

ITERATED REVELATION:

HOW TO INCENTIVIZE EXPERTS TO REVEAL NOVEL ACTIONS

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- ◇ Almost always: **expert** provides *statistical* info about the resolution of uncertainty

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Ph.D student	supervisor	prob. of success

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Ph.D student	supervisor	prob. of success	research ideas
homeowner	architect	???	house design

PROJECT CHOICE

Armstrong and Vickers (2010), Guo and Shmaya (2023) study project choice:

- ◇ A **manager** (decision maker) is uncertain about which projects are feasible
- ◇ A **subordinate** (expert) makes recommendations
- ◇ The manager commits to a selection rule
 - ◇ how to choose a project from the subordinate's recommendations

But what if ex-ante commitment to a selection rule is infeasible?

- ◇ Unawareness: a student unaware of state-of-the-art research ideas
- ◇ Inexpressibility: impractical to express every possible house design
- ◇ Enforceability: A regulator may be unable to make reasonable commitments

LITERATURE

- ◇ Delegation / Project Choice

- ◇ Holmstrom (1980); Armstrong and Vickers (2010); Guo and Shmaya (2023)

- ◇ Incomplete Contracting / Unawareness in Contracting

- ◇ Grossman and Hart (1986); Maskin and Tirole (1999); Tirole (2009); Hart (2017); Piermont (2017); Lei and Zhao (2021); Francetich and Schipper (2021)

- ◇ Strategic Information Transmission

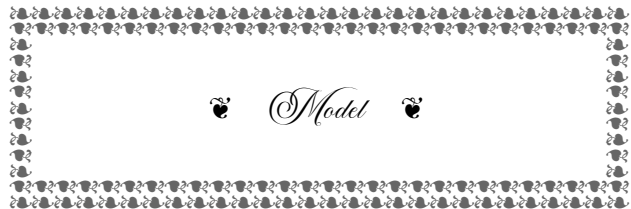
- ◇ Milgrom (1981), Crawford and Sobel (1982); Seidmann and Winter (1997); Aumann and Hart (2003); Chakraborty and Harbaugh (2010)

- ◇ Evidentiary disclosure

- ◇ Dye, 1985; Green and Laffont, 1986; Grossman and Hart, 1986; Bull and Watson, 2007; Ben-Porath et al., 2019

- ◇ Robust Mechanism Design

- ◇ Bergemann and Morris (2005); Jehiel et al., (2006); Carroll (2015, 2019).



ENVIRONMENT

The environment is described by

\mathcal{A} — a (compact) set of actions

(u_d, u_e) — (continuous) utility functions $\mathcal{A} \rightarrow \mathbb{R}$

\mathcal{R} — a collection of (compact) subsets of \mathcal{A} such that

◇ for $r \in \mathcal{R}$, there are a finite $r' \in \mathcal{R}$ with $r' \subseteq r$.

REVELATION TYPES

- ◇ A **revelation type** $r \in \mathcal{R}$ is a set of actions / projects that an agent can express
- ◇ Say that r is **more expressive** than r' , if $r' \subseteq r$
- ◇ Fix types r_d and r_e
 - ◇ common knowledge that $r_d \subseteq r_e$

KEY ASSUMPTIONS

Information Spillover: Only $r \in \mathcal{R}$, such that $r \subseteq r_e$ can be revealed

Voluntary Disclosure: The **expert** can always masquerade as a type $r_d \subseteq r \subseteq r_e$

Hard Evidence: If the **expert** reveals r , then any $a \in r$ is ‘real’

DIRECT MECHANISMS

An **outcome profile** is a function from types to actions:

$$\begin{array}{ccccc} f: & r & \mapsto & a \\ & \cap & & \cap \\ & \mathcal{R} & \rightarrow & r \end{array}$$

- ◇ Outcome profiles are *direct mechanisms*
- ◇ These are the object of study in the project choice literature
- ◇ Inexpressibility precludes direct mechanisms / revelation principle

Call f **monotone** if **ex's** payoff is monotone in her type

$$u_e(f(r')) \leq u_e(f(r)) \quad (1)$$

whenever $r' \subseteq r$, and **strongly monotone** if in addition (1) holds strictly whenever $f(r) \neq f(r')$.

- ◇ If direct mechanisms existed, monotonicity is necessary:
- ◇ Direct mechanisms don't exist: even with monotonicity, there need not be any 'strategic' way of enacting an outcome profile.

Call f **efficient** if outcome is Pareto undominated:

for all $r \supseteq r_d$, is no $a \in r$ such that

$$u_d(a) \geq u_d(f(r)) \quad \text{and} \quad u_e(a) \geq u_e(f(r)), \quad (2)$$

with at least one inequality holding strictly.

So, what can we do without ex-ante commitment to an outcome profile?

