Allocating Common-Value Goods

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Introduction & Model

INTRODUCTION

- Information is **dispersed** across individuals, generating **informational externalities**.
  - Usually, no single agent possesses all the information about the value of an option.
  - Hence, information held by others affects an agent's beliefs and decisions.
- How can society benefit from **leveraging** such informational externalities ?
  - To study this, we construct a minimal model of **allocating common-value goods**.
  - What is the optimal design, and what are the implications of its design?

Model (1/3): Common Value Goods

- Homogeneous **goods** and ex ante homogeneous **agents** $i \in \{1, 2, \ldots, n\}$.
- Goods have **uncertainty** about **common value** $\omega \in \{-1, +1\}$, equally likely.
  - (e.g., vaccines, investment opportunities / quality, effectiveness, degree of side effect, etc.)
- Agent obtains payoff ω from the good, and 0 from not receiving it (normalization).
  - Agents want to receive a good if their beliefs about $\omega = +1$ exceed $1/2$.
  - Remark 3: Can be generalized to payoff $\omega + \varepsilon_i$, where ε_i is an idiosyncratic private value.
- No resource constraint (discussion).

MODEL (2/3): PRIVATE INFORMATION

- Each agent i has **private signal (type)** $s_i \in S$ regarding common value ω.
  - Formally, it is drawn from a state-dependent distribution $\mathbb{F}_\omega \in \Delta(S)$.
  - Signals $s_1, \ldots, s_n$ are independent conditional on ω (but, ex ante correlated).
  - $\texttt{LR}(E) = \frac{\mathbb{P}[E|\omega=+1]}{\mathbb{P}[E|\omega=-1]}$: **likelihood ratio** for event E; $\texttt{LR}(E) \geq 1 \Leftrightarrow \underbrace{\mathbb{P}[\omega = +1 \mid E] \geq 1/2}_{\text{posterior belief exceeds } 1/2}$
  - Normalize $\underbrace{s_i}_{\text{private signal}} = \underbrace{\mathbb{P}[\omega = +1 \mid s_i]}_{\text{private belief}} \in [0,1]$: (e.g., $s_i = 0.6 \Leftrightarrow \mathbb{P}[\omega = +1 \mid s_i] = 0.6$)
- Assumption: CDF $\mathbb{F} = \frac{\mathbb{F}_{-1} + \mathbb{F}_{+1}}{2}$ admits a smooth and full support density f on $[0,1]$.

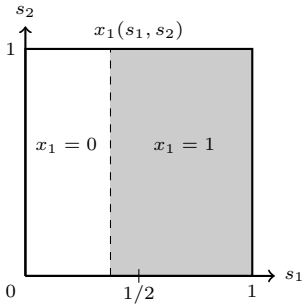
Model (3/3): Mechanism

- A direct mechanism is an **allocation rule** $x_i(s_1, \ldots, s_n) \in [0, 1]$ such that

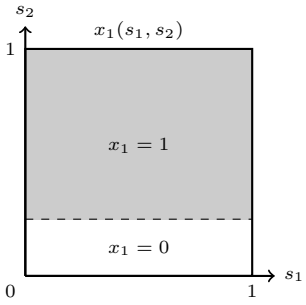
  (P) : $\mathbb{E}[\omega \cdot x_i(s_i, s_{-i}) \mid s_i] \geq 0$ and (IC) : $\mathbb{E}[\omega \cdot x_i(s_i, s_{-i}) \mid s_i] \geq \mathbb{E}[\omega \cdot x_i(\hat{s}_i, s_{-i}) \mid s_i]$.

- x_i may depend on others' signals, and thus shapes the informational externality.
  - Screening and aggregating private signals, and leveraging them for allocation.
- Designing allocation rules may effectively reduce **discard rates** and **inefficiency**.
  - We focus on a direct mechanism maximizing **allocation probability** $\mathbb{E}_\omega \mathbb{E}_s[\sum_i x_i(s)]$.
  - Remark 1: Can be generalized to a convex combination with **utilitarian sum**.

