Quality Uncertainty in Vertical Relations: Mutual Dependency Mitigates Inefficiencies*

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Abstract

We consider an infinitely repeated game where an upstream firm sells one good to a downstream firm. While the downstream firm can specify a target quality to be delivered by the upstream firm, the upstream firm has private information about the actual quality of her product. Analyzing delivery contracts that are contingent on quality announcements made by the upstream firm, we show that delivery contracts are more efficient the higher the mutual dependency between both firms. The same results holds with respect to the target quality chosen by the downstream firm.

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1 Introduction

The number of product recalls due to product failures that involve substantial safety or health risks has drastically increased over the recent years. By now, the U.S. food industry as well as the U.S. toys industry recall twice as much products per year as they did one decade ago.[1] The annual number of recalls in the German automotive industry has almost tripled between 1998 and 2007.[2] Product failures can be caused at various stages of the value chain: Improper shipping, handling or storing can lead to quality losses that may harm consumers in the same way as defaults when developing or manufacturing the product. Among the different sources of product failures manufacturing defaults have gained in importance vis-à-vis flaws made in designing or developing the product.[3] For example, DaimlerChrysler recalled about 1.3 million cars in order to check the battery control unit software for the electrical and braking systems as well as the voltage regulator in the alternator in 2005.[4] Two years later, Mattel recalled about 18 million toys that were produced in China because of small dislodgeable magnets as well as toxic lead paint.[5] More recently, the Chinese Melamine-scandale forced manufacturers such as Arla, Nestle and Cadbury to recall their products in a worldwide action.[6] Finally in December 2008, the Irish Republic ordered to recall domestically-produced pork products because pigs may have eaten feed contaminated with cancer-causing dioxin.[7] Despite the increasing importance of defaults at the input level consumers tend to attribute quality defects mainly to the labels of final products or to the retailers who sold the faulty products. The latter is especially true in the case of non-branded vegetables, fruits or meat where retailers are thought to be responsible for controlling the quality of the products they offer.

[1] According to the U.S. Food Safety and Inspection Service (FSIS), the number of recalls in the U.S. food industry has increased from 27 in 1997 to 58 in 2007 (see www.fsis.usda.gov). Likewise the recalls in the toy industry raised from 23 in 2001 to 40 in 2007 (see Bapuji and Beamish, 2007).

[2] A strong increase of recalls is likewise documented for the German automotive industry: In 1998 automobile manufacturers run 55 recalls, the number of recalls increased up to 157 in 2007 (see Annual Report of the Kraftfahrtsbundesamt www.kba.de).

[3] See Bapuji and Beamish (2007).

[4] http://www.dw-world.de/dw/article/0,,1543346,00.html

[5] In particular, the recall of Mattel induced questions about the safety of products that were manufactured in China. However, Beamish and Bapuji (2008) find that most of the recalls were due to design flaws, although the importance of manufacturing flaws has increased over the last years.

[6] http://www.food-business-review.com/article_news.asp?guid=BFA77A40-A4E9-4674-AA62-3A65EAE69EDD

[7] http://news.bbc.co.uk/1/hi/world/europe/7769391.stm

Against this background we examine how quality uncertainty and potential reputation losses can affect the relationship between an upstream and a downstream firm. We analyze an infinitely repeated game where the upstream firm can invest in order to meet the quality requirements of the downstream firm. Assuming that the upstream firm has private information about the product's quality, we focus on delivery contracts that are contingent on the quality the upstream firm may announce. Both firms negotiate about delivery contracts after the downstream firm has chosen her quality requirements but before the upstream firm decides on her investment. This set up allows us to analyze the impact asymmetric information as well as potential reputation effects have on the efficiency of delivery contracts and the quality set by the downstream firm. We show that both the delivery conditions as well as the quality are distorted when the upstream firm's incentives to deviate from truthful announcement are high enough. Wholesale prices tend to be higher then marginal production cost, while the target quality chosen by the downstream firm can be either inefficiently low or high. An inefficiently low quality is more likely the less distorted the wholesale prices are. However, inefficiently high qualities correspond to severe distortions of wholesale prices. These results are due to the fact that distortions of wholesale prices and qualities do not only serve to satisfy the upstream firm's incentive constraints. They are also used to minimize the expected losses from potential underinvestment at the upstream level. Specifically, an increase in the target quality enhances the upstream firm's incentives to invest when wholesale prices are rather high. Therefore, the quality chosen by the downstream firm tends to become inefficiently high if wholesale prices are increasing.

