# EFFICIENT ORGANIZATION OF OUTSOURCING: NESTED VERSUS HORIZONTAL

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# 1. Introduction

Case: The launching of Boeing’s new 787 Dreamliner.

- Chains of outsourcing contracts

Our analysis: A characterization of the efficient outsourcing structure by comparing nested outsourcing with horizontal outsourcing in industries where production relies on component-specific monitoring.

The existing literature on outsourcing has focused on two issues:

(1) The “make-or-buy” decision: In-house production or outsourcing

- *contract-theoretic approaches*: Williamson (1985), Grossman & Hart (1986), Holmström & Roberts (1998)

- *the industrial organization approach*es:

  Grossman & Helpman (2002): equilibrium production mode explained by certain industry-specific features

  Cachon & Harker (2002), Shy & Stenbacka (2003): strategic incentives for outsourcing

(2) Which types and which proportion of components to outsource?

- Shy & Stenbacka (2005)

This analysis: Comparison of nested (vertical) and horizontal outsourcing in a model where both in-house production and outsourcing require component-specific monitoring costs.

## 2. The Model

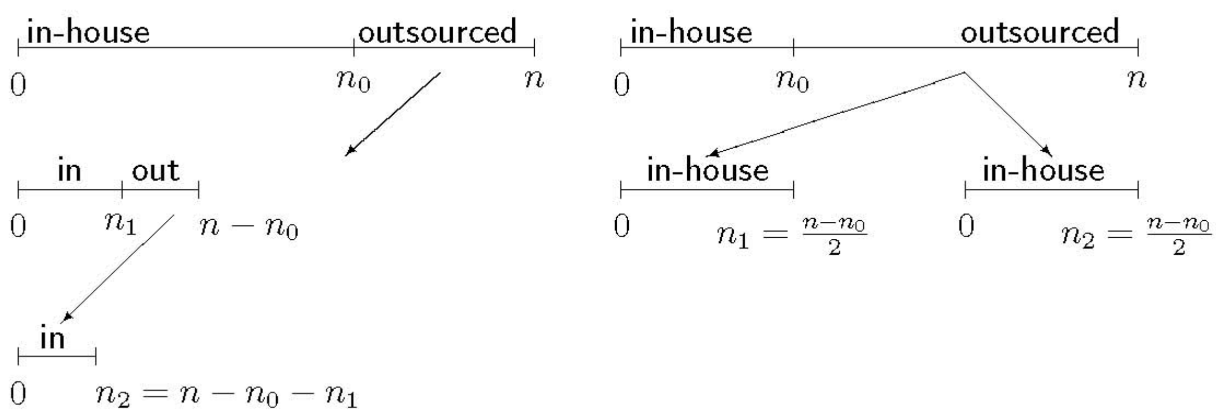


**Figure 1:** *Left*: Nested (vertical) outsourcing ($V$). *Right*: Horizontal outsourcing ($H$).

Each component is produced with marginal cost $\gamma$

Identical subcontractors, each charging the price $p_s$ for each component

Each firm bears a fixed cost $\phi$ as well as monitoring costs of two types: Monitoring of in-house production ($\mu_f$) and monitoring of outsourced production processes ($\mu_s$).

Total cost for firm 0 when it outsources $n - n_0$ components:

$$C_0(n_0) = \begin{cases} \phi + \gamma n_0 + p_s (n - n_0) + \mu_f (n_0)^2 + \mu_s(1)(n - n_0)^2 & \textit{nested} \\ \phi + \gamma n_0 + 2 p_s (\frac{n - n_0}{2}) + \mu_f (n_0)^2 + 2 \mu_s(2) (\frac{n - n_0}{2})^2 & \textit{horizontal} \end{cases}$$

The monitoring costs associated with outsourcing depend on the number of subcontractors with which firm 0 interacts ($\mu_s(1)$, $\mu_s(2)$).

**Definition 1**: We say there are diseconomies [economies] wrt the number of subcontractors if $\mu_s(2) > \mu_s(1)$ [$\mu_s(2) < \mu_s(1)$]. In particular, if $\mu_s(2) > 2\,\mu_s(1)$ we say there are strong diseconomies wrt the number of subcontractors.

