Competition in persuasion

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Motivation

- Does competition among persuaders increase information?

Long tradition in political and legal thought says: Yes

Media ownership regulation

First Amendment law

Adversarial judicial system
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  - First Amendment law
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Example

- Two pharmaceutical companies, $j = 1, 2$
- $\omega_{ij} \in \{l, h\}$ is the quality of drug $j$ for consumer $i$
- Qualities are independent and $Pr(\omega_{ij} = h) = \frac{1}{5}$
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- Qualities are independent and \( Pr(\omega_{ij} = h) = \frac{1}{5} \)
- Unit mass of consumers, all prefer high to low quality
  - \( \frac{1}{2} \) always buy the drug with higher expected quality
  - \( \frac{1}{2} \) buy the drug with higher expected quality if \( Pr(\omega_i = h) > \frac{1}{2} \)
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  - \textit{null}: an uninformative signal
  - \textit{reveal}_j: fully reveals quality of own drug for all \( i \)
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Prisoners’ dilemma

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- Prisoners’ dilemma
  - revealing information beneficial for the firm’s joint profits
  - revealing information unilaterally unattractive
  - null is a dominant strategy

- Unique equilibrium: (null, null)
- Unique collusive outcome: (reveal<sub>1</sub>, reveal<sub>2</sub>)
- Enhancing competition (blocking a merger) leads to less information
Framework and goal

- Symmetric information
- Number of senders simultaneously choose signals about the state
- Each sender has arbitrary preferences over the information revealed
Framework and goal

- Symmetric information
- Number of senders simultaneously choose signals about the state
- Each sender has arbitrary preferences over the information revealed

- Competition can reduce information

Goal: Find a condition on the information environment such that competition unambiguously increases information if and only if this condition is satisfied.
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- Symmetric information
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- Competition can reduce information
- Competition can increase information
Framework and goal

- Symmetric information
- Number of senders simultaneously choose signals about the state
- Each sender has arbitrary preferences over the information revealed

- Competition can reduce information
- Competition can increase information
- Information environment specifies information available to each sender
- Goal: Find a condition on the information environment such that

Theorem

*Competition unambiguously increases information if and only if this condition is satisfied.*
Model
Model

- Finite state space $\Omega$; typical state $\omega$
- $n$ senders with a common prior
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- A \textit{signal} is a random variable (potentially) correlated with \( \omega \)
- A set of signals \( P \) induces a distribution of posteriors \( \langle P \rangle \)
- Simultaneous move game:
  - sender \( i \) chooses signal \( \pi_i \in \Pi_i \)
  - strategy profile \( \pi = (\pi_1, \ldots, \pi_n) \)
  - sender \( i \)'s payoff: \( v_i(\langle \pi \rangle) \)
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- Focus on pure strategy equilibria
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- Focus on **pure strategy** equilibria
- Assumption:
  - $\pi \in \Pi_i \ \forall i$: $\langle P \cup \pi \rangle = \langle P \rangle \ \forall P$
Model

- Finite state space $\Omega$; typical state $\omega$
- $n$ senders with a common prior
- A *signal* is a random variable (potentially) correlated with $\omega$
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**Simultaneous move game:**

- sender $i$ chooses signal $\pi_i \in \Pi_i$
- strategy profile $\pi = (\pi_1, \ldots, \pi_n)$
- sender $i$'s payoff: $v_i(\langle \pi \rangle)$

**Focus on pure strategy equilibria**

**Assumption:**

- $\bar{\pi} \in \Pi_i \forall i$: $\langle P \cup \bar{\pi} \rangle = \langle P \rangle \forall P$

**Terminology:**

- $\tau$ is *feasible* if $\exists \pi \in \Pi$ s.t. $\tau = \langle \pi \rangle$
The Blackwell order

- Blackwell order $\succeq$ on the set of outcomes
- Partial order
The Blackwell order

- Blackwell order $\succeq$ on the set of outcomes
- Partial order
  - $\tau \succeq \tau' \rightarrow \tau$ is *more informative* than $\tau'$
  - $\tau' \not\succeq \tau \rightarrow \tau$ is *no less informative* than $\tau'$
Key features of the set-up

- Information generated directly observed
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- Senders have no private information when they choose their signals
- All available signals are equally costly
  - Arbitrary $\Pi_i$’s allow some signals to be prohibitively costly
  - Allow for comparative advantage
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- Information generated directly observed
- Senders have no private information when they choose their signals
- All available signals are equally costly
  - Arbitrary $\Pi_i$’s allow some signals to be prohibitively costly
  - Allow for comparative advantage
- No sender can down out information provided by others:
  - $P' \subset P \implies \langle P \rangle \succeq \langle P' \rangle$
Basic intuition
The sum game

- Each player $i$ chooses $q_i \in \mathbb{N}$
- Outcome of the game is $\tau = \sum_i q_i$
- Player $i$’s payoff is $v_i(\tau)$
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Proposition

*Any pure strategy equilibrium outcome is weakly greater than the collusive outcome.*
The sum game

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Proposition

Any pure strategy equilibrium outcome is weakly greater than the collusive outcome.

