Prizes vs Contracts as Incentive for Innovation

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Issue: How to procure innovative projects?

- Two aspects
  - *Ex ante*: Encouraging innovation (proposals)
  - *Ex post*: Efficient implementation (of selected projects)
- Questions
  - Monetary prizes vs contract rights
  - Bundling vs unbundling

Practice

- Unsolicitated proposals
  - Many public authorities do not directly reward unsolicited ideas (U.S)
    An innovating firm is rewarded only by participating in the tender for implementation, should the authority decide to go ahead.
  - Chile, Korea: Grant an advantage at implementation stage
    Bidding credit in the tender for implementation, bidding support.
  - Philippines, India: Swiss challenge system
    The proposer can counter-match the best offer
  - Argentina, South Africa: Best and final offer system
    The proposer automatically participates in the final round
- Public procurement of innovation: Pure bundling vs full unbundling
  - "Pre-commercial procurement" (PCP): The public authority procures R&D activities (up to prototyping and testing), but reserves the right to tender competitively the newly developed products or services.
  - "Innovation Partnerships:" Development and production are procured through one single tender (the innovator thus also obtains the contract rights over the production of the innovation).

This paper

- Framework
  - *Ex ante* R&D incentives
    Innovators invest to generate valuable proposals
  - *Ex post* productive efficiency
    The buyer decides which project to implement, if any
    ... in which case multiple contractors compete with the proposer
- Two instruments, contingent on project values
  - Monetary transfers ("prizes")
  - Contract rights (which project, which implementor)
- Two situations
  - Start with single innovator (unsolicited proposals)
  - Extend to multiple innovators (procuring innovation)

Insights

- Absent agency problems at implementation stage: Monetary prize
  - For particularly valuable proposal, and equal to its full value
  - Contractor selected purely on the merits
- Agency problems at implemention stage: Distort contract allocation
  - Intuition: Reward innovation with agency rents
- Single innovator
  - Bias for/against the innovator when project is/is not highly valuable
  - Monetary prize may still be optimal for particularly valuable innovation
- Multiple innovators
  - Project values still affect choice of contractor (similar logic)
  - Project selection can be done ex interim (ahead of implementation) if no interdependence btw project & contractor
    Otherwise, project selection depends also on (reported) costs
  - At most one prize (still equal to the full expected value of the project) when innovation is particularly valuable / needs to be incentivized

Single innovator (unsolicitated proposals)

- Innovation stage: Firm 1 exerts research effort e
  - Costs $c(e)$, generates a proposal with value v for the buyer
    - v is distributed over $V = [\underline{v}, \bar{v}] \sim$ density $f(\cdot|e)$
    - for $v' > v$, $\frac{f(v'|e)}{f(v|e)}$ increases in e (MLRP)
  - The value v is publicly observable and verifiable.
- Implementation stage: n potential contractors, including the innovator
  - Each firm i faces a cost θ_i, which is privately observed
    - distributed over $\Theta = \left[\underline{\theta}, \overline{\theta}\right] \sim$ cdf $G_i(\cdot)$, density $g_i(\cdot)$
    - $\underline{\theta} < \overline{v}$ and $\frac{G_i(\theta_i)}{g_i(\theta_i)}$ increases in θ_i
  - If the project is not implemented, all parties obtain zero payoff.

Timing

1. The principal offers a direct revelation mechanism:
   - whether the project will be implemented, and if so by which firm
   - a payment to each firm
   as functions of the value v and of firms' reports on their costs.
2. The innovator chooses e; the value v is realized and observed by all.
3. Firms observe their costs; all parties decide whether to participate.
4. Participating firms report their costs; the project is implemented (or not) and transfers are made according to the procedure.

Note: Limited liability (all parties can "opt out" once v is realized)