EXAMPLE

- ◇ A **regulator** (the **decision maker**) is evaluating mergers (i.e., projects) :
 - ◇ can only choose a merger structure it is aware of
- ◇ A **firm** (the **expert**) may be aware of novel ways of structuring a merger
- ◇ choice of merger structure determines payoffs for both players
 - ◇ the **firm** cares about producer welfare
 - ◇ the **regulator** cares about consumer welfare foremost, but
 - ◇ also cares about efficiency

EXAMPLE A

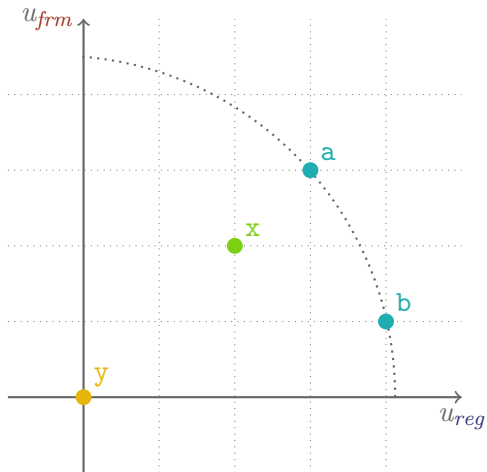
- ◇ Each merger yields (x_{reg}, x_{frm}) :
 - ◇ x_{reg} is regulator's payoff (consumer welfare)
 - ◇ x_{frm} is firms's (producer welfare)
- ◇ The regulator is initially aware of two ways to structure the merger:

$$\mathbf{x} = (2, 2) \quad \mathbf{y} = (0, 0)$$

- ◇ The firm is also aware of:

$$\mathbf{a} = (3, 3) \quad \mathbf{b} = (4, 1)$$

EXAMPLE A



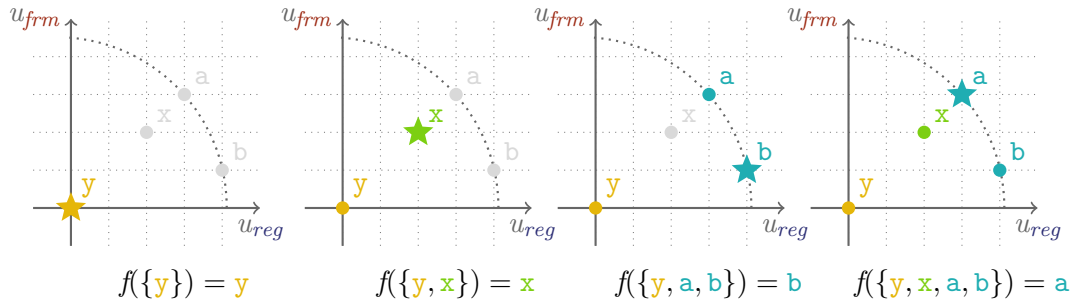
EXAMPLE A

- ◇ If the **firm** had full control over what to reveal: simply reveal $\mathbf{a} = (3, 3)$
- ◇ However, not all mergers can be independently revealed:
 - ◇ Revealing one merger in a ‘class’ reveals the existence of the whole class, etc
- ◇ What if \mathbf{a} and \mathbf{b} must be revealed together?

$$\mathcal{R} = \{\{\mathbf{y}\}, \{\mathbf{y}, \mathbf{x}\}, \{\mathbf{y}, \mathbf{a}, \mathbf{b}\}, \{\mathbf{y}, \mathbf{x}, \mathbf{a}, \mathbf{b}\}\}$$

EXAMPLE A

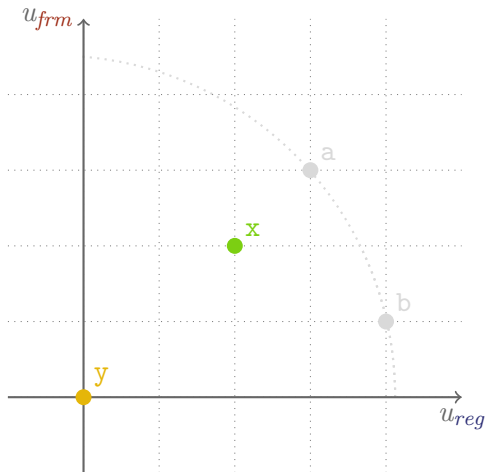
A monotone and efficient outcome profile:



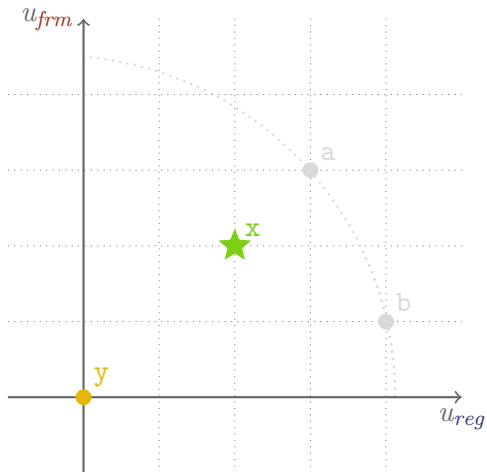
But, the regulator cannot express **a** and **b**:

- ◇ Cannot commit to these mergers until they are revealed
- ◇ Cannot express the direct outcome profile above

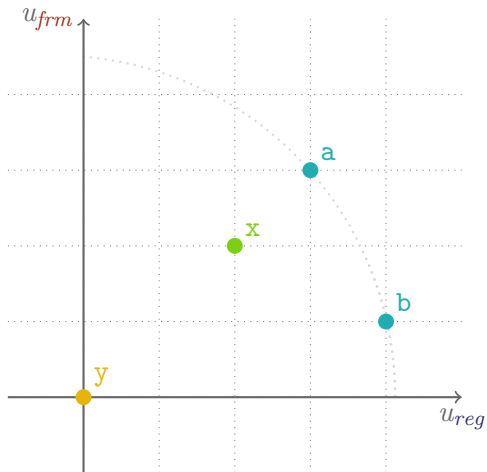
EXAMPLE A



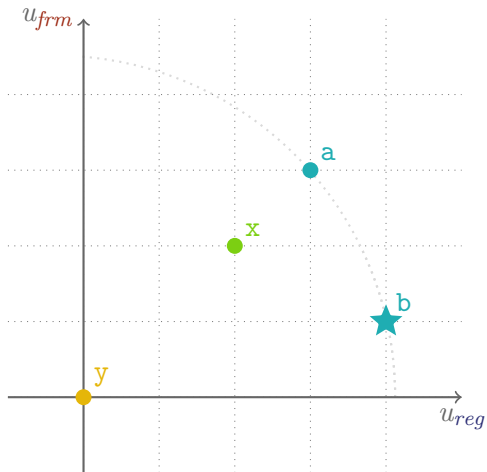
EXAMPLE A



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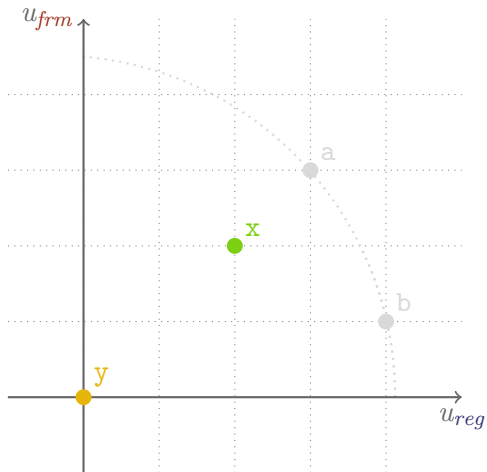
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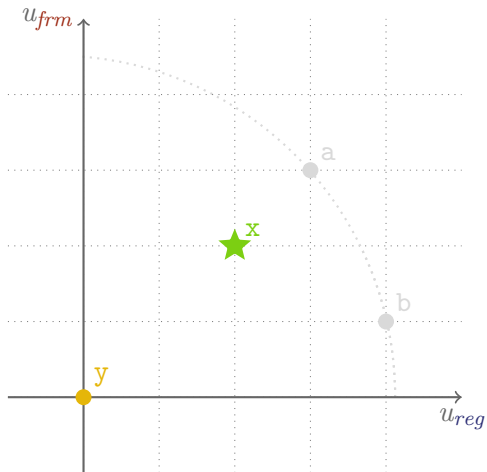
EXAMPLE A

- ◇ Since the **firm** prefers **x** to **b**, she would choose not to reveal.
- ◇ This is Pareto Inefficient: **a** dominates **x**
- ◇ What if **regulator** and **firm** can create the following contract (before revelation):
 - ◇ shortlist an 'outside option' (that the **regulator** is aware of)
 - ◇ this can be re-negotiated after revelation
 - ◇ the **regulator** can propose a new merger, but the **firm** can veto (therefore implement outside option)

