Organized Information Transmission

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Introduction

Question: What outcomes can be implemented by simple, realistic information protocols?

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Observation: In reality, information is often transmitted in horizontal or vertical ways.

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- Transmitting information to many people at once, instead of to each of them individually, minimizes the number of communication channels.

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- Examples: hierarchical communication in organizations, viral marketing, etc.
- Delegating information transmission to the receivers themselves also minimizes the number of communication channels.

Contribution

Formalize the concepts of horizontal and vertical transmission.

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Focus on two limit-case families of information structures as proof of concept.

Characterize the outcomes they implement in general finite games.
$\Rightarrow$ Organizational perspective on incomplete information/ constrained information design.

Optimality in binary-action environments with complementarities.
$\Rightarrow$ When optimal outcomes can be implemented by simple protocols. (E.g., optimality of posted prices in mechanism design.)

Contribution

In comparison, direct information structures, which invoke the Revelation Principle (Myerson (1991)) and make incentive-compatible action recommendations, do not constrain information horizontally or vertically.

This can make them very difficult to implement in reality.

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Contribution

"The Revelation Principle in mechanism design is both a blessing and a curse [...] It is a curse because direct mechanisms provide such an unrealistic picture of decision-making in organizations."

Van Zandt (2007)

Related Literature

Solution Concepts Forges (1993, 2006), Bergemann & Morris (2016)

Information Design
Binary action supermodular: Arieli & Babichenko (2019), Candogan & Drakopoulos (2020), Candogan (2020)
Adversarial selection: Morris, Oyama & Takahashi (2020), Li, Song & Zhao (2019), Inostroza & Pavan (2020), Mathevet, Perego & Taneva (2020)

Structure of Information Brooks, Frankel & Kamenica (2022), Galperti & Perego (2020)

Communication in Organizations Radner (1993), Van Zandt (1999), Hori (2006), Crémer, Garicano & Prat (2007), Rantakari (2008), Alonso, Dessein & Matouschek (2008), Deimen & Szalay (2019)

Mechanism Design under Restricted Communication Mookherjee & Reichelstein (2001), Mookherjee & Tsumagari (2014)

Preliminaries

Model & Basic Definitions

- Set of players: $\mathcal{I} = \{1, \ldots, n\}$.
- Uncertain state: $\omega \in \Omega$ (finite).
- Prior: $\mu \in \Delta(\Omega)$.
- Actions: $a_i \in A_i$ (finite).
- Payoffs: $u_i : A \times \Omega \to \mathbb{R}$.

Model & Basic Definitions

- Outcome distribution: $p \in \Delta(A \times \Omega)$.

SMS DH

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- Outcome distribution: $p \in \Delta(A \times \Omega)$.
- An outcome distribution $p \in BCE(\mu)$ if [Bergemann and Morris 2016]
  1. Consistency with prior: $p(A \times \{\omega\}) = \mu(\omega)$ for all ω, and
  2. Obedience: $\sum_\omega \sum_{a_{-i}} p(a, \omega) \left(u_i(a; \omega) - u_i(a_i', a_{-i}; \omega)\right) \geqslant 0$ for all i, a_i, a_i'.

SMS DH

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- p is implemented by (S, P) if there is a (pure) BNE a^* s.t.

$$p(a, \omega) = \mu(\omega) P(\{s : \; a^*(s) = a\}|\omega) \quad \forall a, \omega.$$

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Informedness

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- $i \succeq^s_{\text{Inf}} j$: i is weakly more informed than j at s if

$$\mu_i(\omega, s_{-i}|s_i, s_j) = \mu_i(\omega, s_{-i}|s_i)$$

for all $\omega \in \Omega$ and $s_{-i} \in S_{-i}$.

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- $i =^s_{\text{Inf}} j$: i and j are equally informed at s if $i \succeq^s_{\text{Inf}} j$ and $j \succeq^s_{\text{Inf}} i$.

