Quality Uncertainty in Vertical Relations: Mutual Dependency Mitigates Inefficiencies

Pio Baake Vanessa von Schlippenbach

DIW Berlin

Quality Uncertainty in Vertical Relations

- Increase of product recalls due to product failures involving safety or health risks for consumers
  - In the U.S. food and toys industry number of recalls almost doubled
  - In the German automotive industry even tripled
- Product failures can be caused at various stages of the value chain
- However, manufacturing defaults have gained in importance
  - DaimlerChrysler recalled 1.3 million cars for checking battery control unit software + voltage regulator in the alternator (2005)
  - Mattel recalled 18 million toys because of small dislodgeable magnets as well as toxic lead paint (2007)
  - Arla and Nestle recalled their products worldwide because of the Chinese melamine scandale (2008)
  - Irish Republic recalled domestically-produced meat because of dioxin contaminated feed (2008)
- Problem: Consumers tend to attribute quality defects mainly to brands or retailers.

Main Objective & Result

Objective:
Examining the impact of quality uncertainty and potential reputation losses in the downstream market on the bargaining relation between suppliers and buyers

Result:
Efficient delivery contracts in intermediate goods markets as well as efficient quality decisions are more likely the higher the mutual dependency in vertical relations

Related Literature

Buyer Power

- Wide literature on sources of buyer power (i.e. Katz 1987, Inderst-Shaffer 2007, Snyder 1996)
- Some papers related to efficiency effects of buyer power:
  - Inderst-Wey (2003, 2007): increase of upstream investment incentives
  - Montez (2008): downstream merger $\rightarrow$ higher capacity choice upstream
  - Inderst-Shaffer (2007): retail merger reduces upstream variety
  - Battigalli et al. (2007): buyer power weakens supplier's incentives to invest in quality
- Our contribution: Mutual dependency enhances efficiency of a vertical structure

Umbrella Branding

- Literature is mainly related to downstream markets (i.e. Choi 1998, Andersson 2002, Cabral 2008)
- Our contribution: Umbrella branding can enhance efficiency of vertical relations

The Model

Structure & Timing

Structure:

- Repeated game with imperfect information
- Downstream firm D offers two goods x and y (complements)
- Upstream firm U offers good x (y is offered competitively)
- Quality of good x is stochastically determined in each period

Timing

1. D decides on target quality $\overline{\theta}$ for good x
2. D and U negotiate a menu of two-part tariff delivery contracts
3. U can invest in order to increase the probability of reaching $\overline{\theta}$
4. U observes the actual quality θ and announces a quality $\widehat{\theta}$
5. D sets the consumer prices conditional on $\widehat{\theta}$
   (and selects the respective delivery contract)

Assumptions

- **Demand:**

$$\begin{aligned} X(p,q,\theta) \text{ with } X_p, X_{pp} &< 0 < X_\theta \text{ and } X_q < 0 \\ Y(q,p,\theta) \text{ with } Y_q, Y_{qq} &< 0 < Y_\theta \text{ and } Y_p < 0. \end{aligned}$$

- **Quality:**

$$\theta \in \{\underline{\theta}, \overline{\theta}\} \ \textit{with} \ \underline{\theta} < \overline{\theta}$$

$$\theta = \begin{cases} \overline{\theta} \text{ with probability } \rho(e,\overline{\theta}) \\ \underline{\theta} \text{ with probability } 1-\rho(e,\overline{\theta}) \end{cases}$$

- **Probability:**

$$\rho(e,\overline{\theta}) : \rho_{\overline{\theta}} < 0 < \rho_e \text{ and } \rho_{e\overline{\theta}} < 0$$

- **Effort costs:**

$$c(e) : c', c'' > 0$$

Assumptions (cont'd)

- **Negotiated Delivery Tariffs:**

$$T(w, F, \widehat{\theta}) = \begin{cases} (\overline{w}, \overline{F}) \text{ if } \widehat{\theta} = \overline{\theta} \\ (\underline{w}, \underline{F}) \text{ if } \widehat{\theta} = \underline{\theta} \end{cases} .$$