Our findings indicate that efficient delivery contracts and efficient quality decisions are more likely the higher the mutual dependency in vertical relations. Higher gains from trade imply that the upstream firm has stronger incentives to rely on truthful announcements. This leads to more efficient qualities and delivery contracts. Since mutual dependency refers to the difference between the firms' joint profits and their respective outside options, the same reasoning applies if the firms' outside options are considered separately. When the outside option of either the upstream or the downstream firm is decreasing, the overall gains from trade become higher resulting in more efficient qualities and delivery contracts. Interpreting the upstream firm's outside option as an inverse measure for the downstream firm's buyer power we can also state that an increase in buyer power may well lead to more efficient vertical relations. Similarly, the more the downstream firm depends on the product delivered by the upstream firm or the higher the reputation loss she incurs if the upstream firm deviates from truthful announcement, the more likely the downstream firm will opt for efficient qualities. For example, umbrella branding that is often used by multi-product firms in order to transfer reputation from one product to another can reduce efficiency losses in the case of asymmetric information. That is, umbrella branding may induce more efficient qualities and delivery contracts as it allows for higher profits and thus implies a (relative) decrease in the downstream firm's outside option.

Our paper contributes to the wide literature on buyer power which analyzes the sources of buyer power and its impact on the overall efficiency of vertical relations.[8] Considering the sources of buyer power, credible threats to vertically integrate or to support market entry at the upstream level are analyzed by Katz (1987) and Sheffman and Spiller (1992). Inderst and Shaffer (2007) focus on potential delisting strategies after downstream mergers, while Snyder (1996) shows that large buyers can destabilize collusion at the upstream level. The impact of capacity constraints at the supplier side as well as of increasing marginal costs is considered by Inderst and Wey (2007) and Chipty and Snyder (1999). More closely related to our paper are those articles tackling the efficiency effects of buyer power. Inderst and Wey (2003, 2007) point out that the formation of large buyers and thus the emergence of buyer power may increase consumer surplus as well as overall welfare as suppliers' investment incentives increase. Montez (2008) shows that an upstream firm may choose higher capacities when buyers merge as long as the cost of capacity are sufficiently low. Negative welfare effects due to increased buyer power are analyzed by Inderst and Shaffer (2007). They show that a retail merger can induce the manufacturers to reduce the variety of their products in order to comply with "average" preferences (see also Chen (2004)). Battigalli et al. (2007) find that buyer power weakens a supplier's incentive to invest in quality improvement. While this result is based on the observation that buyer power tends to decrease the supplier's marginal profits from investing in higher qualities, our results point to a contrary effect. Focusing on a repeated game and asymmetric information we show that efficient quality decisions are more likely the lower the upstream firm's outside option and thus the higher the downstream firm's buyer power.

The literature on umbrella branding mainly focuses on the relation between firms and con-

[8] For a survey on the sources and consequences of buyer power see Inderst and Mazarotto (2008) as well as Inderst and Shaffer (2008).

sumers. Choi (1998) uses an adverse selection model and argues that umbrella branding allows to transfer reputation from one market to another such that high qualities can be signalled with rather low price distortions. Similarly, analyzing a dynamic model Wernerfeldt (1988) shows that firms can stretch their brands over several periods in order to signal high qualities of new products (see also Cabral, 2000). Andersson (2002) considers an infinitely repeated game with moral hazard and shows that umbrella branding tend to lower the costs for credible certification. Focussing on implicit contracts between firms and consumers, Cabral (2008) finds that umbrella branding leads to higher qualities. Considering a vertical structure we argue that umbrella branding can enhance the efficiency of vertical relations as long as it affects the relation between the downstream firm's profit and her outside option positively.

The remainder of the paper is organized as follows: In Section 2 we specify our model. Section 3 concentrates on the downstream firm's pricing decisions as well as the upstream firm's incentives to invest and to announce the quality of her product truthfully. In Section 4, we analyze the bargaining process in the intermediate good market and consider the quality choice of the downstream firm. We then provide an example in order to illustrate our findings. Finally, we conclude and discuss our results.