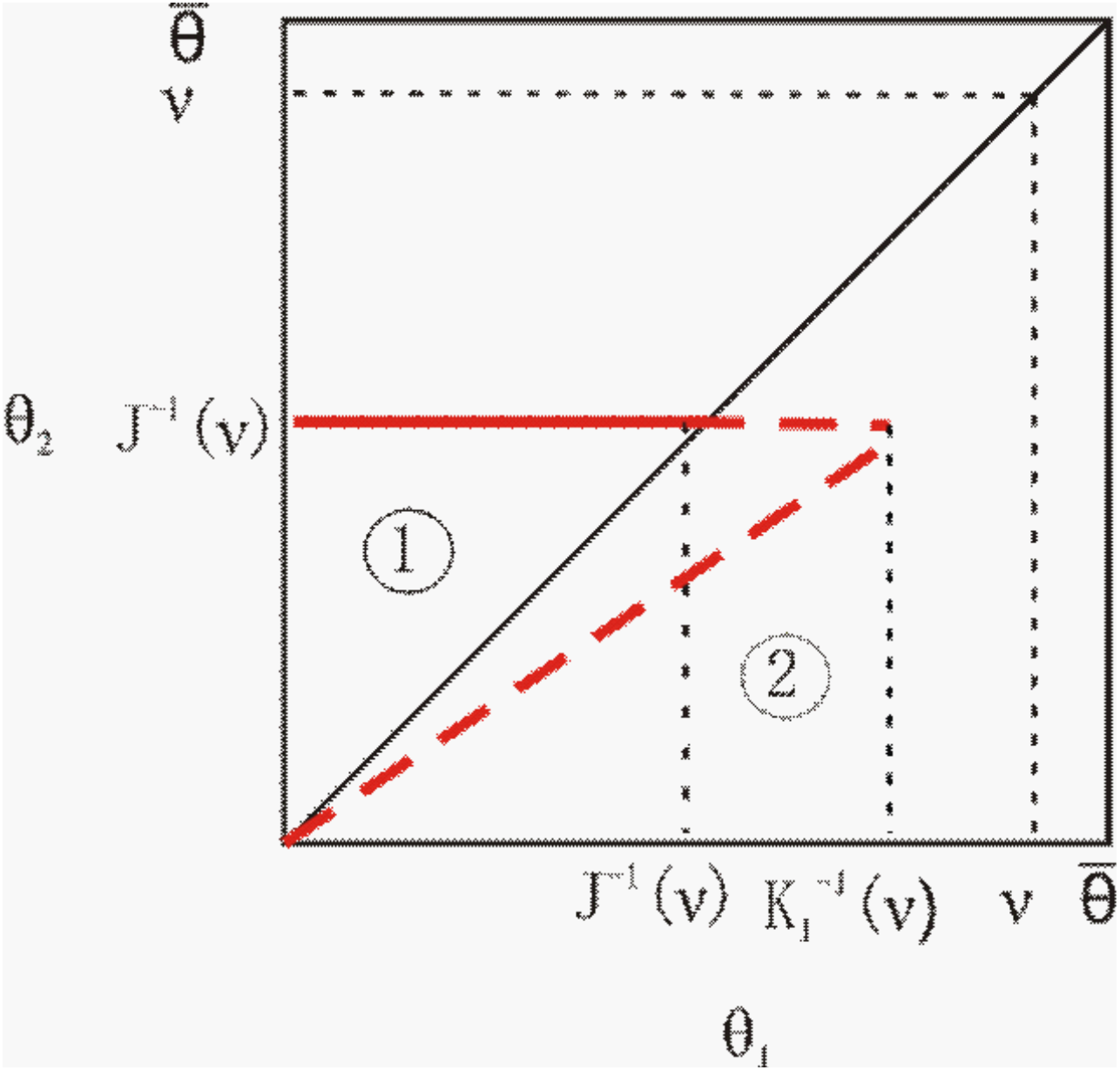
Benchmarks

- No agency problem *ex post* (implementation stage)
  - Suppose that firms' realized costs are publicly observable
  - First-best allocation: implement the project if $v > \min_i \{\theta_i\}$
  - Monetary prize if v is "high enough"
    ... in which case it is equal to the full net value $v - \min_i \{\theta_i\}$
- No agency problem *ex ante* (innovation stage)
  - Standard procurement auction *ex post* (Myerson)
  - Firm i obtains the contract if $J_i(\theta_i) \leq \min\left\{v, \min_{j \neq i} J_j(\theta_j)\right\}$, where $J_i(\theta_i)$ represents firm i's *virtual cost*:

$$J_i(\theta_i) = \theta_i + \frac{G_i(\theta_i)}{g_i(\theta_i)}$$

Optimal mechanism

- A standard auction is optimal only if induces maximal effort
- Otherwise, there exists $\tilde{v} > \underline{v}$ and $\hat{v} > \tilde{v}$ such that:
  - The innovator is *favored* if $v > \tilde{v}$, *handicapped* if $v < \tilde{v}$.
    - A bonus can be achieved by giving the innovator a bidding credit in the tendering procedure; additional points in the score of the original proponent's bid, financial support for bidding purposes.
    - Likewise, under-implementation less/more severe than in standard second-best.
  - *Full delegation* if $v > \hat{v}$ (where $\hat{v} \leq \overline{v}$):
    - The innovator
      - is awarded a monetary prize equal to the full value of the project (net of informational rents)
      - is allocated the contract if $\theta_1 < \min\left\{v, \min_{i \neq 1} J_i(\theta_i)\right\}$
    - This can be achieved by delegating the procurement to the innovator, for a fixed price equal to the value of the project.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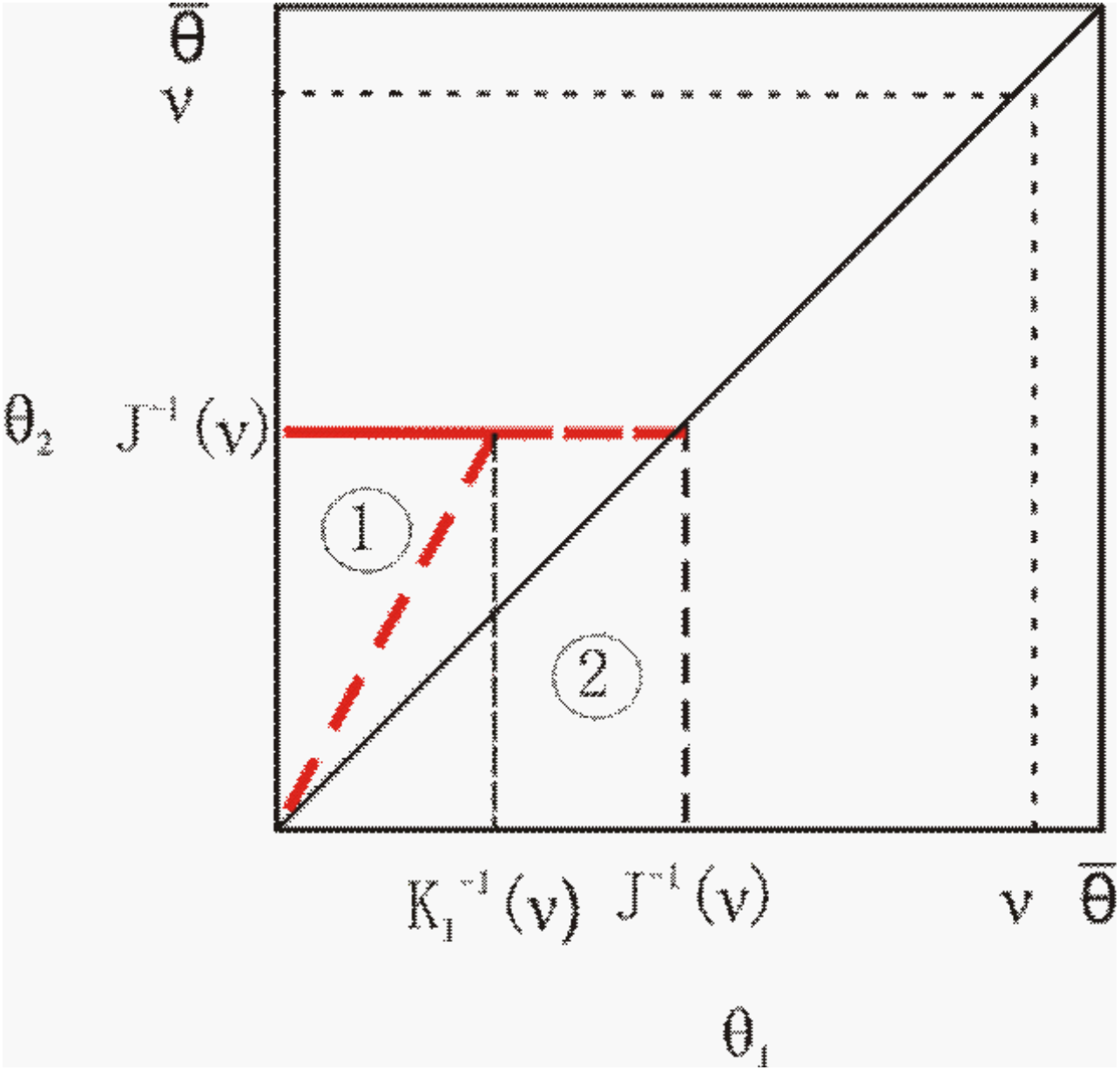
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Multiple innovators (procuring innovation)