- **Focus on tariffs such that firm U will announce truthfully:**

$$\widehat{\theta}(\theta, T(\cdot)) = \theta$$

Expected Profits per Period

Upstream firm:

$$\begin{aligned} E\pi^U &= \rho(e,\overline{\theta})\overline{\pi}^U + (1-\rho(e,\overline{\theta}))\underline{\pi}^U - c(e) \\ \text{with} &: \overline{\pi}^U = \overline{w}\overline{X} + \overline{F} \text{ and } \overline{X} := X(p,q,\overline{\theta}) \\ \text{with} &: \underline{\pi}^U = \underline{wX} + \underline{F} \text{ and } \underline{X} := X(p,q,\underline{\theta}). \end{aligned}$$

Downstream firm:

$$\begin{aligned} E\pi^D &= \rho(e,\overline{\theta})\overline{\pi}^D + (1-\rho(e,\overline{\theta}))\underline{\pi}^D \\ \text{with} &: \overline{\pi}^D = (p-\overline{w})\overline{X} + q\overline{Y} - \overline{F} \text{ and } \overline{Y} := Y(p,q,\overline{\theta}) \\ \text{with} &: \underline{\pi}^D = (p-\underline{w})\underline{X} + q\underline{Y} - \underline{F} \text{ and } \underline{Y} := Y(p,q,\underline{\theta}). \end{aligned}$$

Solving the Model

Prices

Downstream firm's profit π^D :

$$\begin{aligned} \pi^D(\cdot) &= (p-w)X(\cdot,\theta) + qY(\cdot,\theta) - F \\ &\rightarrow (p,q) = \arg\max \pi^D(\cdot) \end{aligned}$$

Announcement

Truthful announcement by firm U as long as

$$IC_1 \quad : \quad \underline{\pi}^U + \frac{1}{\delta}\overline{E\pi^U} \geq \overline{w}X(\overline{p}, \overline{q}, \underline{\theta}) + \overline{F} + \frac{1}{\delta}\Gamma^U$$

$$IC_2 \quad : \quad \overline{\pi}^U + \frac{1}{\delta}\overline{E\pi^U} \geq \underline{w}X(\underline{p}, \underline{q}, \overline{\theta}) + \underline{F} + \frac{1}{\delta}\Gamma^U.$$

$$\begin{aligned} \delta \quad &: \quad = \text{Interest rate} \\ \overline{E\pi^U} \quad &: \quad = \text{Firm } U'\text{s continuation profits} \\ \Gamma^U \quad &: \quad = \text{Outside option of firm } U \end{aligned}$$

Investment

- **Firm U's optimal effort $e^*(\cdot)$ is implicitly given by**

$$\begin{aligned} E\pi^U &= \rho(e,\overline{\theta})\overline{\pi}^U + (1-\rho(e,\overline{\theta}))\underline{\pi}^U - c(e) \\ e^*(\cdot) &: \rho_e = \frac{c'(e)}{\Delta\pi^U} \text{ with } \Delta\pi^U := \overline{\pi}^U - \underline{\pi}^U. \end{aligned}$$

- **Effort increases in $\overline{w}$.**

Delivery Tariffs

- **Bargaining over delivery tariffs: Nash-Product in each period**

$$N = \left[E\pi^D(\cdot) - \Gamma^D + \frac{1}{\delta}\left(\overline{E\pi^D} - \Gamma^D\right)\right]\left[E\pi^U(\cdot) - \Gamma^U + \frac{1}{\delta}\left(\overline{E\pi^U} - \Gamma^U\right)\right]$$

$$\begin{aligned} E\pi^D &: = \rho(\cdot)\overline{\pi}^D + (1-\rho(\cdot))\underline{\pi}^D \\ \Gamma^D &: = \widetilde{q}\,Y(\widetilde{q},\infty,\cdot) \text{ with } \widetilde{q} := \arg\max qY(q,\infty,\cdot) \\ \Gamma^U &: = \text{Outside option of firm } U \end{aligned}$$

- **Note: We consider profits over all periods.**

Unconstrained Solution

- **Delivery tariffs:**

$$\begin{aligned} \underline{w}^* &= \overline{w}^* = 0 \\ \overline{F}^* - \underline{F}^* &= \overline{p}\overline{X} + \overline{q}\overline{Y} - (\underline{p}\underline{X} + \underline{q}\underline{Y}) \\ \text{Implying:} \quad & \overline{\pi}^D - \underline{\pi}^D = 0 \end{aligned}$$

- **Thus, risk is fully borne by upstream firm such that effort decision is efficient.**

Unconstrained Solution (cont'd)

- **Optimal target quality $\overline{\theta}^*$ implictly given by**

$$\rho\left[\overline{p}\overline{X}_{\overline{\theta}} + \overline{q}\overline{Y}_{\overline{\theta}}\right] + \rho_{\overline{\theta}}\left[\overline{p}\overline{X} + \overline{q}\overline{Y} - \left(\underline{p}\underline{X} + \underline{q}\underline{Y}\right)\right] = 0$$

Proposition

If the incentive constraints are not binding, the bargaining outcome is efficient.

