The Extensive Margin of Bayesian Persuasion

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SMYE

Motivation

Information does not come for free (Simon '96).

Information provider (*Sender*) faces a heterogeneous audience.

I study the persuasion of an **inattentive** Receiver who is **privately informed** about her cost and benefit of information.

Example

A persuader wants citizens to stay home during a pandemic, and controls the media.

Additional information has two effects:

1. On stay-at-home decisions if people are attentive.
   Do citizens change their behavior if they watch the media?
2. On attention decisions.
   Do citizens watch the media?

Questions: Who accesses information? What's the persuader-optimal information structure?

Example 2

A seller designs a signal S of the product's quality θ to persuade a buyer to buy.

Increasing the correlation between S and θ has two effects:

1. On the buyer's decision to buy if she observes the realization of S (**intensive margin** of persuasion).
2. On the buyer's **attention** (**extensive margin** of persuasion).

Results:

1. Characterization of the extensive margin.
2. Signals are equivalent to persuasion mechanisms.
3. Optimal signal in applications.

Model

Receiver's payoff from **action** $a \in \{0,1\}$ and **state** $\in [0,1]$ is

$$U_R(a,\theta,e;c,\lambda) = \underbrace{a(\theta - c)}_{\text{material payoff } u_R} - \underbrace{\lambda k(e)}_{\text{effort cost}},$$

in which:

- $c \in [0,1]$ is the threshold for action.
- $\lambda \in [0,1]$ is the attention cost.
- $e \in [0,1]$ is the attention **effort**, and k is strictly convex (this talk).
- $\theta \sim$ abs. cont. CDF F_0, with mean x_0.

Sender's payoff is $U_S(a) = a$.

Receiver is privately informed about her **type**: $(c,\lambda) \in T$, drawn from CDF H and independent of θ.

Timing

1. Sender publicly commits to a signal $\sigma\colon \Theta \to \Delta M$ ($M = [0,1]$, meas. σ).
2. Receiver chooses an **effort** e, knowing her **type**.
   3.1 Nature draws the state θ from F_0;
   3.2 Nature draws a message m from $\sigma(\theta)$.
4. **With probability** e, Receiver observes the message m; and then chooses action a.

Optimal Action given belief μ, of type-(c, λ) Receiver, is:

$$a^\star = \mathbf{1}\{\mathbb{E}_\mu \theta \geq c\}.$$

Marginal Benefit of Effort given belief distribution p, of type-(c, λ) Receiver, is:

$$A(c) = \mathbb{E}_p\left[\mathbb{E}_\mu u_R(a^\star, c, \theta)\right] - u_R(\mathbf{1}\{x_0 \geq c\}, c, x_0).$$

Literature

Persuasion of privately informed Receiver, with costless access to signal. (Rayo-Segal '10; Kolotilin *et al.* '17; Kolotilin '18; Guo-Shmaya '19; ...)

Persuasion of inattentive Receiver, without private information. (Bizzotto *et al.* '20; Wei '21; Matyskova-Montes '23.)

- Bloedel-Segal wp:

  main specification: costly mutual information.
  alternative: costly attention effort $e \to$ binary signals.

Attention management: $U_S = u_R$. (Lipnowski *et al.* '20, '22.)

Incomplete-Information beauty contests (Myatt-Wallace '14; Chahrour '14; Galperti-Trevino '20.)

Signals as Information Policies

We identify a signal with its induced **information policy**.