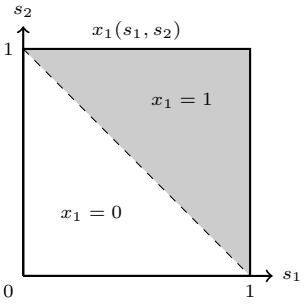
ILLUSTRATIVE EXAMPLES



- $x_1(s_1, s_2) = x_1(s_1)$.
- Violating (P) and (IC).



- $x_1(s_1, s_2) = x_1(s_2)$.
- Violating (P).



- $x_1(s) = \mathbb{I}\{\mathtt{LR}(s) \geq 1\}$.
- Feasible and **Efficient**

LITERATURE

- Mechanism design with **interdependent values**:
  - Crémer and McLean (1985, 1988), McAfee and Reny (1992), Lopomo *et al.* (2022).
  - No transfer: Kattwinkel (2020), Niemeyer and Preusser (2022), Kattwinkel and Winter (2024), etc.
- Majorization and duality in mechanism design:
  - Indirect utility and duality: Daskalakis *et al.* (2017), Kleiner (2022)
  - Extreme points: Kleiner *et al.* (2021), Yang and Zentefis (2024), Augias and Uhe (2025), etc.
- Mechanism design with **money burning**:
  - McAfee and McMillan (1992), Hartline and Roughgarden (2008), Condorelli (2012), etc.
  - Noda and Okada (2024), Tokarski (2024, 2025), Yang (2025), Yang *et al.* (2025), Dworczak (2026).

RESULTS

Optimal Mechanism

Theorem 1

The optimal mechanism is a monotone threshold rule: there is a partition $\mathcal{S}_i$ of the signal space $[0,1]$ into intervals such that, for each interval $S_i \in \mathcal{S}_i$ we have $x_i(s_i, s_{-i}) = \kappa \cdot \mathbb{I}\{\mathtt{LR}(s_{-i}) \geq \tau\}$ for all $s_i \in S_i$, for some $\kappa \in [0,1]$, and $\tau \geq 0$.

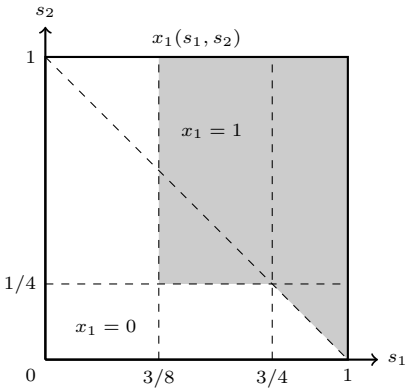
- The optimal mechanism partitions the signals/types into disjoint intervals.
- Then, a common allocation rule is applied to all types within the same interval.
- A common allocation rule consists of two parameters (κ, τ):
  - $\kappa \in [0,1]$ controls the **"volume"** of allocation.
  - $\tau \geq 0$ determines state-dependent allocation probabilities (**"degree of learning"**).

EXAMPLE: UNIFORM DISTRIBUTION WITH TWO AGENTS

- No allocation for $s_1 \leq 3/8$.
- Constant allocation for $s_1 \in [3/8, 3/4]$.
- Efficient allocation for $s_1 \geq 3/4$.
- Partition

$$\mathcal{S}_1 = \{\underbrace{[0, 3/8]}_{x_1(s)=0}, \underbrace{[3/8, 3/4]}_{x_1(s)=\mathbb{I}\{\mathtt{LR}(s_2)\geq 1/3\}}, \underbrace{\{s_1 : s_1 \geq 3/4\}}_{x_1(s)=\mathbb{I}\{\mathtt{LR}(s)\geq 1\}}\}$$

- Exclusion at the bottom types.



EXCLUSION AT THE BOTTOM

Proposition 1

The optimal mechanism excludes bottom types:

there is an interval $[0, \varepsilon_i]$ such that $x_i(s_i, s_{-i}) = 0$ for all $s_i \in [0, \varepsilon_i]$ and $s_{-i} \in [0,1]^{n-1}$.