- Innovation stage: every firm k can invest
  - costs $c^k\left(e^k\right)$
  - comes up with a project of value $v^k \sim f^k(v^k|e^k)$
- Implementation stage: If firm i implements project k, costs $\theta_i + \psi_i^k$
  - $\theta_i \sim G_i(\cdot)$ is an idiosyncratic shock; privately observed by firm i
  - ψ_i^k captures the interplay btw project & contractor; common knowledge
- Buyer's surplus:

$$w\left(\mathbf{v},\theta\right) = \sum_{k,i}\left[v^k x_i^k\left(\mathbf{v},\theta\right) - t_i\left(\mathbf{v},\theta\right)\right]$$

- Firm i's payoff:

$$u_i(\mathbf{v},\theta_i'|\theta_i) = \mathbb{E}_{\theta_{-i}}[t_i(\mathbf{v},\theta_i',\theta_{-i}) - (\theta_i + \psi_i^k)x_i^k(\mathbf{v},\theta_i',\theta_{-i})]$$

Optimal mechanism - multiple innovators

- The values of the projects still affect contract assignment
  - Same logic as before: favor good proposers against poor ones
  - For each firm i, $\exists\ \tilde{v}^i$ such that $K_i(\mathbf{v}, \theta_i) < J_i(\theta_i)$ if and only if $v^i > \tilde{v}^i$
- One firm at most is adjudicated a prize
  - This is the one that yields the highest incentive benefit

$$\beta^i(v^i) = \lambda^i \frac{f_e^i(v^i|e^{i*})}{f^i(v^i|e^{i*})}$$

(valuable innovation and/or worth incentivizing)

  - The prize winner need not be the firm whose project is implemented

Implications

- If no interdependence project/implementor ($\psi_i^k = \psi_i + \psi^k$), then project selection can be made independently of the choice of the implementor:
  - The project is simply selected on the basis of "net values," $v^k - \psi^k$, without regard to whom will implement the chosen project
  - However, full unbundling is not optimal: The realized values **v** affect the choice of contractor
- Otherwise, project selection connected to contract assignment
  - Suppose that firms have a cost advantage on their projects:
$$\psi_k^k = 0 < \psi_i^k = \bar{\psi} \text{ for } i \neq k$$
  - If for instance $v^1 > v^2$ and $\theta_2 << \theta_1$, the desire to exploit this cost advantage may lead to choosing project 2
  - If $\bar{\psi}$ large enough, "pure bundling;" however, the selection of the project/contractor depends on both **v** and θ.

Remark: Targeted groups

- Targeted groups such as *SMEs*: Separation
  - US: The Small Business Innovation Research (SBIR)
  - UK: Small Business Research Initiative (SBRI)
- Our analysis supports such approach
  - *SMEs* may be unable to compete on large implementation contracts
  - They are at a clear disadvantage in case of bundling
- Consider the following situation:
  - Implementation costs: $\psi_i^k \to \infty$ for *SMEs*, $\psi_i^k = 0$ otherwise
  - Allocation based on:
    - best value v^k (*SMEs* and non-*SMEs*)
    - lowest virtual cost $J_i(\mathbf{v}, \theta_i)$ (non-*SMEs*)
  - Prizes: Only reward for *SMEs* (if any, goes to best value v^k)
- Similar reasoning for university research

THANK YOU!

Related literature

- Prizes versus property rights to motivate innovation
  - IPRs generate *ex post* distortion (output restriction, market foreclosure) Kremer (1998)
  - But can be an optimal way to motivate *ex ante* innovation Weyl and Tirole (2012)
- Bundling sequential tasks
  - Group lending; Laffont and Rey (2003)
  - Externalities across tasks; Bennett and Iossa (2006)
  - Budget constraints; Schmitz (2013)
- Discrimination vs bidding parity in auctions
  - Discriminating against efficient types Myerson (1981), McAfee and McMillan (1985).
  - Can also encourage bidders to reduce their costs Laffont and Tirole (1988), Bag (1997)

Optimal mechanism (single innovator)

