H_0 = p^L_1 = (1 - p_T)^2$
  - $p_T \in \left(\frac{1}{2}, 1\right)$ measures informativeness of test’s signals
- Can think of test receiving two i.i.d. draws from binary signal set
Figure 2: \( R(1) - R(0) \)
Figure 3: $\max \left\{ R(1), R(0) \right\} - R(\text{No Test})$
Choice of test matters

Choosing correct extreme: up to 15% of max possible revenue
Optimal test vs. no test: up to 50% of max

When toughest test is best

Choosing correct extreme matters more
Scope for prices to fall after failing a soft test

As $p_T$ rises
Importance of choosing to be tested goes up

Over most of range of $p_T$

Toughest test best until $p_A$ rises high enough
So Theorem 3 extends in natural way
Not true for very low $p_T$ though
Figure 5: $R(1) - R(0)$ for $p_T = 0.55$
In Gill & Sgroi GEB 08

- Principal seeks endorsement from sequence of agents
- Potential for herding effects

As length of sequence goes to 1

- Becomes simplified analogue of this model
- Except "price" is fixed
- And information structure much less general

P1: Any test with $\phi_P^U < \frac{1}{2}$ preferred to any other test with $\phi_P^U \geq \frac{1}{2}$

P2: From continuum principal selects test with $\phi_P^U$ just below $\frac{1}{2}$

Proof method is very different

- Recursive method used to find $R$

Despite differences, helps elucidate impact of prices

- They drive optimal choice of test to an extreme
H. Conclusion

- Public tests
  - Can be important and effective way of transmitting information
  - But have received little attention in the literature
- Our principal always prefers to be tested
  - And choice of test can matter a lot
- With conditional pricing, choosing an extreme test is optimal
  - Toughest test where quality of information and prior are low
  - Softest test where quality of information is high
- In IO setting, integrate two key choices for firm launching a new product
  - Choice of initial price
  - Testing as a product marketing strategy
- Findings might explain existence and survival of
  - Reviewers with harsh styles, biases and critical approaches
  - And very easy tests or “yes-men”