Public Goods: Public Vs Private Provisioning

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Question
Can we apply the model of incomplete contracts to discuss the ownership and provisions of public goods and service?

Yes.

We can think of the above model as a model of provision of public good/service

- Suppose M1 is a govt official
- Suppose M2 is a private individual
- ‘Widget’ is public good/service
  - Prison, hospital, road, airport
- Non-integration as privatization (private ownership) of a2
M2 owns a2

Type-1 integration as nationalization (public/govt ownership) of a2

Govt owns a2

M2 is govt employee

PRT would predicts that:

- M2 would undertake greater number of innovations if he owns a2 rather than when he is govt employee

But,

- M1 may not undertake greater number of innovations if govt owns a2, compared to the case when a2 is owned by M2 (private individual)
In real world:

- The provision of Public good requires M2 to undertake multiple tasks; Specifically,
  - Building of the project facility
  - O&M of the project facility
- Procurement Contract determines the level of delegation
  - The domain of decision making delegated to private sector
- Depending of the tasks delegated to him, M2 may be able to undertake several types of innovations
- Levels of these innovations will depend whether if he owns a2 not
- Some of the innovations could be socially undesirable
Procurement Contracts

- Procurement Contracts are used for provisions of public goods such as road and railways services, school.

- Provision public goods requires procurement/building of assets - road, school building, etc.

- A Procurement Contract specifies responsibilities, rights and compensation mode for the contractor.

- Allocates construction, maintenance, and commercial risks between contracting parties.

- Procurement Contracts differ in terms of delegation of decision making power and risk allocation b/w public and private sector.
Traditional Contracts Vs PPPs: Risk Allocations

- **Traditional Procurement:**
  - Contractor builds the pre-designed good
  - *Per-unit* cost risk mostly borne by the contractor
  - Work quantities related risk mostly borne by the Govt.
  - Contractor does not bear any O/M cost and related risk

- **PPP:**
  - Contractor designs, builds and maintains the good (D-B-F-O-M)
  - All of Construction cost related risks are borne by contractor by contractor
  - Contractor bears all O/M costs are risks risk
  - PPP delegates more decision rights to the contractor
Traditional Contracts Vs PPPs: Comparison of Outcomes

We

- Compare the incentive structures generated by PPP contracts with the one induced by Tradition Procurement Contracts
- Compare the actual construction cost for PPP contracts with Non-PPP Contracts

Main Claims

- PPP Contracts induce lower Life-cycle costs of project
- PPP Contracts induce relatively high Construction Costs
- Relatively high Construction Costs in PPP projects are attributable to non-contractible quality investments/efforts
Approach

- We model construction costs under PPPs and TP contracts
- we compare the costs ratio

\[ CO = \frac{C^a}{C^e} = \frac{\text{Actual project cost}}{\text{Estimated project cost}} \]

The above claims are corroborated by showing that:

- *Ceteris paribus*, \( \frac{C^a}{C^e} \) is significantly higher for PPPs
Model: Project Design I

Project Design requires three tasks:

- Description of ‘output’ features of the project facility/assets
- Description/listing of the work-items
- Estimation of the number of the quantities of the work-items and their per-unit cost

For a given project, let

- $d$ denote the effort in project designing
- $[0, \overline{W}], \ 0 < \overline{W}$ be the set of total work-items needed to be performed
- $W$ be the number of works covered by the initial design; $W = W(\tau, l, d)$, where
- $l$ denotes experience of the designers with project planning; and
- $\tau$ denotes technical complexity of the project.
Model: Project Design II

- \( W(\tau, l, 0) = 0, \ W(\tau, l, \infty) = \bar{W}, \)
- \( \frac{\partial W(\tau, l, d)}{\partial d} > 0 \)
- \( \frac{\partial W(\tau, l, d)}{\partial l} > 0 \)
- \( \frac{\partial W(\tau, l, d)}{\partial \tau} < 0 \)

As a result of \( d \), the designer

- specifies works \([0, W]\), and
- gets \( C_{[0, W]}^e \) as the signals of \( C_{[0, W]}^a \), where

\[
C_{[0, W]}^e = C_{[0, W]}^a + \epsilon
\]

Assume

\[
E(\epsilon) = 0
\]
The actual Construction Cost depends on

- the cost of inputs (material, labour, capital, etc); and
- various non-contractible efforts/investment made by the builder contractor
  
  - a organizational effort before construction starts
  - e cost reducing but quality-shading effort
  - i quality improving effort
- e and i are put during construction.
For given $a$, $e$ and $i$,

$$C_{[0,\bar{w}]}^a(a, e, i) = C_{[0,\bar{w}]}^0 - \kappa^1(a) - \kappa^2(e) + \kappa^3(i),$$

where

$$\frac{\partial \kappa^1(a)}{\partial a} > 0, \quad \& \quad \frac{\partial^2 \kappa^1(a)}{\partial a^2} < 0.$$ 

$$\frac{\partial \kappa^2(e)}{\partial e} > 0, \quad \& \quad \frac{\partial^2 \kappa^2(e)}{\partial e^2} < 0.$$ 

$$\frac{\partial \kappa^3(i)}{\partial i} \geq 0, \quad \& \quad \frac{\partial^2 \kappa^3(i)}{\partial i^2} \geq 0.$$
Actual Costs III