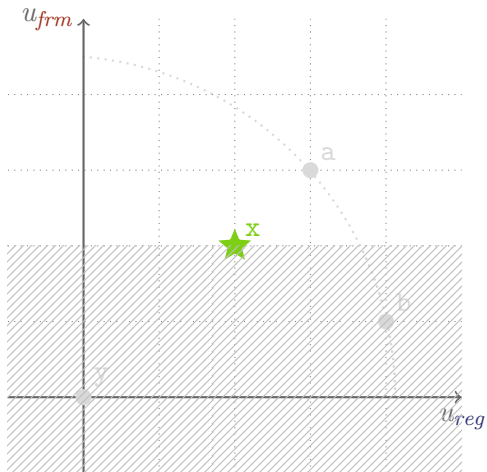
EXAMPLE A



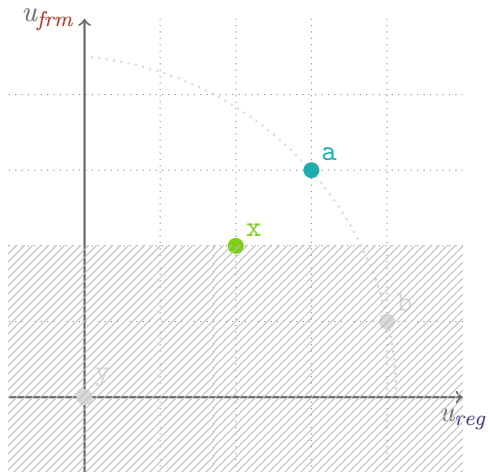
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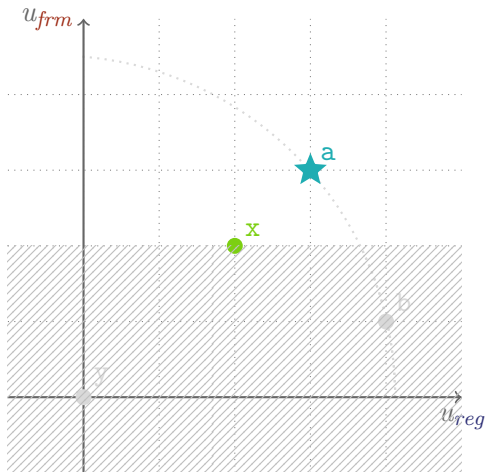
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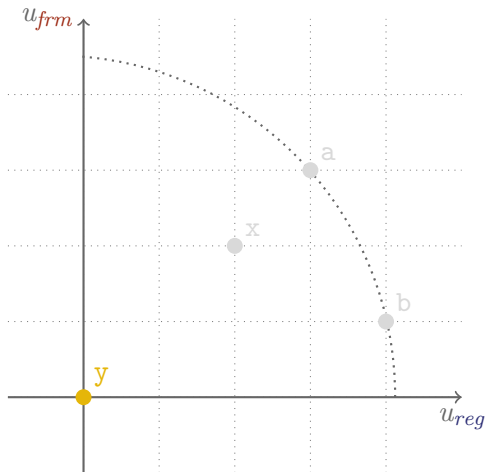
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Does this always work? No

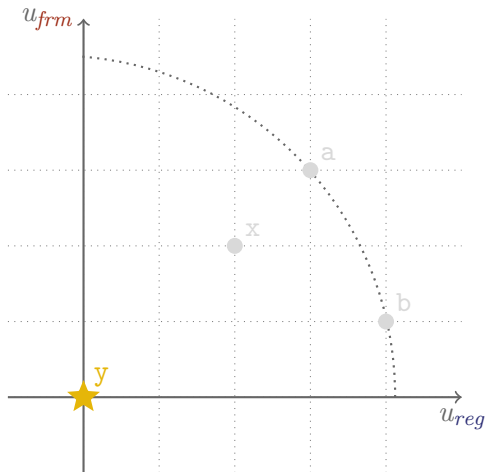
EXAMPLE B

- ◇ What if the **regulator** was also initially unaware of **x**
- ◇ **x** and $\{a, b\}$ can be revealed independently

