

# Subcontracting Away Strategic Uncertainty

## Contracts from the Horse's Mouth

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CRETE ◦ July 13th 2022

# Building Bridges

The state wants to build a bridge. Needs effort from

- Construction company and
- Engineering company.

Each can **work** or **shirk**.

Only observable outcome is a stable or unstable bridge.

Efforts are **complements**.

State wants to ensure **both work** with non-negative transfers.

Should the state **centralize** payments or **subcontract**?

## Getting A Stable Bridge

Least-cost way of implementing "both work"?

- Only give rewards if the bridge is stable.
- Make each agent *indifferent* in equilibrium.

## Getting A (Partially!) Stable Bridge

Least-cost way of implementing "both work"?

- Only give rewards if the bridge is stable
- Make each agent *indifferent* in equilibrium.

But... there's a rather unfortunate second equilibrium.

Remember, state wants to **ensure** both work.

# Hierarchies

Winter (2004) solves this by a hierarchical contract:

- Favored agent's bonus big enough that Work dominant
- Other agent treated (almost) as before

Minimizes expected transfers subject to unique implementation.

Gives up **strategic rents** to favored agent.

## This paper: subcontracting

State makes (wlog) construction firm a **subcontractor**.

- State sets a **budget** to be paid if the bridge is stable...
- according to whatever division the subcontractor chooses.

A centralized mechanism can replicate any division.

- So, why subcontract?

Subcontracting costs **agency rents**, no gain in expertise.

## Why subcontract?

Subcontracting costs **agency rents**, no gain in expertise.

What is the subcontractor informed about? Own *intentions*.

*Choosing certain divisions and shirking is not rationalizable.*

Should cause other agent to deduce subcontractor will work.

State chooses budget to make such divisions that induce effort subcontractor-optimal; may be cheaper than centralization.

## Related Work

### Unique Implementation in Winter settings

- Winter (2004)
- Halac, Kremer and Winter (2020, 2022WP)
- Halac, Lipnowski and Rappoport (2021)

### Unique Implementation

- Ma, Moore and Turnbull (1988)
- Mookherjee and Reicehlstein (1992)
- Abreu and Matsushima (1992)

### Extensive Form Rationalizability and Forward Induction

- Pearce (1984)
- Kohlberg and Mertens (1986)
- Reny (1992)



# Why *else* subcontract?

## Why else delegate/subcontract?

- Communication issues e.g. Melumad, Mookherjee and Reichelstein (1992)
- Information processing issues e.g. Radner (1993)
- Commitment issues e.g. Poitevin (2000)
- Why *not*? e.g. Baron and Besanko (1992)

# Setup

Two agents, 1, 2.

Effort choices  $e_1, e_2 \in \{W, S\}$

Cost of effort is 1.

# Setup

Common project. Succeeds with probability  $P(e_1, e_2)$ .

$P$  is an 'O-ring production function':

$$P(W, W) = 1$$

$$P(W, S) = \theta_2$$

$$P(S, W) = \theta_1$$

$$P(S, S) = \theta_1\theta_2$$

Qualitatively: efforts are complements in producing a success.

We dub  $1/\theta_i$  agent  $i$ 's *pivotality*.

# Principal's Objective

Principal's objective is to **minimize expected total transfers** subject to mechanism induces  $(W, W)$  in **every equilibrium**.

- No messages
- Limited Liability

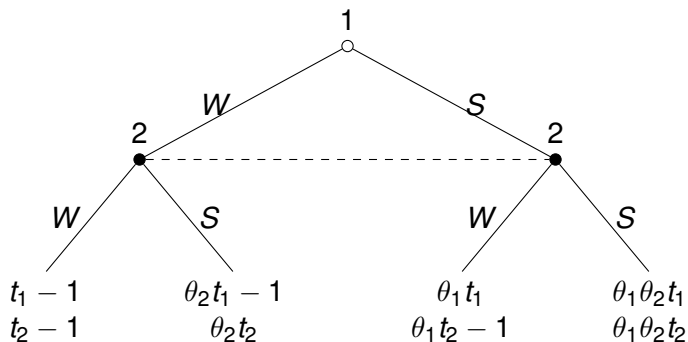
Equilibrium set not LHC: replace min with inf.

# Centralized Mechanism Benchmark

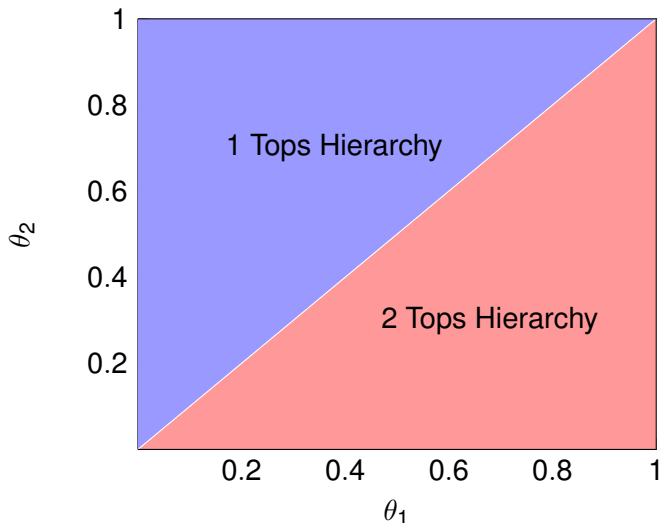
Principal chooses  $t_1, t_2 \geq 0$  to be paid on success.