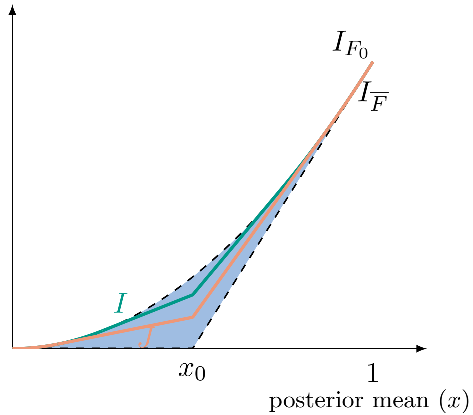
The *information policy* of CDF F is:

$$I_F(x) = \int_0^x F(\widetilde{x})\,\mathrm{d}\widetilde{x}, \quad x \geq 0.$$

1. I_F is convex $\leftarrow$ F is nondecreasing.
2. $I_{\overline{F}} \leq I_F \leq I_{F_0}$, in which:
   $\overline{F}$ is posterior mean's CDF induced by an **uninformative signal**.
   F_0 is posterior mean's CDF induced by a **fully informative signal**.

Every signal induces an information policy of the CDF of the posterior mean. **Fact 1** (Gentzkow-Kamenica '16; Kolotilin '18). If $I \colon \mathbb{R}_+ \to \mathbb{R}_+$ satisfies 1. and 2., then: I is the information policy of the CDF of the posterior mean for some signal.

Information Policies



Blackwell's ranking of information policies
$I \geq J$ iff I is more Blackwell informative than J.

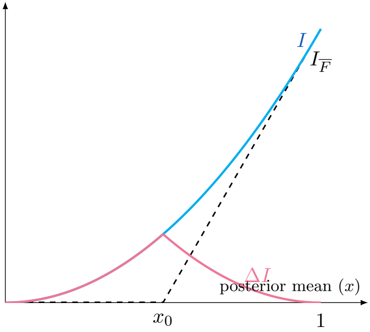
Interval Structure of the Extensive Margin

"Net informativeness" is denoted by

$$\Delta I = I - I_{\overline{F}}.$$

Lemma 1 (Marginal Benefit of Effort) The marginal benefit of effort given information policy I satisfies:

$$A(c) = \Delta I(c), \quad \text{for all } c \in [0, 1].$$



Extensive Margin

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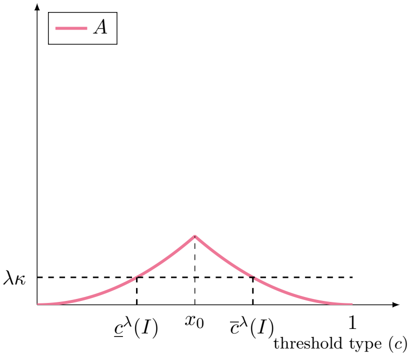


Linear Cost ($k(e) = \kappa e$) There exist *cutoff types*, given attention-cost λ: $\underline{c}^{\lambda}(I)$, $\overline{c}^{\lambda}(I)$.

Supermodularity

Receiver's *value of information policy* I is her interim payoff, given her type:

$$V_R(\Delta I(c), \lambda) := \max_{e \in [0,1]} e \Delta I(c) - \lambda k(e).$$

A *persuasion mechanism* is a menu of information policies: $I_\bullet = (I_r)_{r \in T}$.

A persuasion mechanism $I_\bullet$ is *incentive compatible* (IC) if:

$$V_R(\Delta I_{(c,\lambda)}(c), \lambda) \geq V_R(\Delta I_{\widetilde{(c,\lambda)}}(c), \lambda)$$

for all types $(c, \lambda) \in T$ and reports $\widetilde{(c, \lambda)} \in T$.

Equivalence

An IC persuasion mechanism $I_\bullet$ and an information policy J induce the *same effort distribution* if:

$$\arg\max_{e\in[0,1]} e\Delta J(c) - \lambda k(e) = \arg\max_{e\in[0,1]} e\Delta I_{(c,\lambda)}(c) - \lambda k(e),$$

for all types (c, λ).