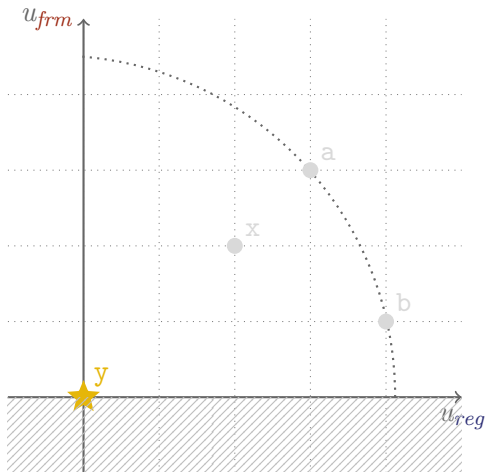
EXAMPLE B



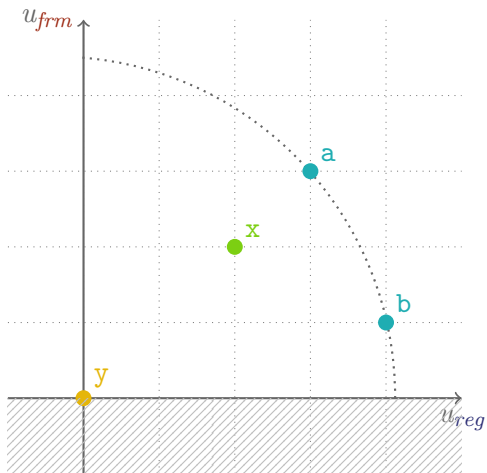
EXAMPLE B



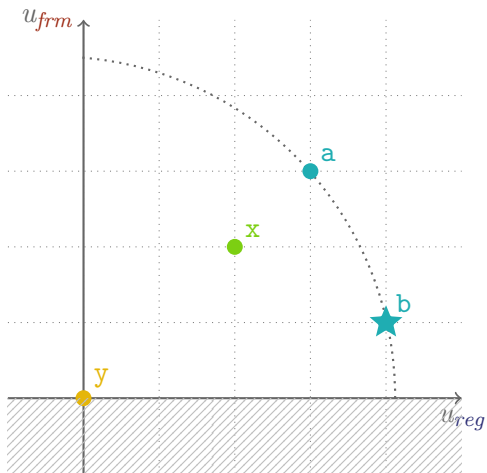
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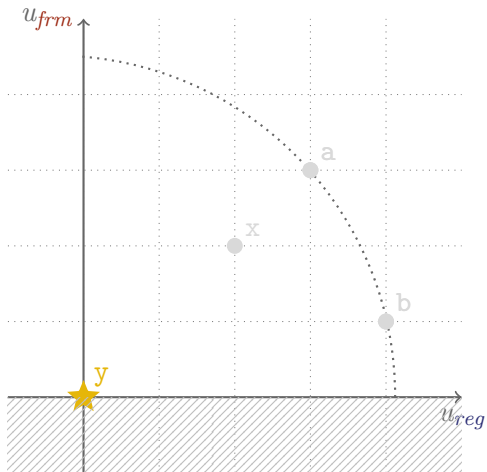


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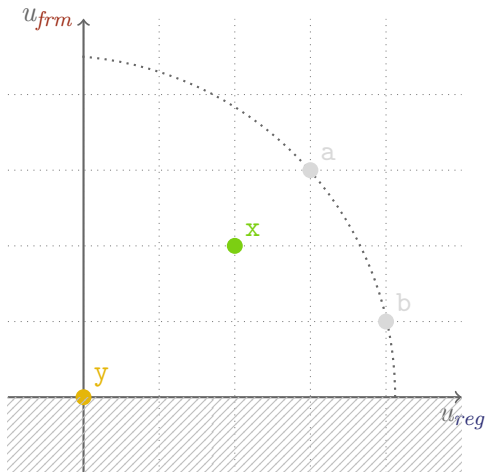


But the **firm** does not have to reveal everything! Instead, reveal only **x**

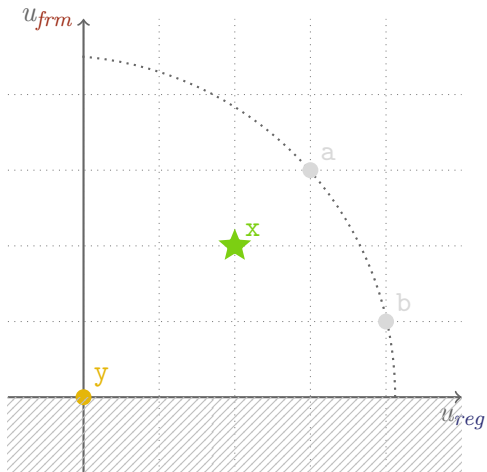
EXAMPLE B



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The **firm** prefers **x** to **b**:

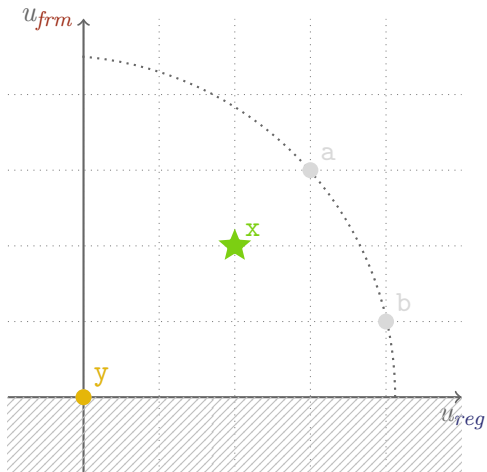
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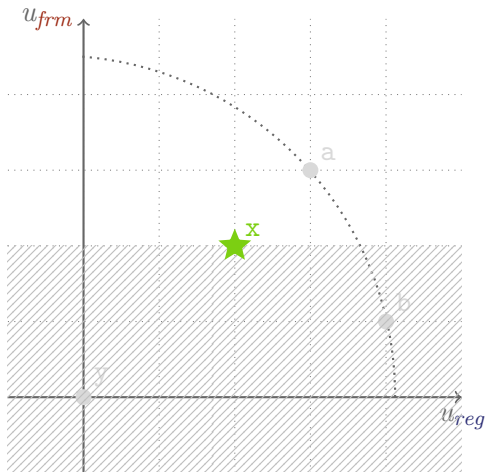
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But, we can repeat!

