Wharton PBL Research Update

Incentive Contracting, Asset Ownership, and Control: Models and Policy Implications

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Wharton Research Projects on PBL

1. How does PBL compare to Cost Plus and Fixed Price contracts in terms of risk sharing and incentives?

2. What are the main drivers of PBL success?

3. Invest in reliability or spare assets?

4. Other research topics
Models of incentive contracting in support and maintenance business

**Service parts inventory management theory**
- METRIC (Sherbrooke, ’68)
- Numerous extensions: MOD-METRIC, VARI-METRIC
- Defense & commercial implementations
- Computational in nature in a single organization setting

**Contract theory: Principal-agent model**
- Analysis of incentives in buyer-seller relationships
- Over 30 years of research in economics
- Moral hazard
- Focus on procurement or intra-firm contacts (bonuses)
Research Issues

• What constitutes PBL?
  – Incentive contracting
  – Delegation of decisions for asset management
  – Asset ownership

• Relationships among reliability, spare assets, availability, and cost of ownership
  – Availability increase and cost reduction can come from
    1. Improvement in product reliability
    2. Better management of spares inventory
    3. Combination of both

• Contrast between traditional contract and PBL
  – How do they impact decisions on reliability and investment in spare assets?
  – Does spare asset ownership play a role?
Reliability, Inventory, and Availability

Reliability

Availability

Responsiveness

Inventory

Total cost during product life time

+  +  -  +  +
Model Outline

Decision: Negotiate and agree to contract terms

Objective: Minimize ownership cost subject to fulfillment of availability target

Customer

Supplier

Decision: Determine
1. Reliability = MTBF
2. Stocking level

Objective: Maximize profit = payment – internal cost

Spare assets owned by?
Lemma 6

Assume $p - c < \delta h$ and let \( \eta_\delta(v, p) \equiv (v + \delta h)\phi(z_\delta(v, p)) \). For $v$ defined on $(c - p, \infty)$, 
\[
\frac{\partial \eta_\delta(v, p)}{\partial v} = L(z_\delta(v, p)) > 0 \quad \text{and} \quad \frac{\partial \eta_\delta(v, p)}{\partial \delta} = h \left( \phi(z_\delta(v, p)) + \frac{z_\delta(v, p)}{v + \delta h} \right) > 0.
\]

**Proof.** \( \lim_{v \rightarrow c - p} \eta_\delta(v, p) = 0 \) by (8) and by L’Hopital’s rule,
\[
\lim_{v \rightarrow \infty} \eta_\delta(v, p) = \lim_{v \rightarrow \infty} \frac{\phi(z_\delta(v, p))}{1/(v + \delta h)} = \lim_{v \rightarrow \infty} \frac{-\frac{\delta h - p + c}{(v + \delta h)^2} z_\delta(v, p)}{-1/(v + \delta h)^2} = \lim_{v \rightarrow \infty} (\delta h - p + c) z_\delta(v, p) = \infty.
\]

Also,
\[
\frac{\partial \eta_\delta(v, p)}{\partial v} = \phi(z_\delta(v, p)) - \left( \frac{\delta h - p + c}{v + \delta h} \right) z_\delta(v, p) = L(z_\delta(v, p)) > 0
\]
for $v \in (c - p, \infty)$. These results imply that \( \lim_{v \rightarrow c - p} [\eta_\delta(v, p) + z_\delta(v, p)] = 0 \), \( \lim_{v \rightarrow \infty} [\eta_\delta(v, p) + z_\delta(v, p)] = \infty \), and
\[
\frac{\partial}{\partial v} [\eta_\delta(v, p) + z_\delta(v, p)] = L(z_\delta(v, p)) + \frac{\delta h - p + c}{(v + \delta h)^2} \phi(z_\delta(v, p)) > 0.
\]

Thus $\eta_\delta(v, p) + z_\delta(v, p) > 0$ for $v \in (c - p, \infty)$ and
\[
\frac{\partial \eta_\delta(v, p)}{\partial \delta} = h \phi(z_\delta(v, p)) + \frac{hz_\delta(v, p)}{v + \delta h} = h \left[ \frac{\eta_\delta(v, p) + z_\delta(v, p)}{v + \delta h} \right] > 0.
\]
Material Contract: Pay for Spares

Contract: Fixed payment + Unit price per spare

As the profit margin increases...

• Does the supplier procure more spares?
  Yes, but:
  - Customer ownership: tendency to acquire too much
    (supplier paid for each spare without incurring ownership cost)
  - Supplier ownership: supplier restrains acquisition
    (costly to own and manage spares)

• Does the supplier improve reliability?
  No, supplier has little incentive to improve reliability

Material contract does not induce reliability improvement
Performance Contract: Pay for Performance

Contract: Fixed payment + Penalty for downtime

As the penalty increases...

• Does the supplier improve reliability?
  Yes, supplier has incentive to improve reliability

• Does the supplier procure more spares?
  Yes in most cases, but subtle:
  - Direct effect: Acquire more spares to reduce downtimes
  - Indirect effect: Reliability is improved, requiring less inventory

Net effect: Inventory goes up if reliability improvement is sufficiently expensive

Performance based contract induces reliability improvement
Incentive Alignment: Graphical Representation

Supply chain is coordinated under PBL with supplier asset ownership
Summary of Findings

• Reliability and inventory are substitutes with respect to availability target

• Traditional material contract gives the supplier little incentive to enhance reliability → minimum reliability, increased inventory in supply chain

• With performance based contract, the supply chain ends up with better reliability and less inventory compared to material contract

• Ownership matters: more efficiency by delegating spare asset ownership to the supplier
Recap: Wharton Research Projects

**Cost Plus vs. Fixed Price vs. PBL**
- Risk sharing vs. performance incentives
- Kim, Cohen, Netessine (2006)

**Reliability vs. Inventory**
- More reliable a product is, less spares are needed
- Impact of PBL on reliability?
- Kim, Cohen, Netessine (2007)

**Explicit vs. Implicit Incentives**
- PBL as a short-term incentive
- Award term contract as a long-term incentive
- Current project

**Supply Chain Structure in PBL**
- PBL with system integrator vs. PBL with subsystem provider
- Accountability, free riding
- Future work

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