- Exclusion occurs even though the designer prefers to allocate. (nontrivial !)
  - Intuition: managing **incentives for downward deviations**.
  - (P): Allocating to low types is allowed only when others have very positive signal.
  - Doing so incentivizes a middle type to misreport her belief downward.
- Exclusion does not arise when there is no information asymmetry about type s_i, and inefficiency does not arise when there is no interdependence or $n = 1$.

PROOF SKETCH OF THEOREM 1

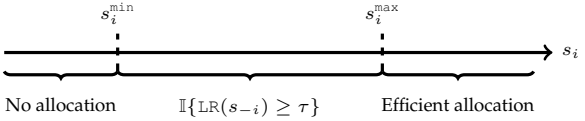
- Focus on **indirect utility function** $U_i(s_i) = \max_{t_i} \mathbb{E}[\omega \cdot x_i(t_i, s_{-i}) \mid s_i]$ (Rochet, 1987).
- Envelope formula transforms the objective into a linear functional of U_i.
- Step 1: Derive necessary conditions for the optimal indirect utility.
  - U_i is **convex**, **increasing**, and **bounded by two convex functions** ($\underline{U}_i \leq U_i \leq \overline{U}_i$).
  - Not a full characterization of feasible indirect utilities, but sufficient under optimality.
- Step 2: Construct monotone threshold mechanisms that implement them.

Optimal Mechanism: Log-Concave Case

Theorem 2

If f is log-concave, a monotone threshold mechnism with two thresholds is optimal:

$$x_i(s_i, s_{-i}) = \begin{cases} 0 & \text{if} \quad s_i \leq s_i^{\min}(\tau) \\ \mathbb{I}\{\mathrm{LR}(s_{-i}) \geq \tau\} & \text{if} \quad s_i^{\min}(\tau) \leq s_i \leq s_i^{\max}(\tau) \\ \mathbb{I}\{\mathrm{LR}(s_i, s_{-i}) \geq 1\} & \text{if} \quad s_i^{\max}(\tau) \leq s_i. \end{cases}$$

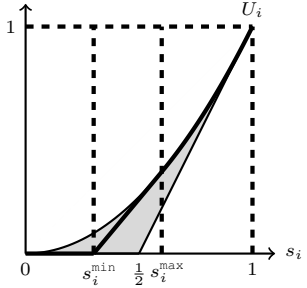


PROOF SKETCH OF THEOREM 2

- The problem is reduced to maximize a linear functional $\int U_i d\mu_i$ subject to

$$\mathcal{U}_i^* = \left\{ U_i \,\middle|\, U_i \text{ is convex, increasing, and } \max\{0, 2s_i - 1\} \le U_i \le \overline{U}_i \right\},$$

- We provide **weak duality**: an upper bound for the objective value.
- Following form of U_i achieves the upper bound and our mechanisms induce this.



Optimal Mechanism: Large Market Case

- Consider a market with **many participants** (and many goods).
- For each market size n, let V_n be the maximum probability of allocation to the agent.

Theorem 3

Fix any agent i. There exists a sequence of mechanisms for agent i of a form

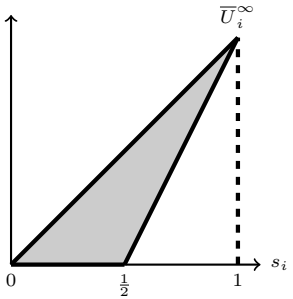
$$x_i(s_i, s_{-i}; n) = \begin{cases} 0 & \text{if} \quad s_i \leq s_i^{\texttt{min}}(n) \\ \kappa(n) \cdot \mathbb{I}\{\texttt{LR}(s_{-i}) \geq \tau(n)\} & \text{if} \quad s_i^{\texttt{min}}(n) \leq s_i \leq s_i^{\texttt{max}}(n), \\ 1 & \text{if} \quad s_i^{\texttt{max}}(n) \leq s_i, \end{cases}$$

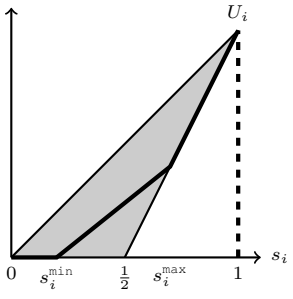
for each market size $n \in \mathbb{N}$, such that the difference $|V_n - \mathbb{E}[x_i(s; n)]| \to 0$ as $n \to \infty$.