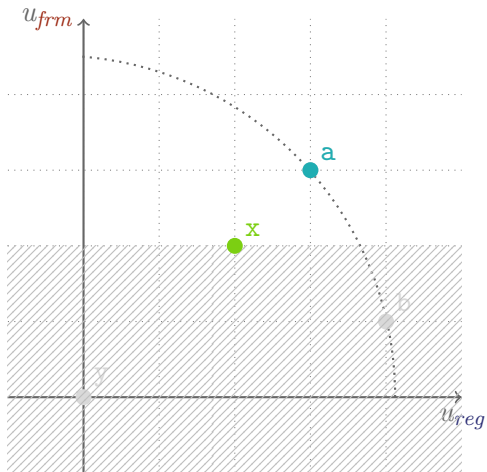
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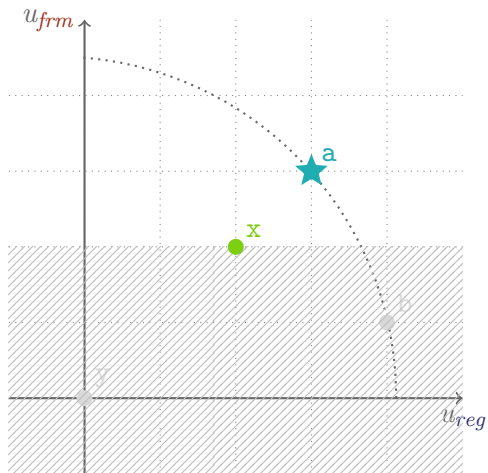
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❖ *Iterated Revelation Protocol* ❖

ITERATED REVELATION PROTOCOL

INITIAL STEP — The **decision maker** announces $r_0 \in \mathcal{R}$, and shortlists $a_0 \in r_0$.

ITERATIVE STEP — Given (r_0, \dots, r_{n-1}) distinct prior revelations, the **expert** reveals $r_n \in \mathcal{R}$.

- ◇ If $r_{n-1} \subsetneq r_n$, the **dm** shortlists $a_n \in r_n$, and the ITERATIVE STEP is repeated
- ◇ Otherwise, the protocol moves to the FINAL STEP

FINAL STEP — Given (r_0, \dots, r_n) distinct revelations, the **expert** chooses an action $a \in \{a_0, \dots, a_n\}$.

Importantly:

- ◇ This protocol can be explained / contracted to without having to express any specific actions/outcomes
- ◇ Specifically, the only contractual obligations in an IRP are actions that *have already been* revealed.

STRATEGIES

Given the IRP, a **strategy**

- ◇ for the **dm** is a function from *sequences of revelations* to actions:

$$s : (r_0 \dots r_n) \mapsto a_n \in r_n$$

- ◇ for the **ex** is a function from *sequences of shortlisted actions* to revelations:

$$\sigma : (a_0 \dots a_{n-1}) \mapsto r_n \in \mathcal{R}$$

(and a choice out of the final shortlist)

IMPLEMENTATION

Let $a(s, \sigma)$ denote the action enacted by playing strategies s and σ .

Say that s **implements** the outcome profile f if for all $r \in \mathcal{R}$

$$f(r) = a(s, \sigma) \quad \text{for some best response for type } r$$

and **fully implements** f if

$$f(r) = a(s, \sigma) \quad \text{for every best response for type } r$$

Theorem

The following are equivalent for an outcome profile f

- (1) f is monotone (resp. strongly monotone)
- (2) there exists some s that implements f , (resp. fully implements)



• *Greedy Strategies & Efficiency* •

Each shortlist proposal in an IRP specifies:

- (1) The outcome should the game end
 - ◇ **dm** wants to maximize his own payoff
- (2) The implicit incentive constraint should the game continue
 - ◇ **dm** wants to minimize **ex's** payoff

In the examples, IRPs solved (1) ignoring (2)

Definition

Call a strategy s (for the **decision maker**) **mostly greedy** if for all $(r_0 \dots r_n)$, there is no $a \in r_n$ such that $V_e(s(r_0 \dots r_{n-1})) \leq V_e(a)$ and

$$u_d(a) > u_d(s(r_0 \dots r_n))$$

or such that

$$u_d(a) = u_d(s(r_0 \dots r_n)) \text{ and } u_e(a) > u_e(s(r_0 \dots r_n))$$

A mostly greedy strategy:

- ◇ maximizes the **dm**'s payoff myopically (subject to IC constraint)
- ◇ does not account for effect on future incentive constraints
- ◇ breaks ties in favor of the **expert** (hence only *mostly* greedy)

Theorem

Let s be mostly greedy. Then s implements the decision maker's preferred efficient outcome profile, f^* .