Total cost of firm 1:

$$C_1(n_1, n_0) = \begin{cases} \phi + \gamma n_1 + p_s (n - n_0 - n_1) + \mu_f (n_1)^2 + \mu_s(1)(n - n_0 - n_1)^2 & \textit{nested} \\ \phi + \gamma (\frac{n - n_0}{2}) + \mu_f (\frac{n - n_0}{2})^2 & \textit{horizontal} \end{cases}$$

Total cost of firm 2:

$$C_2(n_1, n_0) = \begin{cases} \phi + \gamma\,(n - n_0 - n_1) + \mu_f\,(n - n_0 - n_1)^2 & \textit{nested} \\ \phi + \gamma\,(\dfrac{n - n_0}{2}) + \mu_f\,(\dfrac{n - n_0}{2})^2 & \textit{horizontal} \end{cases}$$

# 3. Nested Outsourcing

## 3.1 **Efficient Nested Outsourcing**

$$\max_{n_0, n_1} \quad p - C_0(n_0) + p_s(n - n_0) - C_1(n_1, n_0) + p_s(n - n_0 - n_1) - C_2(n_1, n_0)$$

Note, all expenditures on outsourcing equal subcontractors' revenues.

Efficient nested outsourcing:

$$n_0^V = \frac{n\left[(\mu_f)^2 + 3\,\mu_f\,\mu_s(1) + (\mu_s(1))^2\right]}{\left[\mu_f + \mu_s(1)\right]\left[3\mu_f + \mu_s(1)\right]}$$

$$n_1^V = \frac{n\,\mu_f}{\left[3\mu_f + \mu_s(1)\right]}$$

$$n_2^V = \frac{n\,(\mu_f)^2}{\left[\mu_f + \mu_s(1)\right]\left[3\mu_f + \mu_s(1)\right]}$$

Comparison of the efficient number of components produced by each firm

$$n_0^V - n_1^V \quad = \quad \frac{n\,\mu_s(1)\left[2\,\mu_f + \mu_s(1)\right]}{\left[\mu_f + \mu_s(1)\right]\left[3\mu_f + \mu_s(1)\right]} \quad \geq \quad 0$$

$$n_1^V - n_2^V \quad = \quad \frac{n\,\mu_f\,\mu_s(1)}{\left[\mu_f + \mu_s(1)\right]\left[3\mu_f + \mu_s(1)\right]} \quad \geq \quad 0$$

**Result 1** Under nested outsourcing, firms that are higher on the outsourcing ladder produce a larger number of components than firms that are lower on the outsourcing ladder.

### 3.2 **Profit-Maximizing Nested Outsourcing**

$$\max_{n_0} \qquad p - C_0(n_0)$$

The optimal number of components produced in-house

$$n_0 \quad = \quad \frac{2\,n\,\mu_s(1) + p_s - \gamma}{2\left[\mu_f + \mu_s(1)\right]}$$

## 4. Horizontal Outsourcing

Firm 0 produces $n_0$ components in-house, and divides the remaining $n - n_0$ production activities among the subcontractors (1 and 2).

### 4.1 **Efficient Horizontal Outsourcing**

$$\max_{n_0} \quad p - \left[ \phi + \gamma n_0 + 2\, p_s (\frac{n-n_0}{2}) + \mu_f\,(n_0)^2 + 2\,\mu_s(2)\,(\frac{n-n_0}{2})^2 \right]$$
$$+ \quad 2 \left\{ p_s \frac{n-n_0}{2} - \left[ \phi + \gamma (\frac{n-n_0}{2}) + \mu_f\,(\frac{n-n_0}{2})^2 \right] \right\}$$

Efficient horizontal outsourcing:

$$n_0^H \quad = \quad \frac{n\left\lfloor \mu_f + \mu_s(2) \right\rfloor}{\left[ 3\mu_f + \mu_s(2) \right]}$$

$$n_1^H \quad = \quad n_2^H \quad = \quad \frac{n\,\mu_f}{\left[ 3\mu_f + \mu_s(2) \right]}$$

**Result 2** Under horizontal outsourcing, efficient allocation of component production requires that firm 0 outsources more than 50 % of the components iff $\mu_f > \mu_s(2)$.

### 4.2 **Profit-Maximizing Horizontal Outsourcing**

$$\max_{n_0} \quad p - \left[ \phi + \gamma n_0 + 2\, p_s \left(\frac{n-n_0}{2}\right) + \mu_f\, (n_0)^2 + 2\, \mu_s(2)\, \left(\frac{n-n_0}{2}\right)^2 \right]$$

