Impact of Performance Based Contracting on Product Reliability: An Empirical Analysis

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After-sales service market

- **Industries**: Aerospace, semiconductor, automobile,…
- **Aerospace industry**: revenues of $117 billions for repair and maintenance in 2007
  - **Commercial aircrafts**: revenues of $45 billion
Infrequent equipment failures

Engine services due to malfunction (March 2006 – March 2007)
Regional airline company with installed base of 60 engines

- March 2006: Scheduled check, Vane burn through
- September 2006: Vibration, Compressor degradation, Oil system debris
- March 2007: Fan case corrosion, Oil leak, Liner damage, Vane burn through
Contract types: T&M vs Performance-based

**Time & material**
*Conflicting Incentives*

- **Supplier**
  - Material Products
  - Wants to increase

- **Buyer**
  - Wants to decrease

**Performance-based**
*Aligned Incentives*

- **Service Provider**
  - Value of Services through Products
  - Wants to increase

- **Buyer**
  - Wants to increase

**TIME & MATERIAL CONTRACTS:**
Payment based on resources consumed in the service

**PERFORMANCE-BASED CONTRACTS:**
Payment based on flying hours generated by the service

→ Fleet Availability

**Does contract type influence engine reliability?**
Literature

• Service parts inventory management: Sherbrooke (1968,1992), Muckstadt (2005), Cohen et al. (1990)...

• Incentives in economics: Holmstrom and Milgrom (’91), Bolton and Dewatripont (’05), Gibbons (’05)...

• Empirical research on incentives in other areas (IS, economics, health care, public policy)

• Contracting in supply chains
  – Cachon 2003: *Supply chain coordination with contracts*, more than 200 related papers

  “Considerable amount of theory, but embarrassingly paltry amount of empiricism”
Field Research
Wharton Research on PBL

- Contracts
  - Cost sharing
  - Performance incentives

- Managerial decisions
  - Cost reduction effort
  - Stocking levels
  - Reliability improvement
  - Service capacity

- Performance outcomes
  - Cost reduction
  - Availability
  - Service time

- Exogenous factors
  - Uncertainty in cost
  - Ownership structure
  - Product reliability

Cost sharing and PBL
Kim, Cohen, Netessine (2007a)
*Mgmt Science* 53(12), 1843-58

Reliability or Inventory?
Kim, Cohen, Netessine (2008)
Under review

Contracting for Infrequent Restoration and Recovery of Mission-Critical Systems
Kim, Cohen, Netessine, Veeraraghavan (2009)
Under review

Impact of Performance-based Contracting on Product Reliability:
An Empirical Analysis
Gaujardo, Kim, Cohen, Netessine (2010)
## Contract form evolution

<table>
<thead>
<tr>
<th></th>
<th>Small performance incentive</th>
<th>Large performance incentive</th>
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<tbody>
<tr>
<td>Limited cost sharing</td>
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<td>Product maturity</td>
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<tr>
<td>(Fixed Price)</td>
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<tr>
<td>Extensive cost sharing</td>
<td>Product deployment</td>
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<tr>
<td>(Cost Plus)</td>
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</table>

- **Fixed Price**: Limited cost sharing
- **Cost Plus**: Extensive cost sharing

**Cost Plus**
- **Cost uncertainty**
- **Performance uncertainty**

**Fixed Price + PBL**
- **Time**

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*Slide 8*
Which performance measure?

1. Penalize cumulative
   \[ X = \sum_{i=1}^{N} S_i \]  
   Compound Poisson variable (Time average estimator)

2. Penalize average downtime
   \[ X = \begin{cases} 
   0 & \text{if } N = 0 \\
   \frac{1}{N} \sum_{i=1}^{N} S_i & \text{if } N > 0 
   \end{cases} \]  
   Sample mean estimator

Both incentivize the Supplier to invest in capacity
Supplier’s response to level of reliability under each contract

Cumulative-performance contract

\[ X = \sum_{i=1}^{N} S_i \]

Average-performance contract

\[ X = \left( \frac{1}{N} \sum_{i=1}^{N} S_i \right) \mathbb{1}(N > 0) \]

Supplier’s optimal capacity choice exhibits non-monotonicity in \( \lambda \) under the average-performance contract.

No-failure effect:
Little benefit of sampling
Insight #3: Does PBL induce higher reliability?

- Optimal reliability-inventory combination under old (material) contract
- Optimal reliability-inventory combination under performance contract with customer ownership
- Optimal reliability-inventory combination when supply chain is integrated
  \[ R_{\text{Minimum}} = R_{\text{Material}} \]

Supply chain performs best under **PBL with supplier asset ownership**
How can contract type influence product reliability?

- Quality of service by the OEM is based on fleet availability
- Availability is driven two time based metrics
  - Response time
  - Time between removals (planned and unplanned)
- Have performance incentives (payment scheme) led to higher availability & lower cost of ownership and higher supplier/provider profits? (policy debate)
- Decision rights and risk sharing between OEM & customer
- Customer & supplier behavior
  - T&M customers more reluctant to perform pre-emptive maintenance
  - Performance incented suppliers will provide higher quality support

**Main hypothesis: Performance-based contracts have a positive effect on engine reliability**
Data

• Major OEM of subsystems (engines):
  – Repair and maintenance services
• 5 years of data on removals (2002-2007)

• Sample: ~ 300 engine units
The dependent variable: MTBUR

- MTBUR: mean time between unplanned removals

MTBUR = \frac{4000}{2} = 2000 \text{ flying hours}

Greater MTBUR \rightarrow \text{Greater reliability}
Statistics for the MTBUR

- Distribution by contract type:

  → Avg. MTBUR is slightly higher for PBC (3451 vs 2872)

  → More variability in MTBUR for T&M
Statistics for the MTBUR

• Distribution by aircraft model:
Explanatory model for the MTBUR

TWO STAGE MODEL

Explain **Contract choice**
- Fleet size
- Fleet mix
- Owner Avg. time per flight
- Owner region
- Aircraft model

Explain **MTBUR**
- Initial age
- Initial age sq.
- Avg. time per flight
- PB contract
- MTBUR
- Aircraft model
- Owner region
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Cluster (owner) SE in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Robustness

- Alternative specifications
- Alternative MTBUR proxies
- Duration models

Finding robust to several variations

PB contracts have positive impact on product reliability

- No significant effect if we look at mean time between planned removals
Results and conclusions

• Impact of performance-based contracts on engine reliability

• **Two stage model** approach
  – addresses **endogeneity** in contract choice

• **Significant and positive effect of performance-based contracts on reliability**
  – Finding is robust to several variations

• **One of the few empirical studies on supply chain contracting in OM**
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