- A monotone threshold mechanism with two thresholds is **asymptotically optimal**.

PROOF SKETCH OF THEOREM 3

- LLN implies that, s_{-i} perfectly reveals the true state in the limit.
- Thus, in the limit, the first-best payoff becomes $\overline{U}_i^{\infty}(s_i) = s_i \cdot 1 - (1 - s_i) \cdot 0 = s_i$.
- The set of U_i over which we optimize and an extremal function are follows:



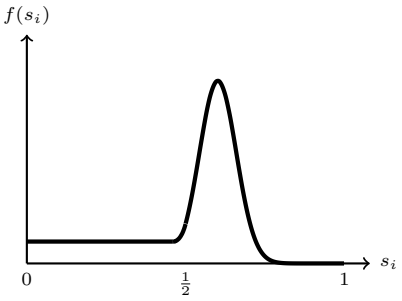


Optimal Mechanism: Laissez-Faire Rule

Proposition 3

If $\log f$ is increasing on $[0, 1/2]$, concave over $[1/2, 1]$, and $\int_{1/2}^{1}(1-t_i)f(t_i)dt_i \geq (1/4)f(1/2)$, then $x_i(s) = \mathbb{I}\{s_i \geq 1/2\}$ is optimal.

- **Independent rule** is optimal if s_i just above $1/2$ are sufficiently likely.
- A sufficient condition for the optimality of **empty network** in network design.



PAYMENT DESIGN

Payment Design

- Pricing is often **infeasible** in many allocation settings (e.g., vaccine allocation).
  - Thus, we assume no monetary transfers so far.
  - **Payment-like instruments**, such as **costly effort and waiting time**, may be feasible.
- Do non-negative payments help improve the allocation rate (and efficiency)?
  - A mechanism is a profile $(x_i, t_i) : [0,1]^n \to [0,1] \times [0,T]$ such that

$$(\text{P}^*) : \mathbb{E}[\omega \cdot x_i(s_i, s_{-i}) - t_i(s_i, s_{-i}) \mid s_i] \geq 0,$$
$$(\text{IC}^*) : \mathbb{E}[\omega \cdot x_i(s_i, s_{-i}) - t_i(s_i, s_{-i}) \mid s_i] \geq \mathbb{E}[\omega \cdot x_i(\hat{s}_i, s_{-i}) - t_i(\hat{s}_i, s_{-i}) \mid s_i].$$

  - Payoff: $\mathbb{E}[\omega \cdot x_i(s) - \boldsymbol{t_i(s)} \mid s_i] \Rightarrow$ allocation becomes **less attractive to agents**.
  - If there is only one agent, positive payments are suboptimal.

Optimal Mechanism: Non-Negative Payment

Theorem 4

Suppose that the designer can also design non-negative payments.

The optimal mechanism is a monotone threshold rule: there exists a partition $\mathcal{S}_i$ of the signal space $[0,1]$ into intervals such that, for each interval $S_i \in \mathcal{S}_i$, we have

$$x_i(s_i, s_{-i}) = \kappa_x \cdot \mathbb{I}\{\mathtt{LR}(s_{-i}) \geq \tau_x\}, \quad t_i(s_i, s_{-i}) = \kappa_t \cdot \mathbb{I}\{\mathtt{LR}(s_{-i}) \geq \tau_t\},$$

for all $s_i \in S_i$ and $s_{-i} \in [\underline{s}, \overline{s}]^{n-1}$, for some $(\kappa_x, \tau_x) \in \mathbb{R}^2$ and $(\kappa_t, \tau_t) \in \mathbb{R}^2$.

- Technical challenge: **revenue equivalence fails** (x_i does not uniquely pin down t_i).
- (Remark: objective can be extended to $\mathbb{E}[\alpha \cdot x_i(s) + (1-\alpha) \cdot U_i(s_i)]$ again.)