2 The Model

Considering a simple vertical structure with one upstream and one downstream firm, we examine the impact of quality uncertainty and asymmetric information on the overall performance of vertical relations. We analyze an infinitely repeated game where the upstream firm U sells a product x to the downstream firm D who distributes the good together with a complementary good y to final consumers. Production costs at the upstream level as well as distribution and transformation costs at the downstream level are normalized to zero. For simplicity we limit our analysis to the relation between U and D by assuming that good y is offered competitively. In each period firm D first determines a target quality $\overline{\theta}$ to be delivered by firm U. Then, both firms negotiate a menu of delivery contracts. Using the revelation principle we focus on contracts that are contingent on the quality $\widehat{\theta}$ which the upstream firm may announce after having observed the actual quality of her product. More specifically, given the target quality $\overline{\theta}$ and the menu of delivery contracts, firm U decides how much effort to spend in order to increase the probability of reaching $\overline{\theta}$. Firm U then observes the realized quality and decides which quality $\widehat{\theta}$ to announce. Finally, the downstream firm D sets the prices for the two products and demand as well as profits realize.

Demand. We assume good x to be an experience good whose quality is immediately learned by consumers. Since the goods x and y are supposed to be complements, a low quality of good x reduces the demand for good x as well as the demand for good y. Goods x and y constitute perfect complements when they are substantial inputs for the downstream firm's production. Alternatively, good x may be part of a larger downstream firm's assortment where y denotes the bundle of other goods sold by downstream firm. If consumers' expectations about the qualities of all goods sold by the downstream firm are positively correlated, a low quality of good x may also decrease the demand for the other goods. We denote the demand for good x by $X(p,q,\theta)$ with $X_p, X_{pp} < 0 < X_\theta$ and $X_q < 0$ where p and q refer to the prices for product x and y respectively. Correspondingly, the demand for good Y is given by $Y(q,p,\theta)$ with $Y_q, Y_{qq} < 0 < Y_\theta$ and $Y_p < 0$.

Quality. In each period the quality of good x is stochastically determined. For simplicity we assume that there are only two realization of θ, i.e. $\theta \in \{\underline{\theta}, \overline{\theta}\}$ with $\underline{\theta} < \overline{\theta}$. Furthermore, while the probability of $\overline{\theta}$ is decreasing in $\overline{\theta}$, it is increasing in the effort e firm U may spend to monitor production or to install quality assurance systems. Denoting $\rho(e,\overline{\theta})$ as the probability of getting $\overline{\theta}$, we have

$$\theta = \begin{cases} \overline{\theta} \text{ with } \rho(e,\overline{\theta}) \\ \underline{\theta} \text{ with } 1-\rho(e,\overline{\theta}) \end{cases} \quad \text{with: } \rho_\theta < 0 < \rho_e \text{ and } \rho_{e\overline{\theta}} < 0. \tag{1}$$

After exerting effort, the upstream firm privately learns the realization of θ and decides whether or not to announce it truthfully. Additionally, we assume that effort induces increasing and convex costs of $c(e)$ per period with $c', c'' > 0$.

Tariffs. Delivery contracts are negotiated before firm U decides how much effort to spend and before she observes the realization of θ. Since the realization of θ is private information of firm U, delivery contracts are assumed to be contingent on the quality $\widehat{\theta}$ which firm U may announce after having observed the actual quality. We restrict the analysis to a menu of two-part tariffs $T(w,F)$ with wholesale prices w and fixed fees F, i.e.

$$T(w,F,\widehat{\theta}) = \begin{cases} (\overline{w},\overline{F}) \text{ if } \widehat{\theta} = \overline{\theta} \\ (\underline{w},\underline{F}) \text{ if } \widehat{\theta} = \underline{\theta} \end{cases}. \tag{2}$$

Employing $T(w,F,\widehat{\theta})$ and assuming truthful announcement, the expected per period profit of the upstream $E\pi^U$ firm is given by

$$\begin{aligned} E\pi^U &= \rho(e,\overline{\theta})\overline{\pi}^U + (1-\rho(e,\overline{\theta}))\underline{\pi}^U - c(e) \\ \text{with} &: \overline{\pi}^U = \overline{w}\overline{X} + \overline{F} \text{ and } \overline{X} := X(p,q,\overline{\theta}) \\ \text{with} &: \underline{\pi}^U = \underline{w}\underline{X} + \underline{F} \text{ and } \underline{X} := X(p,q,\underline{\theta}). \end{aligned} \tag{3}$$