The optimal number of components produced in-house

$$n_0 \quad = \quad \frac{n\, \mu_s(2) + p_s - \gamma}{2\, \mu_f + \mu_s(2)}$$

## 5. Comparisons of Outsourcing Patterns

### 5.1 A Comparison of Efficient Allocations

$$n_0^V - n_0^H \quad = \quad \frac{n\, \mu_f \left\lfloor \mu_f\, (5\mu_s(1) - 2\mu_s(2)) + \mu_s(1)\, (2\mu_s(1) - \mu_s(2)) \right\rfloor}{\left[\mu_f + \mu_s(1)\right]\left[3\mu_f + \mu_s(1)\right]\left[\left[3\mu_f + \mu_s(2)\right]\right]} \quad > \quad 0$$

iff

$$\mu_s(2) \quad < \quad \overline{\mu_2}(2) \quad = \quad \frac{\mu_s(1)\, (5\, \mu_f + 2\mu_s(1))}{2\mu_f + \mu_s(1)}$$

**Result 3** It is efficient to outsource a smaller fraction of production lines under nested outsourcing compared with horizontal outsourcing if and only if $\mu_s(2) \quad < \quad \overline{\mu_2}(2)$.

**Result 4** Nested outsourcing is inefficient relative to horizontal outsourcing if and only if $\mu_s(2) \quad < \quad \overline{\mu_2}(2)$.

Intuition: Nested outsourcing implies duplication of monitoring costs and this effect is dominant as long as there are not sufficiently significant diseconomies wrt the number of subcontractors

| Parameters | $n_0$ | $n_1$ | $n_2$ | $\pi_0 + \pi_1 + \pi_2$ |
|---|---|---|---|---|
| | | Nested Vertical Outsourcing | | |
| $\mu_f = \mu_s = \mu$ | $5n/8$ | $n/4$ | $n/8$ | $p - 3\phi - \gamma n - 5n^2\mu/8$ |
| $\mu_s = 0$ | $n/3$ | $n/3$ | $n/3$ | $p - 3\phi - \gamma n - n^2\mu_f/3$ |
| $\mu_f = 0$ | $n$ | $0$ | $0$ | $p - 3\phi - \gamma n$ |
| | | Horizontal Outsourcing | | |
| $\mu_f = \mu_s = \mu$ | $n/2$ | $n/4$ | $n/4$ | $p - 3\phi - \gamma n - n^2\mu/2$ |
| $\mu_s = 0$ | $n/3$ | $n/3$ | $n/3$ | $p - 3\phi - \gamma n - n^2\mu_f/3$ |
| $\mu_f = 0$ | $n$ | $0$ | $0$ | $p - 3\phi - \gamma n$ |

**Table 1:** A comparison of efficient nested and horizontal outsourcing under $\mu_s(2) = \mu_s(1)$.

## 5.2 The Profit-Maximizing Mode of Outsourcing

$$\pi_0^V - \pi_0^H \quad = \quad \frac{[\mu_s(2) - 2\,\mu_s(1))\,](\,2n\mu_f - p_s + \gamma\,)^2}{4[\mu_f + \mu_s(1)]\,[[2\mu_f + \mu_s(2)]]}$$

**Result 5** Nested outsourcing is more profitable to firm 0 than horizontal outsourcing if there are strong diseconomies wrt the number of subcontractors ($\mu_s(2) > 2\mu_s(1)$).

### 5.3 Profit-Maximization and Efficiency

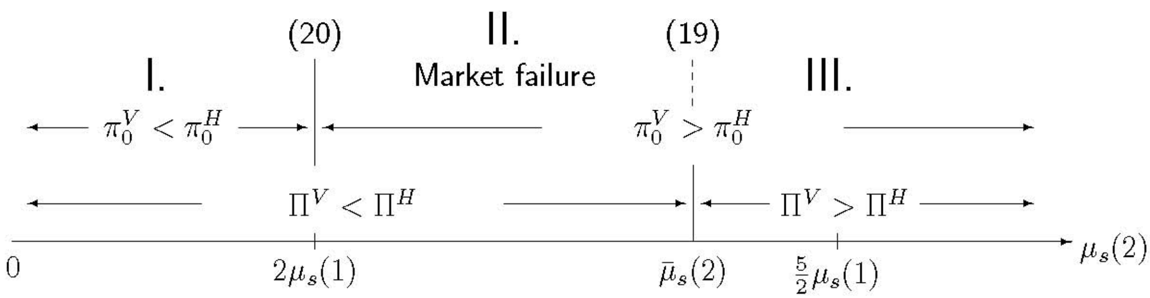


**Figure 2:** Profit maximization and efficiency.

**Result 6** If $2\mu_s(1) < \mu_s(2) < \overline{\mu}_s(2)$ there is a market failure in which nested outsourcing is the market outcome whereas horizontal outsourcing is the efficient outcome.