Optimal Mechanism: Large Market with Money Burning

Theorem 5

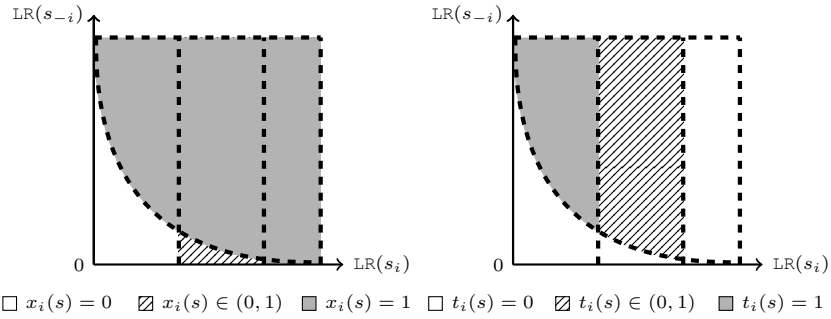
Suppose that the designer can also design non-negative payments and $T \geq 1$.

Then, there exists a sequence of mechanisms for agent i of a form

$$x_i(s_i, s_{-i}; n) = \begin{cases} \mathbb{I}\{\texttt{LR}(s_i, s_{-i}) \geq \eta(n)\} & \text{if} \quad s_i \leq s_i^{\texttt{min}}(n) \\ \kappa_x + (1-\kappa_x) \cdot \mathbb{I}\{\texttt{LR}(s_i, s_{-i}) \geq \tau(n)\} & \text{if} \quad s_i^{\texttt{min}}(n) \leq s_i \leq s_i^{\texttt{max}}(n), \\ 1 & \text{if} \quad s_i^{\texttt{max}}(n) \leq s_i, \end{cases}$$

$$t_i(s_i, s_{-i}; n) = \begin{cases} \delta(n) \cdot \mathbb{I}\{\texttt{LR}(s_i, s_{-i}) \geq \eta(n)\} & \text{if} \quad s_i \leq s_i^{\texttt{min}}(n) \\ \kappa_t(n) \cdot \mathbb{I}\{\texttt{LR}(s_i, s_{-i}) \geq \tau(n)\} & \text{if} \quad s_i^{\texttt{min}}(n) \leq s_i \leq s_i^{\texttt{max}}(n), \\ 0 & \text{if} \quad s_i^{\texttt{max}}(n) \leq s_i. \end{cases}$$

for each $n \in \mathbb{N}$, such that $|V_n^* - \mathbb{E}[x_i(s; n)]| \xrightarrow{n\to\infty} 0$, $\delta(n) \xrightarrow{n\to\infty} 1$, and $\kappa_x, \kappa_t(n) \in [0, 1]$.



- The optimal mechanism **no longer excludes bottom types** unlike in Proposition 1.
- Intuition: positive payments (**money burning**) tighten (P^*) but changes (IC^*).
  - **Different beliefs** leads to **different expected payments** from the same payment rule.
  - A payment rule is **decreasing** in type, which makes **downward deviations less attractive**.

Conclusion

Conclusion

- We consider the allocation of **common-value goods** with uncertainty.
  - The allocation rule shapes **informational externalities**, which in turn affects incentives.
  - The optimal mechanism is a threshold rule based on "**volume**" and "**degree of learning**."
- The optimal mechanism **excludes** low-belief agents to deter downward deviations.
  - Improving **allocation rates** and **efficiency** may require additional policies.
- Introducing **costly effort** or **waiting time** improves the allocation rate and efficiency.
  - Non-negative payments (decreasing in types) deter downward deviations.

The End.