In turn, the downstream firm's expected per period profit $E\pi^D$ can be written as

$$\begin{aligned} E\pi^D &= \rho(e,\overline{\theta})\overline{\pi}^D + (1-\rho(e,\overline{\theta}))\underline{\pi}^D \\ \text{with} &: \overline{\pi}^D = (p-\overline{w})\overline{X} + q\overline{Y} - \overline{F} \text{ and } \overline{Y} := Y(p,q,\overline{\theta}) \\ \text{with} &: \underline{\pi}^D = (p-\underline{w})\underline{X} + q\underline{Y} - \underline{F} \text{ and } \underline{Y} := Y(p,q,\underline{\theta}). \end{aligned} \tag{4}$$

Though firm D cannot directly observe the actual quality of good x, consumers learn the quality of good x immediately. Since consumers will adapt their demand accordingly, the downstream firm is able to detect untruthful announcements through the shift of her demand. However, we assume that the downstream firm cannot verify untruthful announcements ex-post, as low qualities can also be caused by misconduct such as improper shipping or handling at the downstream level. Hence, untruthful announcements cannot be punished contractually. Once cheated, the downstream firm is supposed to refrain from continuing the relation with firm U. In this case the game continues as both firms get their outside options.

Outside options. The outside option of the downstream firm is based on supplying good y only. Hence, the downstream firm's outside option Γ^D can be written as[9]

$$\Gamma^D := \widetilde{q}Y(\widetilde{q},\infty,\cdot) \text{ with } \widetilde{q} := \arg\max qY(q,\infty,\cdot). \tag{5}$$

[9] We make the natural assumption that with $p=\infty$ demand for good y is not affected by the quality of good x.

Note that the downstream firm's disagreement payoff equals zero if x and y constitute perfect complements. The upstream firm's outside option is supposed to be equal to $\Gamma^U \geq 0$. The level of Γ^U can also be interpreted as a proxy for the size of the downstream firm: The larger the downstream firm the more she acts as a gatekeeper to downstream markets which indeed implies a lower outside option for the upstream firm.

Summarizing, we analyze an infinitely repeated game where the following five-stage game takes place in every period: The downstream firm D first determines the target quality $\overline{\theta}$. In the second stage, firms negotiate a menu of two-part tariffs which are contingent on the quality $\widehat{\theta}$ the upstream firm will announce. The upstream firm decides how much effort to spend and observes the realized quality in the third stage. Subsequently, she decides whether or not to report the actual quality truthfully. In the last stage of the game, given the upstream firm's announcement the appropriate delivery conditions are selected. Then, the downstream firm chooses her prices and demand as well as profits realize. The interaction between firms D and U ends if the downstream firm detects an untruthful announcement. In this case, both firms will get their outside option. We focus on subgame perfect equilibria and solve the game by backward induction.

3 Prices, Announcement, and Effort

We begin our analysis by characterizing the optimal downstream prices for given two-part tariffs and an announced quality $\widehat{\theta}$. We then solve the third stage of the game, where we determine the upstream firm's incentives to announce the true realization of θ. Subsequently, we consider the effort the upstream firm spends in order to enhance the probability of achieving the target quality. Delivery contracts as well as the target quality chosen by the downstream firm will be analyzed in the next section.

Downstream Prices. In the final stage of the game, the downstream firm sets prices p and q for both products x and y. These decisions are based on the quality the upstream firm has announced as well as on the respective delivery conditions. Accordingly, the downstream firm's optimal prices $\overline{p}$, $\overline{q}$ and $\underline{p}$, $\underline{q}$, respectively, are derived by solving

$$\max_{p,q} \left[(p-w)X(\cdot,\widehat{\theta}) + qY(\cdot,\widehat{\theta}) - F\right]\Big|_{(w,F)=T(w,F,\widehat{\theta})}, \tag{6}$$

where $\overline{p},\overline{q}$ and $\underline{p},\underline{q}$ denote the solutions of (6) for $\widehat{\theta}=\overline{\theta}$ and $\widehat{\theta}=\overline{\theta}$ respectively.