- suppose $\tau^c > \tau^*$
- for at least one player $v_i(\tau^c) > v_i(\tau^*)$
- player $i$ can profitably deviate to $q_i = q_i^* + (\tau^c - \tau^*)$
The sum game: key properties

- No downward deviation feasible: \( q_i \geq 0 \)
  - Equilibria with excessively high outcomes possible
  - Information also has this feature

- Every upward deviation feasible: every \( i \) can deviate to \( \tau \geq \sum q_i \)
  - Equilibria with excessively low outcomes not possible
  - Information does not always have this feature
The information environment
Refer to $\prod \equiv \times \pi_i$ as the *information environment*.
Information environment

- Refer to $\Pi \equiv \times_i \Pi_i$ as the *information environment*

**Definition**

$\Pi$ is *Blackwell-connected* if $\forall i$, $\forall \pi \in \Pi$, $\pi' \in \Pi_{-i}$ s.t. $\langle \pi \rangle \succeq \langle \pi' \rangle$, $\exists \pi_i \in \Pi_i$ s.t. $\langle \pi \rangle = \langle \pi' \cup \pi_i \rangle$. 

Alternatively, each player $i$ has *information sets* $\Pi_i$ such that $\Pi_{-i}$ is info-superior if

\[\langle \pi \rangle \succeq \langle \pi' \cup \pi_i \rangle \quad \forall \pi \in \Pi_i, \forall \pi' \in \Pi_{-i}\]
Information environment

- Refer to $\prod \equiv \times_i \prod_i$ as the *information environment*

**Definition**

$\prod$ is *Blackwell-connected* if $\forall i, \forall \pi \in \prod, \pi' \in \prod_{-i}$ s.t. $\langle \pi \rangle \succeq \langle \pi' \rangle$, $\exists \pi_i \in \prod_i$ s.t. $\langle \pi \rangle = \langle \pi' \cup \pi_i \rangle$.

- i.e., given any strategy profile, any sender can unilaterally deviate to any feasible outcome that is more informative
Examples of environments

- **Number of draws**: given $\pi$, each sender chooses the number of independent draws.
- **Precisions**: sender $i$ generates an independent signal $\mathcal{N}(\omega, \sigma_i^2)$.
- **Partitions**: each sender chooses a partition of $\Omega$.
- **Facts**: each fact in set $F$ generates an i.i.d. signal; each $i$ chooses $F_i \subset F$.
- **All-or-nothing**: each sender can say nothing or fully reveal everything.
- **Rich**: each sender conducts any experiment, potentially correlated with others.

All of these information environments are Blackwell-connected.
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All of these information environments are Blackwell-connected.
Individual vs. aggregate feasibility

- Key implication of environment being Blackwell-connected:

### Claim

Suppose $\Pi$ is Blackwell-connected. Then, $\{\langle \pi \rangle | \pi \in \Pi_i \} = \{\langle \pi \rangle | \pi \in \Pi \}$ for all $i$. 

Individual vs. aggregate feasibility

- Key implication of environment being Blackwell-connected:

**Claim**

Suppose $\Pi$ is Blackwell-connected. Then, $\{\langle \pi \rangle | \pi \in \Pi_i \} = \{\langle \pi \rangle | \pi \in \Pi \}$ $\forall i$.

- Each sender can provide as much information as many senders can provide together
Individual vs. aggregate feasibility

- Key implication of environment being Blackwell-connected:

**Claim**

Suppose $\Pi$ is Blackwell-connected. Then, $\{\langle \pi \rangle | \pi \in \Pi_i \} = \{\langle \pi \rangle | \pi \in \Pi \}$ $\forall i$.

- Each sender can provide as much information as many senders can provide together
- Necessary but not sufficient for environment to be Blackwell-connected
  - $\Pi$ can also be too ‘coarse’
  - e.g., each sender chooses $n_i \in \{0, 2, 3, \ldots \}$ independent draws
Main result
An outcome $\tau^c$ is *collusive* if it maximizes $\sum_i v_i(\tau)$.
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results generalize to all monotone social welfare functions
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Expositional ease: assume collusive outcome is unique

- generically satisfied
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Compare equilibrium outcomes with the collusive outcome
Proposition

Every equilibrium outcome is no less informative than the collusive outcome (regardless of preferences) if and only if the information environment is Blackwell-connected.
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- Suppose \( \Pi \) is Blackwell-connected
- Suppose \( \tau^c \succ \tau^* = \langle \pi^* \rangle \)
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Every equilibrium outcome is no less informative than the collusive outcome (regardless of preferences) if and only if the information environment is Blackwell-connected.