For any given level of $a$, $e$ and $i$, the actual construction costs of all works, $C^a_{[0,W]}$, is given by

$$C^a_{[0,W]} = C^a_{[0,W]} + C^a_{(W,W)}$$ (0.2)

So,

$$\frac{C^a_{[0,W]}}{C^e_{[0,W]}} = \frac{C^a_{[0,W]}}{C^e_{[0,W]}} + \frac{C^a_{(W,W)}}{C^e_{[0,W]}}$$ (0.3)

In view of (0.1), for given $C^e_{[0,W]}$,

$$E \left[ \frac{C^a_{[0,W]}}{C^e_{[0,W]}} \right] = 1 + \frac{C^e_{(W,W)}}{C^e_{[0,W]}}$$ (0.4)
Actual Costs IV

Proposition

\[ E \left[ \frac{C^a_{[1, \bar{W}]} - C^e_{[1, \bar{W}]}}{C^e_{[1, \bar{W}]}} \right] \geq 1. \]

\[ \frac{\partial E \left[ \frac{C^a_{[1, \bar{W}]} - C^e_{[1, \bar{W}]}}{C^e_{[1, \bar{W}]}} \right]}{\partial d} < 0, \quad \frac{\partial E \left[ \frac{C^a_{[1, \bar{W}]} - C^e_{[1, \bar{W}]}}{C^e_{[1, \bar{W}]}} \right]}{\partial l} < 0, \quad \frac{\partial E \left[ \frac{C^a_{[1, \bar{W}]} - C^e_{[1, \bar{W}]}}{C^e_{[1, \bar{W}]}} \right]}{\partial \tau} > 0. \]

Therefore, for given \( l \) and \( \tau \),

\[ \left( \frac{C^a_{[1, \bar{W}]} - C^e_{[1, \bar{W}]}}{C^e_{[1, \bar{W}]}} \right)^{PPP} > \left( \frac{C^a_{[1, \bar{W}]} - C^e_{[1, \bar{W}]}}{C^e_{[1, \bar{W}]}} \right)^{TP} \]

can hold because

- Either \( d \) is lower for PPPs;
- Or, on account of differences in \( a, e \) and \( i \)
The total Construction costs is

\[ C^a_{[0,W]} + a + e + i \]

\[ C^0_{[0,W]} - \kappa^1(a) - \kappa^2(e) + \kappa^3(i) + a + e + i \]

Let

\[ \Phi(e, i) \] denote the O/M costs.

The total life cycle costs - total cost construction cost plus O& M cost - will be

\[ C_{[0,W]} = C^a_{[0,W]} + \Phi(e, i) \]

\[ = [C^0_{[0,W]} - \kappa^1(a) - \kappa^2(e) + \kappa^3(i)] + \Phi(e, i) \]

\[ + a + e + i \] (0.5)
Optimization Problems I

For any given $d$ and $C_{[1,W]}^e$, the total cost (construction plus O&M) minimization problem is:

$$\min_{a,e,i} \{ \Phi(e, i) - [\kappa_1(a) + \kappa_2(e) - \kappa_3(i)] + a + e + i \}.$$ 

The total cost minimizing efforts $a^*$, $e^*$ and $i^*$ solve the following necessary and sufficient first order conditions, respectively and simultaneously:

$$\frac{\partial \kappa_1(a)}{\partial a} \leq 1 \quad (0.6)$$
$$\frac{\partial \kappa_2(e)}{\partial e} - \frac{\partial \Phi(e, i)}{\partial e} \leq 1 \quad (0.7)$$
$$- \frac{\partial \kappa_3(i)}{\partial i} - \frac{\partial \Phi(e, i)}{\partial i} \leq 1. \quad (0.8)$$
Optimization Problems II

We assume
\[ a^* > 0, \ e^* = 0, \ & i^* > 0. \]

On the other hand, a construction cost minimization problem is

\[
\min_{a,e,i} \left\{ - \left[ \kappa^1(a) + \kappa^2(e) - \kappa^3(i) \right] + a + e + i \right\}
\]

Let \((a^{**}, e^{**}, i^{**})\) be solution to the above optimization problem. Now, it can be seen that \(i^{**} = 0\), and \(a^{**}\) and \(e^{**}\) will solve the following first order conditions:

\[
\frac{\partial \kappa^1(a)}{\partial a} \leq 1 \]
\[
\frac{\partial \kappa^2(e)}{\partial e} \leq 1.
\]

Clearly, \(a^{**} = a^*\). Assume \(e^{**} > 0\).
Under PPP, the contractor solves

$$\max_{a,e,i} \left\{ P^{PP} - \left[ \Phi(e, i) - (\alpha^{PP} \kappa^1(a) + \kappa^2(e) - \kappa^3(i)) \right] + a + e + i \right\}$$

where

$$0 \leq \alpha^{PP} \leq 1$$

and depends on the decision rights delegated to the contractor.