- ◇ If f is any other monotone and efficient outcome profile, then for all

$$r \supseteq r_d$$

$$u_d(f^*(r)) \geq u_d(f(r))$$

COMPARATIVE STATICS: EXPRESSIBILITY

Let f^r denote the efficient, monotone outcome profile induced by the mostly greedy strategy for type r . Then:

- ◇ If the **decision maker** can express more actions ex-ante, he does better
 - ◇ $r_d^\dagger \subseteq r_d^\star \subseteq r_e$ implies $u_d(f^{r_d^\dagger}(r_e)) \leq u_d(f^{r_d^\star}(r_e))$
- ◇ If the **expert** can express more actions ex-ante, the **decision maker's** payoff is unsigned
 - ◇ $r_d^\dagger \subseteq r_e \subseteq r'_e$ implies $u_d(f^{r_d^\dagger}(r_e)) \quad ?? \quad u_d(f^{r_d^\dagger}(r'_e))$

COMPARATIVE STATICS: INFORMATION SPILLOVER

- ◇ Let \mathcal{R} and \mathcal{Q} be two different type spaces over the same set of actions:

$$\mathcal{R} \subseteq \mathcal{Q} \subseteq 2^{\mathcal{A}}$$

- ◇ Let $r_d, r_e \in \mathcal{R}$ and $q_d, q_e \in \mathcal{Q}$ be such that

$$r_d = q_d \subseteq r_e = q_e$$

- ◇ Then $u_d(f^{q_d}(q_e)) \leq u_d(f^{r_d}(r_e))$

COMPARATIVE STATICS: INFORMATION SPILLOVER

- ◇ In the limit $\mathcal{R} = \{\mathcal{A}\}$ (all actions reveal all other actions)
 - ◇ As if **dm** maximizes subject to individual rationality constraint
- ◇ In the limit $\mathcal{R} = 2^{\mathcal{A}}$ (all actions can be revealed independently)
 - ◇ As if **expert** maximizes subject to individual rationality constraint
 - ◇ This coincides with the expert preferred efficient outcome profile
 - ◇ Corollary: efficient outcome profile is unique



❖ *General Strategic Analysis* ❖

Definition

Call a strategy s **greedy** if for all $(r_0 \dots r_n)$, there is no $a \in r_n$ such that

$$V_e(s(r_0 \dots r_{n-1})) \leq V_e(a) \quad \text{and} \quad V_d(s(r_0 \dots r_n)) < V_d(a)$$

- ◇ There is no way to for the **dm** to increase his own payoff
- ◇ Generalization of mostly greedy strategy

Theorem

An outcome profile f is implemented by a greedy s

if and only if

for all $r \in \mathcal{R}$, there is no other monotone outcome profile f' such that

$$\inf_{r' \supseteq r} V_d(f(r')) < \inf_{r' \supseteq r} V_d(f'(r'))$$

Definition

Call a strategy s **locally rational** if for all $(r_0 \dots r_n)$, there is no $a \in r_n$ such that

$$V_e(s(r_0 \dots r_{n-1})) \leq V_e(a) < V_e(s(r_0 \dots r_n)) \quad \text{and} \quad V_d(s(r_0 \dots r_n)) < V_d(a)$$

- ◇ There is no way to simultaneously for the **dm** to
 - ◇ increase his own payoff
 - ◇ decrease the **expert's** payoff

Theorem

An outcome profile f is implemented by a locally rational s

if and only if

for all $r \in \mathcal{R}$, there is no other monotone outcome profile f' such that

$$\begin{array}{ll} V_d(f(r')) \leq V_d(f'(r')) & \text{for all } r' \supseteq r, \\ V_d(f(r')) < V_d(f'(r')) & \text{for some } r' \supseteq r \end{array}$$

- ◇ ‘if’ direction requires a richness condition on \mathcal{R}



♥ *Payoff Uncertainty* ♥

- ◇ The implementation above presupposes **dm** can anticipate **ex**'s acceptance / rejection
- ◇ What happens with private information:
 - ◇ Actions are state-dependent $u : \mathcal{A} \times \Omega \rightarrow \mathbb{R}$
 - ◇ assume **ex** knows the state, $\omega \in \Omega$
 - ◇ **dm** does not

EXAMPLE C

- ◇ $\Omega = \{\omega_L, \omega_R\}$, **ex** knows the state, **dm** believes equally likely
 - ◇ Each action is therefore given by $(\langle x_{d,L}, x_{d,R} \rangle, \langle x_{e,L}, x_{e,R} \rangle)$.