Announcement. After having observed the realized quality, the upstream firm announces the quality $\widehat{\theta}$ which also determines the actual delivery conditions. Deciding whether or not to announce the realized quality truthfully, the upstream firm trades off her potential gains from deviating in the current period with the losses resulting from disagreement with the downstream firm in all future periods. Denoting $\overline{E\pi^U}$ firm U's expected continuation profit and $\delta > 0$ the discount factor, firm U's incentive constraints for truthful announcements can be written as

$$IC_1 \quad : \quad \underline{w}X(\underline{p},\underline{q},\underline{\theta}) + \underline{F} + \frac{1}{\delta}\overline{E\pi^U} \geq \overline{w}X(\overline{p},\overline{q},\underline{\theta}) + \overline{F} + \frac{1}{\delta}\Gamma^U \tag{7}$$

$$IC_2 \quad : \quad \overline{w}X(\overline{p},\overline{q},\overline{\theta}) + \overline{F} + \frac{1}{\delta}\overline{E\pi^U} \geq \underline{w}X(\underline{p},\underline{q},\overline{\theta}) + \underline{F} + \frac{1}{\delta}\Gamma^U. \tag{8}$$

Effort. Turning to the effort chosen by the upstream firm, we focus on the case where the incentive constraints (7) and (8) are satisfied.[10] Employing (3), the supplier's optimal effort $e^*(\cdot)$ is implicitly given by

$$\rho_e\overline{\pi}^U - \rho_e\underline{\pi}^U = c'(e) \Leftrightarrow \rho_e = \frac{c'(e)}{\Delta\pi^U} \text{ with } \Delta\pi^U := \overline{\pi}^U - \underline{\pi}^U. \tag{9}$$

For later reference note further that simple comparative statics leads to

$$sign\frac{\partial e^*}{\partial \overline{w}} = sign\frac{d\Delta\pi^U}{d\overline{w}}. \tag{10}$$

For given $\overline{F}$ and $\underline{F}$ and $\overline{w}$ sufficiently low, the effort level chosen by the upstream firm will thus increase in $\overline{w}$, i.e. $\partial e^*/\partial\overline{w} > 0$. In turn, the effort level reacts ambiguously in $\overline{\theta}$. Since we have

$$sign\frac{\partial e^*}{\partial\overline{\theta}} = sign\left[\rho_{e\overline{\theta}}\Delta\pi^U + \rho_e\frac{d\Delta\pi^U}{d\overline{\theta}}\right] \tag{11}$$

with $\rho_{e\overline{\theta}} < 0$, (11) shows that $\partial e^*/\partial\overline{\theta}$ is negative as long as ρ_e or $d\Delta\pi^U \big/ d\overline{\theta}$ are small enough.

[10] Since the equilibrium delivery conditions will be such that the incentive constraints are satisfied, we do not analyze the optimal effort when either IC_1 or IC_2 are violated.

4 Terms of Trade and Quality

In order to analyze both the target quality $\overline{\theta}$ the downstream firm sets as well as the delivery contracts $T(w, F, \widehat{\theta})$ the firms agree on, we first assume that the incentive constraints are not binding. We will use this solution as a benchmark for the more complicated case where contracts have to ensure truthful announcement.

Analyzing the bargaining process with respect to the delivery contracts, we use the symmetric Nash bargaining solution. Taking the discounted continuation profits $1/\delta\ \overline{E\pi^D}$ and $1/\delta\ \overline{E\pi^U}$ as well as the firms' outside options into account, the Nash Product is given by

$$N = \left[E\pi^D(\cdot) - \Gamma^D + \frac{1}{\delta}\left(\overline{E\pi^D} - \Gamma^D\right)\right]\left[E\pi^U(\cdot) - \Gamma^U + \frac{1}{\delta}\left(\overline{E\pi^U} - \Gamma^U\right)\right]. \tag{12}$$

Employing (12), it is straightforward that the upstream firm's bargaining position is the better the higher her marginal contribution to the joint profit. The larger the difference between $E\pi^D(\cdot)$ and Γ^D the higher the share of the overall surplus the upstream firm will get. Thus, a higher degree of complementarity between the goods offered by the downstream firm benefits the upstream firm. The same results hold with respect to an increase of Γ^U.