An IC persuasion mechanism $I_\bullet$ and an information policy J induce the *same action distribution* if:

$$\underbrace{1 - J'(c^-)}_{\text{Prob. of } \{a^\star = 1\}} = 1 - I'_{(c,\lambda)}(c^-),$$

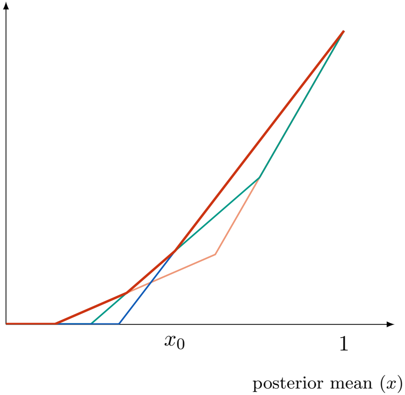
for all types (c, λ) who exert positive effort under $I_\bullet$.

Theorem 1

For every IC persuasion mechanism $I_\bullet$ there exists an information policy J that induces the same effort and action distributions.

Equivalence

Key step: The upper envelope of the information policies in $I_\bullet$ is an information policy.



If $\lambda = 0$ is known to Sender: Kolotilin *et al.* '17.

Sender's Maximization

The Sender's expected payoff from information policy I, if Receiver's cost k is linear, is:

$$V_S(I) = \int_T \underbrace{\mathbf{1}\{\underline{c}^\lambda(I) \leq c \leq \overline{c}^\lambda(I)\}}_{\substack{\text{Extensive margin} \\ e>0}} \underbrace{\left[1 - I'(c^-) - \mathbf{1}\{x_0 \geq c\}\right]}_{\text{Intensive margin}} \mathrm{d}H(c, \lambda).$$

I is an optimal information policy if it solves the Sender's problem:

$$\sup_{I:\, \mathbb{R}_+ \to \mathbb{R}_+} V_S(I)$$

subject to:

1. I is convex.
2. $I_{\overline{F}} \leq I \leq I_{F_0}$.

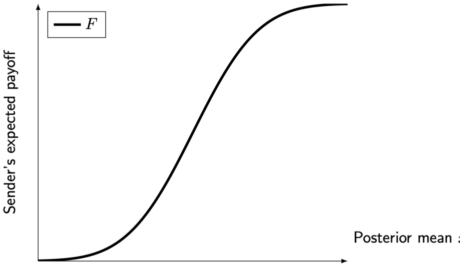
Single-Peakedness

Assumption (SPness)

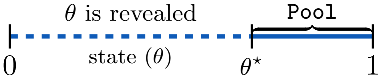
1. Attention cost λ is independent of threshold c.
2. Threshold c admits an abs. cont. PDF f that is single-peaked, with CDF F.

With costless info ($k = 0$):

- Expected payoff at posterior mean x is CDF of c evaluated at x: $F(x)$.
- I' second-order stoch. dominates J' iff: $I \geq J$.



Optimal Signal



Theorem 2

Under the SPness assumption, there exists an optimal information policy that is induced by an upper censorship signal.

Key step

Sender's value functional:

$$V_S(I) = \int_{\lambda=0}^{1} \int_{c=0}^{1} V_R(\Delta I(c), \lambda) h_c'(c) \, \mathrm{d}c h_\lambda(\lambda) \, \mathrm{d}\lambda.$$

Application

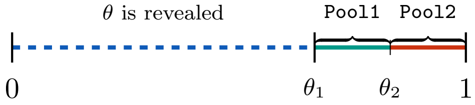
1. Sender knows Receiver's attention cost λ.
2. k is linear.
3. Sender's payoff is:

$$U_S(a, e) = \psi a + \gamma e.$$

Interpretation:

- $\psi \geq 0$ is the mobilizing character of the government.
- $\gamma \geq 0$ is the size of the media market.

Lemma 2 (Media Censorship)
Under 1., 2. and 3., and SPness, there exists an optimal information policy that is induced by a bi-upper censorship signal.



- Kolotilin *et al.* '22: no media market.
- Gehlbach-Sonin '14: Sender knows c, and does not know λ.

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