- ◇ The **dm** is initially aware of one action:

$$x = (\langle 0, 0 \rangle, \langle 0, 0 \rangle)$$

- ◇ The **ex** is also aware of:

$$a_L = (\langle 3, -1 \rangle, \langle 3, -1 \rangle) \quad a_R = (\langle -1, 3 \rangle, \langle -1, 3 \rangle) \quad b = (\langle 2, 2 \rangle, \langle 2, 2 \rangle)$$

- ◇ The only revelation type is $\{a_L, a_R, b\}$.

EXAMPLE C

$$*x = \langle 0, 0 \rangle, \langle 0, 0 \rangle *$$

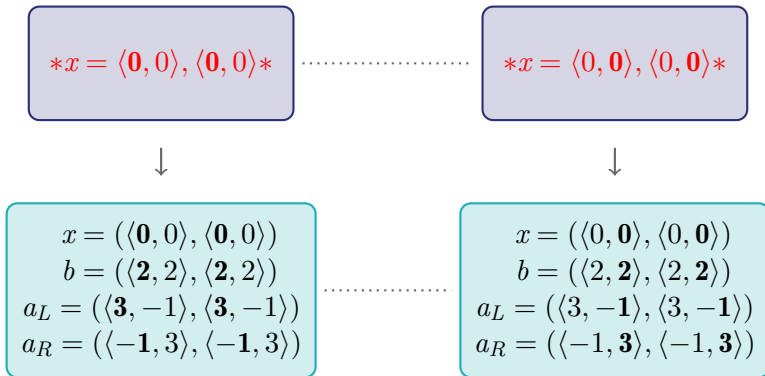
EXAMPLE C

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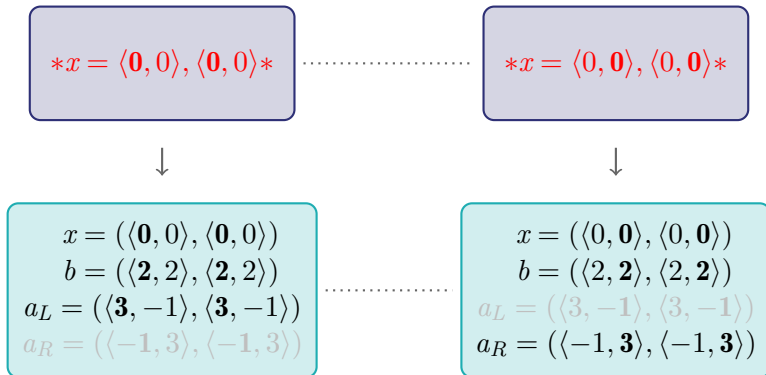
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$$*x = \langle 0, \mathbf{0} \rangle, \langle 0, \mathbf{0} \rangle *$$

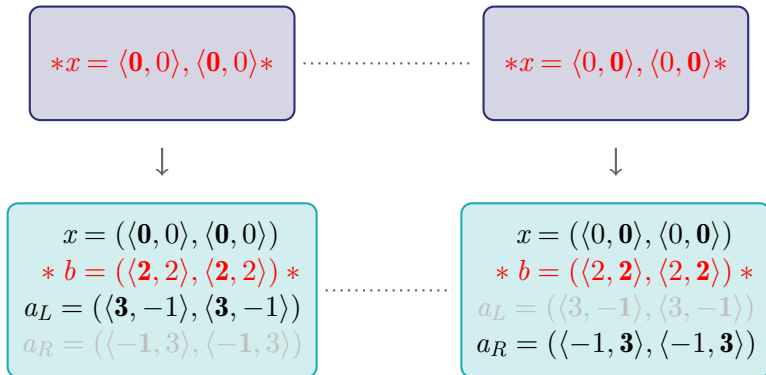
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EXAMPLE C



EXAMPLE C

- ◇ Preferences are completely aligned, but IRP does not allow delegation
- ◇ the protocol cannot use **ex**'s private info.
 - ◇ this *creates* inefficiency
- ◇ Instead, **dm** chooses a **set of actions** $p_1 \subseteq r$. After revelation, propose

$$p_1 = \{a_L, a_R\}$$

and let the **ex** choose.

- ◇ A **generalized IRP** allows the **dm** to choose a set of actions at each step:
 - ◇ At each $(r_0 \dots r_n)$, $s(r_0 \dots r_n) \subseteq r_n$

- ◇ A **generalized outcome profile** is a function $f: \Omega \times \mathcal{R} \rightarrow \mathcal{A}$
 - ◇ For each $r \in \mathcal{R}$, $w \in \Omega$, we have $f(w, r) \in r$

FULL REVELATION

Theorem

The following are equivalent for a gen. outcome profile f

- (1) f can be implemented by a gen. IRP
- (2) f is monotone: for all $\omega, r \in \Omega \times \mathcal{R}$

$$u_e(f(\omega', r'), \omega) \leq u_e(f(\omega, r), \omega)$$

for any other $\omega' \in \Omega$ and $r' \subseteq r$.



❖ *Thank You* ❖