Appendix

Detailed Sketch

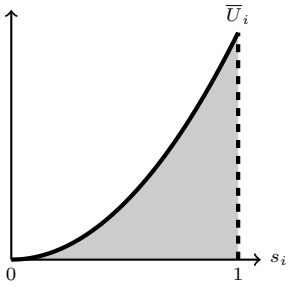
- By normalization, $s_i = \mathbb{P}[\omega = +1 \mid s_i]$, we have

$$U_i(t_i; s_i) = s_i \cdot \underbrace{\sum_{\omega \in \{-1,+1\}} \mathbb{E}[x_i(t_i, s_{-i}) \mid \omega]}_{\text{slope} \in [0,2]} - \mathbb{E}[x_i(t_i, s_{-i}) \mid \omega = -1].$$

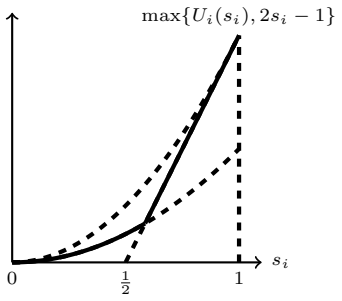
- This is **linear in the private signal** s_i.

- Thus, any feasible U_i is **convex, increasing, and 2-Lipschitz**.

- Additionally, any feasible indirect utility U_i must be **"not too large"**.
  - The **first-best payoff** $\overline{U}_i$ when allocation is efficient: $x_i(s) = \mathbb{I}\{\texttt{LR}(s) \geq 1\}$.
  - Any feasible U_i should lie in the shaded region:

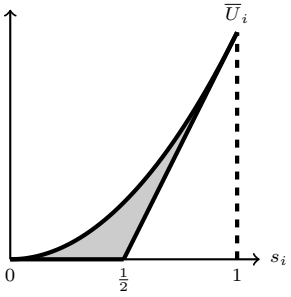


- There is, however, a function in the triangle that cannot be implemented.
  - Lemma 6: Any **optimal** indirect utility must be above $\underline{U}_i(s_i) = \max\{0, 2s_i - 1\}$.
  - Proof: Replace $x_i(s_i, s_{-i}) \in [0, 1]$ with 1 if $U_i(s_i) \leq 2s_i - 1 = \mathbb{E}[\omega \mid s_i]$.



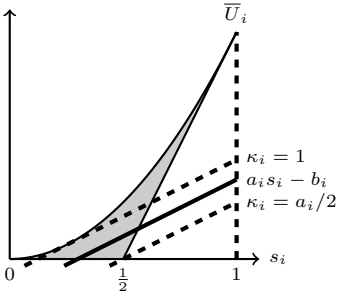
- (This argument works for a convex combination with utilitarian sum.)

- Thus, optimal indirect utility U_i is **sandwiched by functions**, $\overline{U}_i$ and $\underline{U}_i$.



- In addition, optimal U_i is also convex, increasing, and $2-$Lipschitz.

- Finally, consider any linear function $a_i s_i - b_i$. Is it implementable?
  - A **threshold mechanism** $\kappa \cdot \mathbb{I}\{\texttt{LR}(s_{-i}) \geq \tau\}$ induces a linear utility U_i.
  - For each $\kappa \geq a_i/2$, we can find $\tau(\kappa)$ such that U_i has slope a_i.
  - If $a_i s_i - b_i$ intersects with the shaded region, some $\kappa \in [a_i/2, 1]$ induces intercepts b_i.



Summary:

- Mechanisms $\kappa \cdot \mathbb{I}\{\texttt{LR}(s_{-i}) \geq \tau\}$ implement any linear segment in the shaded region.
- We already know that any optimal U_i is convex and in the shaded regions.
- Therefore, it is an upper envelope of such lines.
- A **monotone threshold mechanism** can implement it.

QED.