Horizontal vs. Vertical Transmission

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General formalism: Each information structure can be formally categorized according to the extent to which it allows horizontal and vertical transmission.

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General formalism: Each information structure can be formally categorized according to the extent to which it allows horizontal and vertical transmission.

We focus on two limit-case families of organized information structures:

- Single-Meeting Schemes (SMS) – illustrating horizontal transmission
- Delegated Hierarchies (DH) – illustrating vertical transmission

Characterization:

Single-Meeting Schemes

In principle (1) the content of a meeting is common knowledge among the participants, (2) who also know the non-participants are less informed.

Definition: Single Meeting Schemes

An information structure (S, P) is a single-meeting scheme if there exist a collection $\{M(s) \subseteq \mathcal{I} : s \in S$ s.t. $P(s) > 0\}$ and <u>at most one</u> $\tilde{s}_i \in S_i$ for each i such that:

(1) $i \in M(s)$ implies $s_i \neq \tilde{s}_i$ and $i \succsim^s j$ for all $j \in \mathcal{I}$ and

(2) $i \notin M(s)$ implies $s_i = \tilde{s}_i$.

Properties: Single Meeting Schemes

- Information communicated publicly but to a restricted audience: $i, j \in M(s) \Rightarrow i =^{s}_{\text{Inf}} j$.

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- Non-participation may carry different information for different players: $\mu_i(\cdot|\tilde{s}_i) \neq \mu_j(\cdot|\tilde{s}_j)$ possible.
- Many possible meetings ex-ante: $\{M(s) \subseteq \mathcal{I} : s \text{ s.t. } P(s) > 0\}$ but only one is ever realized.

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Characterization: SMS

Which strategic outcomes can emerge in a game where incomplete information is in the form of single-meeting schemes?

Constrained information design: optimize over a subset of the BCE set.

Characterization: SMS

Theorem 1

A distribution $p \in \Delta(A \times \Omega)$ can be implemented by a SMS if and only if for all $i \in \mathcal{I}$, there is $\tilde{a}_i \in A_i$ such that

$$\sum_{\omega \in \Omega} \sum_{a_{-i}} p(\tilde{a}_i, a_{-i}, \omega) \left(u_i(\tilde{a}_i, a_{-i}; \omega) - u_i(a_i', a_{-i}; \omega)\right) \geqslant 0 \quad \forall a_i' \in A_i,$$

and for all $a_i \in A_i \backslash \{\tilde{a}_i\}$

$$\sum_{\omega \in \Omega} p(a_i, a_{-i}, \omega) \left(u_i(a_i, a_{-i}; \omega) - u_i(a_i', a_{-i}; \omega)\right) \geqslant 0 \quad \forall a_i' \in A_i, a_{-i} \in A_{-i}.$$

BCE

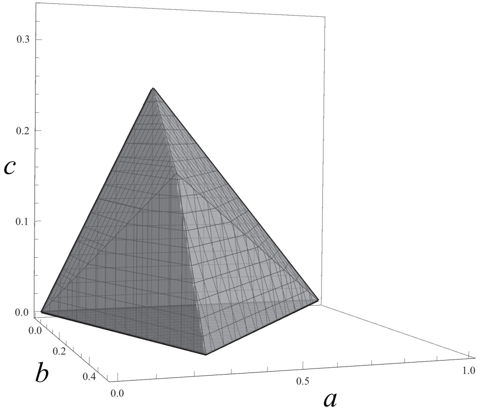
Characterization: SMS in BoS

Example:

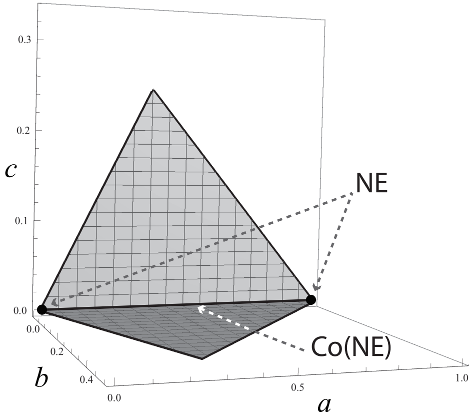
	0	1
0	3, 2	0, 0
1	0, 0	2, 3

Battle of the Sexes

Characterization: SMS in BoS



(a) Correlated Equilibria



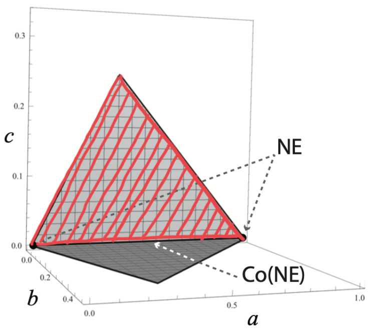
(b) SMS

Characterization: SMS in BoS

- In coordination games with strict equilibria, SMS(μ) is a union of faces of BCE(μ).

- Pure-strategy public information outcomes lie at the intersection of the different classes of SMS (here, the intersection of the faces).

Characterization: SMS in BoS

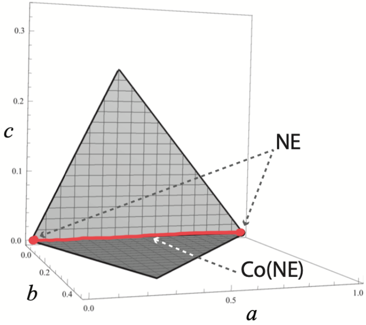


(b) SMS

	0	1
0	a	0
1	c	d

$\tilde{a}_1 = 1, \tilde{a}_2 = 0$

Characterization: SMS in BoS



(b) SMS

	0	1
0	a	0
1	0	d

$\tilde{a}_1 = 0$, $\tilde{a}_2 = 0$ (or $\tilde{a}_1 = 1$, $\tilde{a}_2 = 1$)

Optimality:

Single-Meeting Schemes

Optimality: Context

Identify environments in which single-meeting schemes and delegated hierarchies are overall optimal?

$\Rightarrow$ an optimal BCE outcome satisfies the characterizations

Optimality: Assumptions

Assumption 1 (Binary Actions) For all $i \in \mathcal{I}$, $A_i = \{0, 1\}$.

Assumption 2 (Outside Option) For all $i \in \mathcal{I}$, $u_i = 0$ whenever $a_i = 0$.

Assumption 3 (Complementarities). For all $i \in \mathcal{I}$, $u_i(1, a_{-i}; \omega)$ is weakly increasing in a_{-i} for all $\omega \in \Omega$.

Optimality: Assumptions

Examples :

- Linear network

$$u_i(a_i, a_{-i}; \omega) = \gamma_i(\omega)\, a_i + \sum_{j \neq i} \gamma_{ij}(\omega)\, a_i a_j$$

- Global games of regime change
  [Sakovics and Steiner 2012]

$$u_i(1, a_{-i}; \omega) = \begin{cases} b_i - c_i & \text{if} \quad \kappa_i + \sum_{j \neq i} \kappa_j a_j > 1 - \omega \\ -c_i & \text{otherwise.} \end{cases}$$

and $u_i(0, a_{-i}; \omega) = 0$.

Optimality of Single-Meeting Schemes

$v : A \times \Omega \to \mathbb{R}$ is increasing (on A) if
$a' \geqslant a \Rightarrow v(a'; \omega) \geqslant v(a; \omega)$ for all $\omega \in \Omega$.

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Let $\mathcal{V}^{\mathrm{M}} = \{v : A \times \Omega \to \mathbb{R} : \ v \text{ is increasing}\}$.

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Theorem 4

If $\{u_i\}$ satisfy Assumptions 1-3 and $v \in \text{cone}\left(\mathcal{V}^{\mathrm{M}} \cup \{u_i\}\right)$, then there is $p^* \in \underset{p \in BCE(\mu)}{\text{argmax}}\, \mathbb{E}_p[v]$ that can be implemented by a single-meeting scheme.

Thank you!