WLOG no payment on failure.

# Centralized Mechanism Benchmark: Extensive Form



# Optimal Centralized Mechanism and Pivotality



Most pivotal agent tops hierarchy, getting a big bonus

## Decentralized Mechanism

Principal chooses budget  $b \geq 0$ , sum to be paid on success.

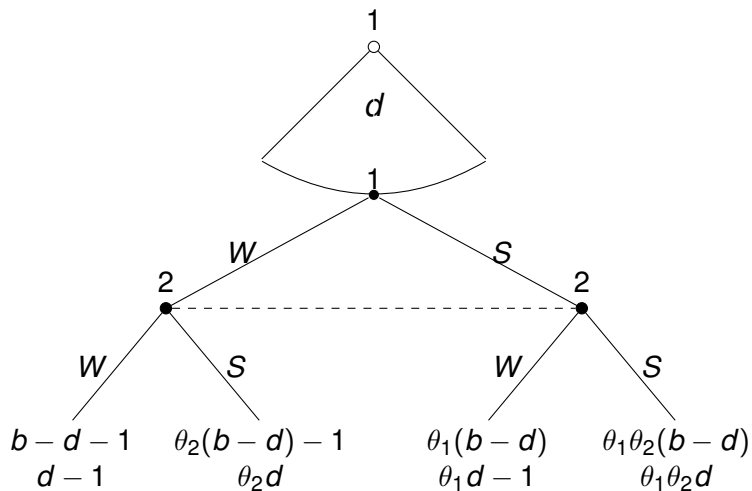
Principal chooses subcontractor: some agent  $i$ .

Subcontractor chooses subordinate's share  $d$ ,  $0 \leq d \leq b$ .

Effort choices follow announcement of  $d$ .



# Decentralized Mechanism: Extensive Form



## Decentralized Mechanism: SPNEs

Unless  $d$  induces dominance-solvable game, always a 'bad' equilibrium in the subgame.

Implementing  $(W, W)$  as a unique SPNE outcome via subcontracting (weakly) more expensive than centralization.

# Extensive-Form Rationalizability

## **Extensive Form Rationalizability (Pearce 1984)**

At each step, delete strategies that do not best-respond to some strategic conjecture at every still-reachable info set

At each reachable info set, strategic conjectures must

- Have support only on surviving strategies.
- Be consistent with self at predecessors, if possible.
- Reach the info set.

*Players should maintain the assumption of common knowledge of rationality, so long as this is not contradicted.*

# Solution Concept

## **NE in Extensive-Form Rationalizable Strategies**

EFR has no bite in Centralized Mechanisms.

- In simultaneous games, EFR = Rationalizability.
- Rationalizability does not refine Nash.

# EFR and Decentralized Mechanisms

Can immediately eliminate strategies for subordinate that

- Shirk at subgames where this is dominated (high  $d$ )
- Work at subgames where this is dominated (low  $d$ )

# EFR and Decentralized Mechanisms

We're looking for values of  $b$  and  $d$  such that

- a Promising  $d$  and shirking is not rat for the subcontractor
- b Offering  $d$  and working is rat for the subcontractor
- c Subordinate works if she infers subcontractor works.

## EFR: First Blood

For  $b$  below a  $b_{\text{Inference}}^*$ , if  $d$  and work is is rat,  $d$  and shirk is rat.

For  $b$  above  $b_{\text{Inference}}^*$ , for no  $d$  is  $d$  and shirking rat.

Generally: if  $b$  is large enough that working is dominant in the  $d = 0$  subgame, then shirking on-path is never rat.

We dub  $b > b_{\text{Inference}}^*$  the **Inference Requirement**.

## EFR: First Blood Part 2

Offer  $d$  and Work is rat for subcontractor if  $d \in [0, d^*(b)]$ .

If the subcontractor is known to work, the subordinate's only best response is to Work if  $d \in (t_{\text{Partial}}^*, \infty)$ .

There is a  $b_{\text{Agency}}^*$  solving  $d^*(b_{\text{Agency}}^*) = t_{\text{Partial}}^*$ .

For an  $d$  to exist that is rat with Work and leads subordinate to work, need  $b > b_{\text{Agency}}^*$ . This the **Agency Requirement**.



## EFR: Last Blood

If  $b > \max\{b_{\text{Inference}}^*, b_{\text{Agency}}^*\}$ ,

- Subcontractor: eliminate  $d$  and shirk for some  $(t_{\text{Partial}}^*, \bar{d})$ .
- Subordinate: eliminate Shirk at those same  $d$ .
- Subcontractor: eliminate all  $d \neq t_{\text{Partial}}^*$ .