We have $e^{PP} = e^*$ and $i^{PP} = i^*$, and $a^{PP}$ solves the following first order condition:

$$\frac{\partial \kappa^1(a)}{\partial a} \leq 1$$
Contracts and Equilibria II

On the other hand, under TP, the contractor solves

\[
\max_{a,e,i} \left\{ p^{TP} - [\alpha^{TP} \kappa_1(a) + \kappa_2(e) - \kappa_3(i)] - [a + e + i] \right\}
\]  \(0.10\)

Assume \(\alpha^{TP} < \alpha^{PP}\).

\[
\begin{align*}
  i^{PP} &= i^* > i^{TP} = i^{**} = 0 ; \\
  e^{PP} &= e^* = 0 < e^{**} = e^{TP} . \\
  a^{TP}(\alpha^{TP}) &= a^{PP}(\alpha^{PP}) \leq a^* .
\end{align*}
\]  \(0.11\)
Cost Comparisons I

Proposition

For any given $d$ and $C_{[1,w]}^{e}$:

\[ C_{PPP}^{a} < C_{UR}^{a} \]

Proposition

For any given $d$, and $C_{[1,w]}^{e}$:

\[ a^{TP} = a^{PP} \implies \left( \frac{C_{PPP}^{a}}{C_{e}^{a}} \right)^{PP} > \left( \frac{C_{PPP}^{a}}{C_{e}^{a}} \right)^{TP} \]

\[ e^{TP} = e^{PP} \text{ and } i^{TP} = i^{PP} \implies \left( \frac{C_{PPP}^{a}}{C_{e}^{a}} \right)^{PP} < \left( \frac{C_{PPP}^{a}}{C_{e}^{a}} \right)^{TP} \]

However, $a^{TP} < a^{PP}$, $e^{TP} > e^{PP}$ and $i^{TP} < i^{PP}$. Therefore,
Cost Comparisons II

- \((\frac{Ca}{Ce})^{PPP} \geq (\frac{Ca}{Ce})^{TP}\) is possible

- But, if it turns out that \((\frac{Ca}{Ce})^{PPP} > (\frac{Ca}{Ce})^{TP}\) then it must be on account of differences in \(e\) and \(i\)

- Moreover, the actual cost difference b/w PPPs and TPs on account of \(e\) and \(i\) is greater than what data will show
DATA: NHAI

- National highways (NH) projects, sponsored by the National Highways Authority of India (NHAI);
- All over India;
- Completed 1995 onwards.
- All projects: 453
  - PPPs 176
  - Non-PPPs/IR 277
- Completed Projects: 195
  - PPPs 50
  - Non-PPPs/IR 145
Higher $\frac{C^a}{C^e}$ for PPPs: Other possible reasons

However, $\frac{C^a}{C^e}$ can be higher for PPPs for the following reasons:

- **At Project Designing/Contracting Stage:**
  - Purposeful Under-estimation of $C^e$ for PPPs
  - Choice of PPPs by Department
  - Choice of PPPs by contractors - Endogeneity

- **During Construction Stage:**
  - Ex-post addition to works for PPP projects
  - Trade-off between Construction Costs and completion Time;
    - Lower $\frac{T^a}{T^e}$ can increase $\frac{C^a}{C^e}$
    - Lower $\frac{T^a}{T^e}$ can decrease $\frac{C^a}{C^e}$; inflation, etc

- **Trade-off between Construction Costs and O&M Costs**
Empirical Framework

\[ \frac{C^a}{C^e} = CO = \alpha_0 + \alpha_1 \text{TIMELAPSE}_t + \alpha_2 \text{TIMELAPSE}_t^2 + \alpha_3 \text{INITIALCOST}_t + \alpha_4 \text{IMPLPHASE}_t + \alpha_5 \text{DPPP}_t + \alpha_6 \text{PSGDP}_t + \alpha_7 \text{TO}(\frac{T^a}{T_e}) + \epsilon_{2t} \]

Hypothesis

Ceteris paribus, average cost overruns, i.e., \( \frac{C^a}{C^e} = CO \)

- are higher for PPP projects;
- decrease with experience/TIMELAPSE, i.e., \( t \);
- increase with TIME-OVERRUN, i.e., \( TO = (\frac{T^a}{T_e}) \);
- increase with IMPL-PHASE, i.e., \( \tau \);