Constrained Solution

- **Binding constraint**

$$IC_1 \quad : \quad \underline{\pi}^U + \frac{1}{\delta}\overline{E\pi^U} \geq \overline{w}X(\overline{p}, \overline{q}, \underline{\theta}) + \overline{F} + \frac{1}{\delta}\Gamma^U$$

$$\text{Implying} \quad : \quad \overline{F} = \underline{\pi}^U - \overline{w}X(\overline{p}, \overline{q}, \underline{\theta}) + \frac{1}{\delta}\left(\overline{E\pi^U} - \Gamma^U\right)$$

- **Fixed Fees**
  - Used to ensure truthful announcement and to allocate joint surplus
  - Allocation of risk and thus effort decision inefficient
- **Wholesale Prices**
  - $\underline{w}^* = 0$, $\overline{w}^* > 0$
  - Note: higher $\overline{w}$ implies higher effort
- **Target Quality**
  - Optimal target quality $\overline{\theta}^*$ distorted (either too high or too low)
  - $\overline{\theta}^*$ is more likely to be inefficiently low (high), the lower (higher) $\overline{w}$

Constrained Solution (cont'd)

Corollary:

Mutual dependencies in terms of low outside options may help to mitigate high wholesale and retail prices and may lead to more efficient quality decisions.

- Γ^U = inverse measure of buyer power
- Thus, buyer power may not only cause lower wholesale and retail prices it may also lead to more efficient quality decisions.
- Low values of Γ^D can result from high complementarities or the use of umbrella-branding.
- Hence, as long as umbrella-branding increases the interdependency between the products offered by the downstream firm it can also induce lower wholesale prices.

Example

Assumptions

- **Dixit uitility function:**

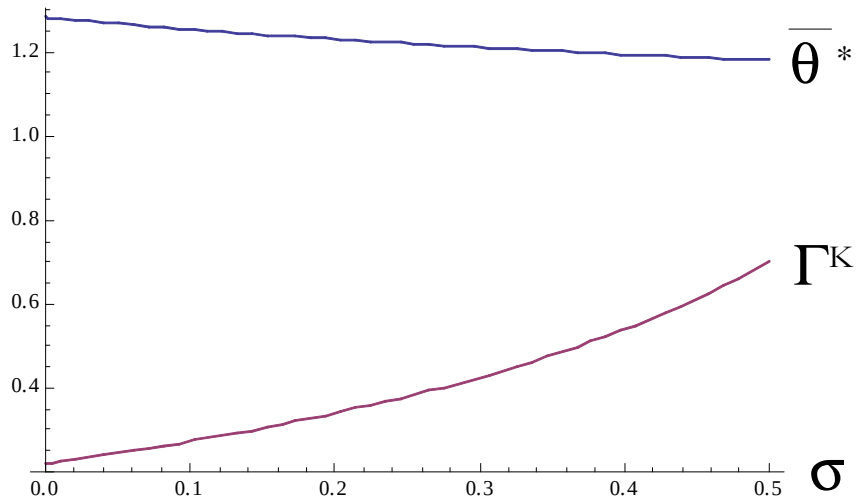
$$U(x, y, \theta) = (1 + \frac{1}{4}\sqrt{\theta})x + y - \frac{1}{2}(x^2 + y^2 - 2\sigma xy) - px - qy,$$

- **Probability and effort costs:**

$$\begin{aligned} \rho(e, \theta) &= \min\left\{\frac{e}{1+\theta}, 1\right\} \\ c(e) &= \frac{e^2}{2} \\ \delta &= 0.1 \end{aligned}$$