Intuition: With nested outsourcing the duplication of monitoring costs is not internalized by firm 0. However, when $\mu_s(2)$ grows sufficiently horizontal outsourcing becomes so costly to firm 0 so as to induce the efficient mode of outsourcing.

## 6. Endogenous Prices of Outsourced Components

So far: exogenous component prices

Endogenously determined component prices these would typically differ between horizontal and nested outsourcing

Here: Analysis focusing on the competitive market-clearing price of outsourced components

- large number of symmetric and standardized components
- all subcontractors have the capability of producing any component

Which component price would clear the market for outsourced components?

## 6.1 Nested Outsourcing

The market clearing condition $n_0^V + n_1^V + n_2^V = n$ yields the competitive price equilibrium

$$p_S^V = \gamma + \frac{2n(\mu_f)^3}{3(\mu_f)^2 + 3\mu_f\ \mu_s(1) + (\mu_s(1))^2}$$

The equilibrium number of components

$$n_0^V = \frac{n\left\lfloor(\mu_f)^2 + 2\mu_f\ \mu_s(1) + (\mu_s(1))^2\right\rfloor}{3(\mu_f)^2 + 3\mu_f\ \mu_s(1) + (\mu_s(1))^2}$$

$$n_1^V = \frac{n\ \mu_f\left\lfloor\mu_f + \mu_s(1)\right\rfloor}{3(\mu_f)^2 + 3\mu_f\ \mu_s(1) + (\mu_s(1))^2}$$

$$n_2^V = \frac{n\ (\mu_f)^2}{3(\mu_f)^2 + 3\mu_f\ \mu_s(1) + (\mu_s(1))^2}$$

## 6.2 Horizontal Outsourcing

The competitive price equilibrium

$$p_S^H = \gamma + \frac{2n(\mu_f)^2}{3\mu_f + \mu_s(2)}$$

The equilibrium number of components

$$n_0^H = \frac{n\left[\mu_f + \mu_s(2)\right]}{3\mu_f + \mu_s(2)}$$

$$n_1^H = n_2^H = \frac{n\,\mu_f}{3\mu_f + \mu_s(2)}$$

**6.3 Comparing Component Prices: Nested Versus Horizontal**

$$p_S^H - p_S^V = \frac{2n(\mu_f)^2\left[(\mu_s(1))^2 + \mu_f\,(3\mu_s(1) - \mu_s(2))\right]}{\left[3\mu_f + \mu_s(2)\right]\left[3(\mu_f)^2 + 3\mu_f\,\mu_s(1) + (\mu_s(1))^2\right]}$$

The competitive component price under horizontal outsourcing exceeds (falls short of) that associated with nested outsourcing iff

$$\mu_s(2) \quad < \quad (>) \quad 3\mu_s(1) \quad + \quad \frac{(\mu_s(1))^2}{\mu_f}.$$

**Result 7 (a)** The competitive component price under horizontal outsourcing exceeds that associated with nested outsourcing unless there are sufficiently strong diseconomies wrt the number of subcontractors.

**(b)** Firm 0 outsources a higher proportion of the components under horizontal outsourcing than under nested outsourcing unless the diseconomies wrt the number of exceeds the threshold defined by

$$\mu_s(2) \quad = \quad \left( \frac{2\,\mu_s(1) + 3\,\mu_f}{\mu_s(1) + 2\,\mu_f} \right) \mu_s(1)\ .$$

With competitive component prices firm 0 outsources a higher proportion of components under horizontal outsourcing if $\mu_s(2) \quad < \quad \left( \frac{2\,\mu_s(1) + 3\,\mu_f}{\mu_s(1) + 2\,\mu_f} \right) \mu_s(1)$. Under these circumstances horizontal outsourcing is also more efficient than nested outsourcing.

If $\left( \frac{2\,\mu_s(1) + 3\,\mu_f}{\mu_s(1) + 2\,\mu_f} \right) \mu_s(1) \quad < \quad \mu_s(2) \quad < \quad 2\mu_s(1)$ firm 0 outsources a higher proportion under nested outsourcing even though horizontal outsourcing would be socially efficient.

## 7. Concluding Comments

Nested outsourcing was generally found to be inefficient unless the cost of monitoring outsourced production lines increases sharply with the number of subcontractors (and not only with the number of outsourced components).

There is a market failure for an intermediate range of monitoring costs associated with outsourcing to multiple subcontractors.

The competitive component price under horizontal outsourcing exceeds that associated with nested outsourcing unless there are sufficiently strong diseconomies wrt the number of subcontractors.