- Suppose $\Pi$ is Blackwell-connected
- Suppose $\tau^c \succ \tau^* = \langle \pi^* \rangle$
- There is some sender $i$ s.t. $v_i(\tau^c) > v_i(\langle \pi^* \rangle)$
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- Suppose $\tau^c \succcurlyeq \tau^* = \langle \pi^* \rangle$
- There is some sender $i$ s.t. $v_i (\tau^c) > v_i (\langle \pi^* \rangle)$
- Let $\pi^*_{-i} = (\pi^*_1, \ldots, \pi^*_{i-1}, \pi^*_{i+1}, \ldots, \pi^*_n) \in \Pi_{-i}$
- We have $\tau^c \succeq \langle \pi^* \rangle \succeq \langle \pi^*_{-i} \rangle$
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- Suppose \( \tau^c \succeq \tau^* = \langle \pi^* \rangle \)
- There is some sender \( i \) s.t. \( v_i(\tau^c) > v_i(\langle \pi^* \rangle) \)
- Let \( \pi^*_{-i} = (\pi_1^*, ..., \pi_{i-1}^*, \pi_{i+1}^*, ..., \pi_n^*) \in \Pi_{-i} \)
- We have \( \tau^c \succeq \langle \pi^* \rangle \succeq \langle \pi^*_{-i} \rangle \)
- \( \Pi \) Blackwell-connected \( \Rightarrow \exists \pi_i^d \in \Pi_1 \) s.t. \( \tau^c = \langle \pi^*_{-i} \cup \pi_i^d \rangle \)
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- Suppose $\Pi$ is Blackwell-connected
- Suppose $\tau^c \succ \tau^* = \langle \pi^* \rangle$
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- We have $\tau^c \succeq \langle \pi^* \rangle \succeq \langle \pi^*_{-i} \rangle$
- $\Pi$ Blackwell-connected $\Rightarrow \exists \pi^d_i \in \Pi_i$ s.t. $\tau^c = \langle \pi^*_{-i} \cup \pi^d_i \rangle$

- only if part is constructive
Caveats

- Equilibrium outcomes might not be comparable to the collusive outcome
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Proposition

Every equilibrium outcome is more informative than the collusive outcome (regardless of preferences) if and only if the information environment is Blackwell-connected and any two feasible outcomes are comparable.
Caveats

- Equilibrium outcomes might not be comparable to the collusive outcome

Proposition

*Every equilibrium outcome is more informative than the collusive outcome (regardless of preferences) if and only if the information environment is Blackwell-connected and any two feasible outcomes are comparable.*

- With mixed strategies, the environment is never Blackwell connected
  - mixed strategy equilibria are not unambiguously more informative than collusive outcomes
Illustration of the result

- Will a merger of two pharmaceuticals lead to more information?

Scenario A: each firm commissions RCT from a third-party each batch of subjects yields an i.i.d. signal about the two drugs informational environment is Blackwell-connected merger will reduce information regardless of the demand structure

Scenario B: each firm can only generate information about its own drug informational environment is not Blackwell-connected impact of merger will depend on demand for some demand structure, merger will make consumers more informed
Illustration of the result

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- Scenario B:
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Scenario B:
- each firm can only generate information about its own drug
- informational environment is not Blackwell-connected
- impact of merger will depend on demand
- for some demand structure, merger will make consumers more informed
Characterizing the equilibrium set

A simple equilibrium characterization if the environment is Blackwell-connected and $\Pi_i = \Pi \forall i$
Characterizing the equilibrium set

- A simple equilibrium characterization if the environment is Blackwell-connected and $\Pi_i = \Pi \forall i$

- Outcome $\tau$ is *unimprovable* for $i$ if for any feasible $\tau' \succeq \tau$, we have $v_i(\tau') \leq v_i(\tau)$
Proposition

Suppose $\Pi_i = \Pi \ \forall i$, $\Pi$ is Blackwell-connected, and $n \geq 2$. A feasible outcome is an equilibrium outcome if and only if it is unimprovable for each sender.
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- Only if follows directly from definition of Blackwell-connected.
Characterization result

**Proposition**

*Suppose \( \Pi_i = \Pi \forall i, \Pi \) is Blackwell-connected, and \( n \geq 2 \). A feasible outcome is an equilibrium outcome if and only if it is unimprovable for each sender.*

- Only if follows directly from definition of Blackwell-connected
- Suppose some feasible \( \tau \) is unimprovable for each sender
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Suppose $\Pi_i = \Pi \forall i$, $\Pi$ is Blackwell-connected, and $n \geq 2$. A feasible outcome is an equilibrium outcome if and only if it is unimprovable for each sender.