EXTENSIONS OF THEOREM 1

- Objective can be anything as long as it is increasing in agents' payoffs over $s_i \geq 1/2$.
  - It can be a **convex combination with utilitarian sum** (allocation rates and efficiency).
- Distribution $\mathbb{F}_i$ can be heterogeneous across agents $i \in \{1, \ldots, n\}$.
- Can restrict to **queue-based allocations** $x_i(s) = x_i(s_1, \ldots, s_i)$.
  - It does not use information gathered from those who will arrive after i.
  - **Corollary:** The optimal queue-based allocation mechanism is monotone partitional.
- Can be generalized to payoff $\omega + \varepsilon_i$, where ε_i is an idiosyncratic **private value**.
  - Let $t_i = \frac{(1+\varepsilon_i)s_i}{(1+\varepsilon_i)s_i + (1-\varepsilon_i)(1-s_i)} \in [0,1]$. Then, the interim payoff is proportion to $\propto U_i(t_i(s_i, \varepsilon_i)) = t_i \mathbb{E}[x_i(s_i, \varepsilon_i, s_{-i}) \mid \omega = +1] - (1 - t_i)\mathbb{E}[x_i(s_i, \varepsilon_i, s_{-i}) \mid \omega = -1]$.
  - The analysis goes through by focusing on the effective type t_i and others' signals s_{-i}.

PROOF SKETCH OF THEOREM 4

- Any positive payment **only reduces** expected payoffs.
- As in Theorem 1, any optimal indirect utility U_i lies between $\overline{U}_i$ and $\underline{U}_i$.
- For fixed t_i, replace x_i with a monotone threshold rule preserving $\mathbb{E}[x_i(s)]$ and U_i.
- If t_i cannot be replaced by a monotone threshold rule preserving $\mathbb{E}[x_i(s)]$ and U_i, mechanism must involve **high payments when the state is low**.
- Jointly perturbing (x_i, t_i) increases $\mathbb{E}[x_i(s)]$ while preserving U_i, a contradiction.

Full Surplus Extraction

- Suppose any pricing schemes, including negative payment (**subsidies**), are feasible.

Proposition 4

There is a feasible mechanism (x_i, t_i) such that $\mathbb{E}[t_i(s)] = 0$ and $x_i(s) = 1$ for all s.

- Under the interdependent values, any allocation rule is implementable.
  (Crémer and McLean, 1985, 1988; McAfee and Reny, 1992; Lopomo *et al.*, 2022)

- (Not a corollary of the literature, but a similar construction works.)

- For example, if there are only two agents, $x_i(s) = 1$ and $t_i(s) = \frac{2s_j - 1}{\mathrm{Cov}(s_i, s_j)}$.

Resource Constraint

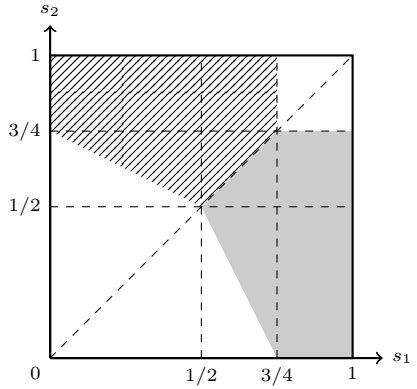
- Suppose that there is a **resource constraint (RC)** such that $\sum_i x_i(s) \leq 1$.
- Limitation: in general, we cannot derive the optimal mechanism. (complicated)
  - Payoff externalities complicate the analysis, and the problem is no longer separable.
- We restrict attention to **contest allocation rules**: $x_i(s) = 0$ if $s_i < s_j$ for some $j \neq i$.
  - Allocation occurs only to the agent with the highest report.
  - This restriction may be natural in practice because of "fairness" and "simplicity".
  - Technically, this restriction makes the problem separable across agents again.

EXAMPLE: UNIFORM DISTRIBUTION WITH TWO AGENTS

- Contest and two-sided threshold rules:

$$x_i(s) = \mathbb{I}\{s_i > \max_{j \neq i} s_j\} \cdot \mathbb{I}\{\mathtt{LR}(s_{-i}) \in [\underline{\tau}(s_i), \overline{\tau}(s_i)]\}$$

- Scarcity creates **distortions** for top types.
  - This is to deter upward deviations.
- Contest allocations are **suboptimal**.
  - Dominated by the mechanism:
    (i) randomly choose an agent i, and
    (ii) allocate the good if $s_i \geq 1/2$.



□ $x_1(s) = x_2(s) = 0$ ▨ $x_1(s) = 1$ ▨ $x_2(s) = 1$

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