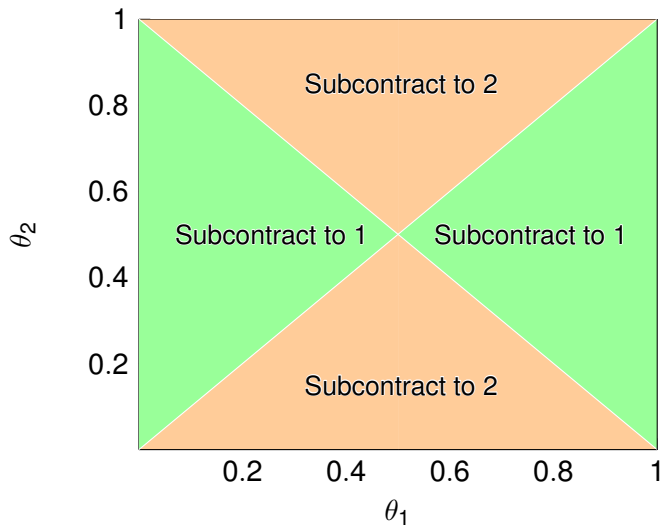
# Equilibrium Outcome

For  $b > \max\{b_{\text{Inference}}^*, b_{\text{Agency}}^*\}$ , only equilibrium outcome is

- Subcontractor offers  $t_{\text{Partial}}^*$  and works
- Subordinate works

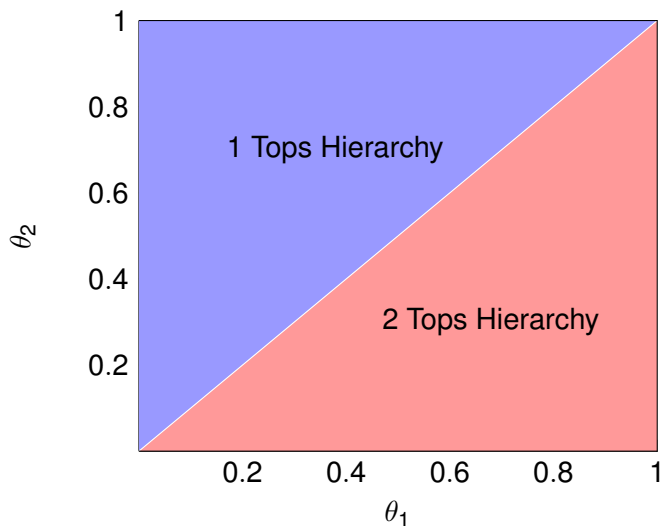
Infimal cost of UI by decentralization  $\max\{b_{\text{Inference}}^*, b_{\text{Agency}}^*\}$

## Pivotality and Subcontracting



When agents are pivotal, subcontract to *most* pivotal;  
When agents are not pivotal, subcontract to *least* pivotal.

## Pivotality and Centralization



Winter hierarchy always places the most pivotal agent on top.

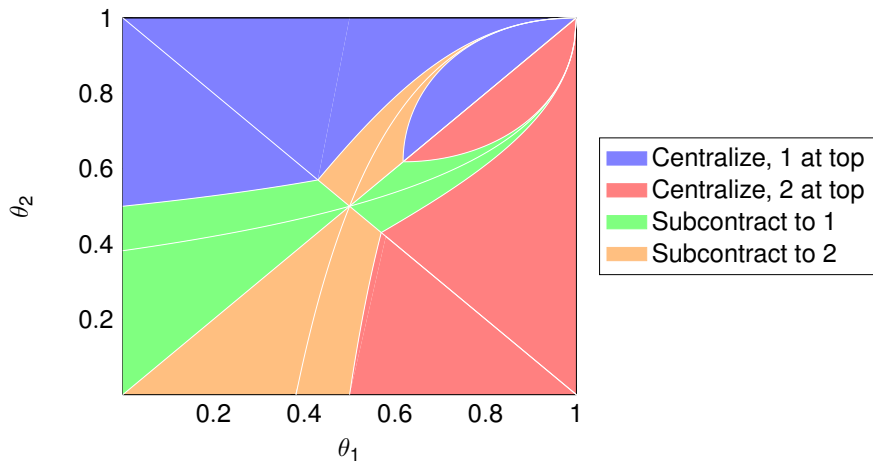
# Centralization vs. Decentralization: Symmetric Case

In the symmetric case when  $\theta_1 = \theta_2 = \theta$ :

- Subcontracting is optimal when  $1/\theta \leq \varphi$  (agents pivotal)
- Centralization is optimal when  $1/\theta \geq \varphi$  (agents not pivotal)

*Subcontracting is optimal when hierarchy shares would be more unequal than  $\varphi : 1$ .*

And now, the Rorschach test portion of the talk.



Subcontract if both pivotal, centralize if very asymmetric.

# Conclusions

A contract from the horse's mouth can convince.

- Intuitively, agents' contracts convey *intentions*.

Subcontracting sometimes kills strategic uncertainty cheaply.

- Chiefly, but not only, when agents need each-other.

Not always best to subcontract to the most pivotal agent.

Thank You!