- Notation:
  - $x_i(v,\theta)$: probability that firm i implements the contract
  - $t_i(v,\theta)$: transfer to firm i
  - Buyer's surplus: $w(v,\theta) = \sum_i [x_i(v,\theta)\, v - t_i(v,\theta)]$
  - Firm i's payoff: $U_i(v,\theta_i) = \mathbb{E}_{\theta_{-i}}[t_i(v,(\theta_i,\theta_{-i}))) - \theta_i x_i(v,(\theta_i,\theta_{-i}))]$
- Buyer's problem: $\max_{x,t} \mathbb{E}_{v,\theta}[w(v,\theta) \mid e]$ subject to:
  - *interim individually rationality*: $\forall i, v, \theta_i, \qquad U_i(v,\theta_i) \geq 0$
  - *interim incentive compatibility:*

$$\forall i, v, \theta_i, \theta_i', \qquad U_i(v,\theta_i) \geq u_i(v,\theta_i'|\theta_i),$$

    where $u_i(v,\theta_i'|\theta_i) = \mathbb{E}_{\theta_{-i}}[t_i(v,(\theta_i',\theta_{-i}))) - \theta_i x_i(v,(\theta_i',\theta_{-i})))]$
  - *limited liability*: $\forall v, \quad \mathbb{E}_\theta[w(v,\theta)] \geq 0$
  - *moral hazard*: $e \in \arg\max_{\tilde{e}} \{\mathbb{E}_{v,\theta}[U_1(v,\theta_1) \mid \tilde{e}] - c(\tilde{e})\}$

Solution (single innovator)

Let e^* denote the optimal effort and λ the associated Lagrangian multiplier

- Firm i obtains the contract if $K_i(v,\theta_i) \leq \min\left\{v, \min_{j\neq i} K_j(v,\theta_j)\right\}$, where $K_i(v,\theta_i) = J_i(\theta_i)$ if $i \neq 1$ and

$$K_1(v,\theta_1) = J_1(\theta_1) - \min\left\{\beta(v), 1\right\}\frac{G_1(\theta_1)}{g_1(\theta_1)}, \text{ with } \beta(v) = \lambda\frac{f_e(v|e^*)}{f(v|e^*)}.$$

  $\longrightarrow$ informational rent $\int_{\theta_i}^{\overline{\theta}} \mathbb{E}_{\theta_{-i}}\left[x_i^*(v,(\theta,\theta_{-i}))\right] d\theta$.

- If in addition $\beta(v) > 1$, then the innovator obtains a monetary prize, equal to the full interim expected net value of the project:

$$\rho^*(v) = \mathbb{E}_\theta\left[\sum_i x_i^*(v,\theta)\left[v - J_i(\theta_i)\right]\right](>0).$$

Optimal mechanism (multiple innovators)

Given the optimal effort profile $\mathbf{e}^*$ and associated multipliers $\boldsymbol{\lambda}$:

- Firm i implements project k if
  $v^k - K_i(\mathbf{v}, \theta_i) - \psi_i^k \geq \max\left\{0, \max_{(l,j)\neq(k,i)} v^l - K_j(\mathbf{v}, \theta_j) - \psi_j^l\right\}$,
  where
  $$K_i(\mathbf{v}, \theta_i) = J_i(\theta_i) - \frac{\beta^i\left(v^i\right)}{\max\left\{\max_k\left\{\beta^k\left(v^k\right)\right\}, 1\right\}} \frac{G_i(\theta_i)}{g_i(\theta_i)},$$
  and $\beta^i\left(v^i\right) = \lambda^i \frac{f_e^i(v^i|e^{i*})}{f^i(v^i|e^{i*})}$ denotes firm i' "incentive benefit"
  $\longrightarrow$ informational rent $\int_{\theta_i}^{\overline{\theta}} \mathbb{E}_{\theta_{-i}}\left[\sum_{k\in N} x_i^{k*}\left(\mathbf{v}, \theta, \theta_{-i}\right)\right] d\theta$.
- If in addition $\beta^i\left(v^i\right) > \left\{\max_{j\neq i} \beta^j\left(v^j\right), 1\right\}$, then firm i obtains a monetary prize equal to the full expected value of its project
  $$\rho_i^*(v) = \mathbb{E}_\theta\left[\sum_{k,i} x_i^{k*}(\mathbf{v}, \theta)\left\{v^k - J_i(\theta_i)\right\}\right](>0).$$