Unconstrained Solution

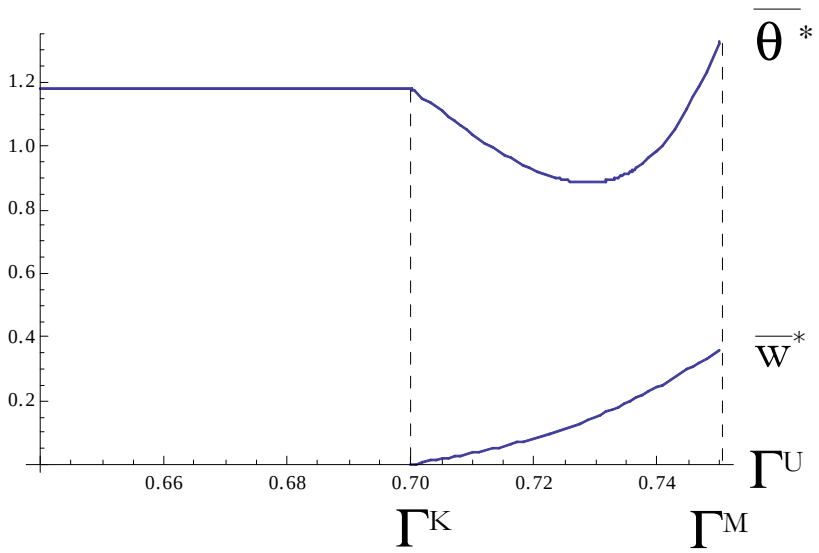
- $\overline{\theta}^*$ decreases in σ
  - Trade off from higher $\overline{\theta}^*$: Marginal revenue from θ increases in σ, while U's effort level is decreasing in $\overline{\theta}$ if $\overline{w} = 0$.
- IC_2 is binding for all $\Gamma^U > \Gamma^K(\sigma)$
  - $\Gamma^{K\prime}(\sigma) > 0$ since joint profits are increasing in σ



Optimal target quality and critical outside option of firm U

Constrained Solution

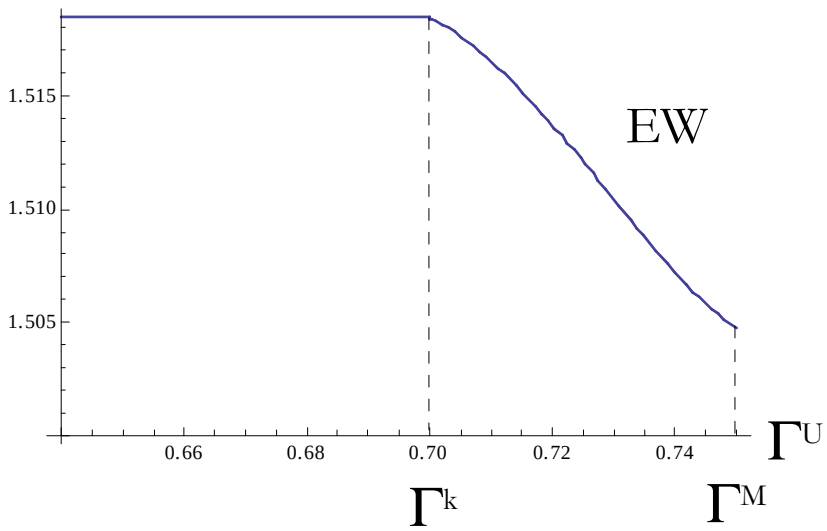
- Γ^U unambiguously increases the optimal wholesale price $\overline{w}^*$
- $\overline{\theta}^*$ is not monotone in Γ^U
  - First decrease of $\overline{\theta}^*$ in order to avoid inefficient low effort, then increase because of higher $\overline{w}^*$ and thus higher effort investment with high $\overline{\theta}$.



Optimal target quality for $\sigma = 0.5$

Welfare

- Both relatively low and high target qualities combined with positive $\overline{w}^*$ reduce expected welfare.



Expected Welfare in Γ for $\sigma = 0.5$

Conclusion

Conclusion

- **Analysis of a simple vertical structure:**
  - Good's quality is stochastically determined and private information of U
  - Delivery contracts negotiated and contingent on actual quality

- **Results:**
  - Delivery conditions as well as target quality are distorted when U's incentives to deviate from truthful announcement are high enough.
  - Mutual dependency increases efficiency of the vertical structure.
  - Thus, buyer power leads to lower wholesale prices and more efficient quality decisions.
  - Furthermore: Relation specific investments upstream as well as umbrella branding at the downstream level may enhance the efficiency of the vertical chain.
  - Finally, outsourcing more attractive the more both firms depend on their interaction.