- Only if follows directly from definition of Blackwell-connected
- Suppose some feasible $\tau$ is unimprovable for each sender
- Consider $\pi \in \Pi$ s.t. $\langle \pi \rangle = \tau$
Proposition

Suppose $\Pi_i = \Pi \forall i$, $\Pi$ is Blackwell-connected, and $n \geq 2$. A feasible outcome is an equilibrium outcome if and only if it is unimprovable for each sender.

- Only if follows directly from definition of Blackwell-connected

- Suppose some feasible $\tau$ is unimprovable for each sender

- Consider $\pi \in \Pi$ s.t. $\langle \pi \rangle = \tau$

- Strategy profile $(\pi, ..., \pi)$ is an equilibrium
  - $i$ can only deviate to $\tau' \succeq \tau$
  - $\tau$ unimprovable implies $v_i(\tau') \leq v_i(\tau)$
Characterization result illustrated

\[ v_1(\tau) \]

\[ v_2(\tau) \]
Comparative statics illustrated

$v_1(\tau) + v_2(\tau)$
Other results

- Three notions of increased competition
  - Equilibrium outcomes vs. collusive outcomes
  - Presence of additional senders
  - Misalignment of senders’ preferences
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- Three notions of increased competition
  - Equilibrium outcomes vs. collusive outcomes
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- Focus on $\Pi_i = \Pi$ and minimally informative equilibria

- If $\Pi$ is Blackwell-connected
  - adding senders cannot lead to less information
  - more misalignment cannot lead to less information
Other results

- Three notions of increased competition
  - Equilibrium outcomes vs. collusive outcomes
  - Presence of additional senders
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- Focus on $\Pi_i = \Pi$ and minimally informative equilibria
- If $\Pi$ is Blackwell-connected
  - Adding senders cannot lead to less information
  - More misalignment cannot lead to less information
- Comparative statics on sets
Thank you
Minimal equilibria

- Suppose the informational environment is Blackwell-connected.
- Suppose \( \tau \) and \( \tau' \) are two equilibrium outcomes and \( \tau' \succ \tau \).

Say \( \tau \) is a minimal equilibrium outcome if there is no equilibrium outcome \( \tau' \) s.t. \( \tau' \succ \tau \).
Minimal equilibria

- Suppose the informational environment is Blackwell-connected
- Suppose $\tau$ and $\tau'$ are two equilibrium outcomes and $\tau' \succ \tau$
- Then, $v_i(\tau) \succeq v_i(\tau')$ for all senders $i$
Minimal equilibria

- Suppose the informational environment is Blackwell-connected
- Suppose $\tau$ and $\tau'$ are two equilibrium outcomes and $\tau' \succ \tau$
- Then, $v_i(\tau) \geq v_i(\tau')$ for all senders $i$
- Say $\tau$ is a *minimal equilibrium outcome* if there is no equilibrium outcome $\tau'$ s.t. $\tau' \succ \tau$
Adding senders

- Compare minimal equilibria when
  - set of senders is $J$
  - set of senders is $J' \subset J$

Blackwell-connectedness no longer sufficient also need $\Pi_i = \Pi$ for all $i$. If the information environment is Blackwell-connected, then (regardless of $p$ references) any minimal equilibrium outcome when the set of senders is some set $J$ is no less informative than any minimal equilibrium outcome when the set of senders is some set $J' \subset J$. 
Adding senders

- Compare minimal equilibria when
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Adding senders

- Compare minimal equilibria when
  - set of senders is $J$
  - set of senders is $J' \subset J$
- Blackwell-connectedness no longer sufficient
  - also need $\Pi_i = \Pi$

**Proposition**

*Suppose $\Pi_i = \Pi$ for all $i$. If the information environment is Blackwell-connected, then (regardless of preferences) any minimal equilibrium outcome when the set of senders is some set $J$ is no less informative than any minimal equilibrium outcome when the set of senders is some set $J' \subset J$.***
Preference misalignment

- Suppose there are two senders $j$ and $k$ with

  \[
  v_j(\tau) = f(\tau) + bg(\tau)
  \]

  \[
  v_k(\tau) = f(\tau) - bg(\tau)
  \]

- Parameter $b \geq 0$ measures misalignment of preferences
Preference misalignment

Suppose there are two senders $j$ and $k$ with

$$ v_j(\tau) = f(\tau) + bg(\tau) $$
$$ v_k(\tau) = f(\tau) - bg(\tau) $$

Parameter $b \geq 0$ measures misalignment of preferences

Proposition

Suppose $\Pi_i = \Pi$ for all $i$. If the information environment is Blackwell-connected, then any minimal equilibrium outcome when the level of misalignment is $b$ is no less informative than any minimal equilibrium outcome when the level of misalignment is some $b' < b$. 