4.1 Unconstrained Bargaining

Assuming that the incentive constraints (7) and (8) are not binding and maximizing (12) with respect to the tariffs $\overline{F}, \overline{w}$ and $\underline{F}, \underline{w}$, we obtain[11]

$$\underline{w}^* = \overline{w}^* = 0 \text{ and } \overline{F}^* - \underline{F}^* = \overline{p}\overline{X} + \overline{q}\overline{Y} - (\underline{p}\underline{X} + \underline{q}\underline{Y}). \tag{13}$$

As expected, wholesale prices equal marginal costs in order to maximize the joint profit of both firms. In turn, the fixed fees are used to divide the joint profit and to allocate the risk of getting a low quality. Using (13), we immediately get $\overline{\pi}^D - \underline{\pi}^D = 0$. Thus, any risk is fully borne by the upstream firm which also implies that the upstream firm's decision with respect to e maximizes the expected joint profit of both firms (see (9)).

Anticipating the outcome of the negotiation process, the downstream firm specifies the target

[11] These results are derived in the proof of Proposition 1.

quality in the first stage of the game. Using (13) and solving for the absolute values of $\overline{F}^*$ and $\underline{F}^*$, the downstream firm's expected profit can be written as

$$\begin{aligned} E\pi^D &= \frac{1}{2}\left[\rho\Delta + \underline{p}\underline{X} + \underline{q}\underline{Y} - c(e^*) + \frac{1}{\delta}\left(\overline{E\pi^U} - \overline{E\pi^D} + (1+\delta)(\Gamma^D - \Gamma^U)\right)\right] \qquad (14) \\ \text{with} &: \Delta := \overline{p}\overline{X} + \overline{q}\overline{Y} - \left(\underline{p}\underline{X} + \underline{q}\underline{Y}\right) \end{aligned}$$

Maximizing (14) with respect to $\overline{\theta}$ and using the envelope theorem, the optimal target quality $\overline{\theta}^*$ is implicitly defined by

$$\rho\left[\overline{p}\overline{X}_{\overline{\theta}} + \overline{q}\overline{Y}_{\overline{\theta}}\right] + \rho_{\overline{\theta}}\Delta = 0. \qquad (15)$$

Hence, we get

Proposition 1 *If the incentive constraints are not binding, the bargaining outcome is efficient.*

Proof. See appendix. ■

Since unconstrained bargaining allows for efficient wholesale prices and an efficient allocation of risk, the target quality chosen by the downstream maximizes the firms' expected joint surplus. Note that we would get the same result if firms negotiated about the delivery tariffs as well as the target quality.

Turning to the upstream firm's constraints and employing (13) and (15), it is obvious that (8) is satisfied as long as (7) holds. Moreover, considering the continuation profits we must have $E\pi^D = \overline{E\pi^D}$ and $E\pi^U = \overline{E\pi^U}$. Using these equations in order to calculate the equilibrium values of $\overline{F}^*$ and $\underline{F}^*$ it is easy to show that (7) is equivalent to

$$\Gamma^U + \Gamma^D \leq (\rho - 2\delta)\Delta + (\underline{p}\underline{X} + \underline{q}\underline{Y}) - c(e^*). \qquad (16)$$

Obviously, (16) is more likely to be violated the higher the firms' outside options. Likewise, an increase in the marginal revenues from increasing $\overline{\theta}$ improves the likelihood that (16) is violated:

Corollary 1 *The higher the marginal revenues from increasing the quality, the more likely the incentive constraint (16) is binding.*

Proof. See appendix. ■

Applying Corollary 1 to the question of how the complementarity of products affects the efficiency of vertical relations, we get that a higher degree of complementarity may well soften the upstream firm's incentive constraints. As long as complementarities mainly affect overall revenues, marginal revenues from increasing a single product's quality become relatively less important. Hence, efficient quality decisions are less likely to violate the upstream firm's incentive constraints the higher the complementarity between the products offered to final consumers. Accordingly, umbrella branding makes efficient quality decisions more likely the higher the number of goods sold by the downstream firm and the stronger consumers beliefs about the products' qualities are correlated.

4.2 Constrained Bargaining

When (16) is binding, the previous results indicate that delivery contracts as well as the target quality chosen by the downstream will be distorted. Analyzing the constrained bargaining problem we get that the wholesale price $\overline{w}$ is strictly positive and that the allocation of the risk is inefficient. Moreover, the target quality serves to reduce potential efficiency losses due to inefficient effort decisions by the upstream firm.

Starting with (7), $\overline{F}$ leads to truthful announcements as long as

$$\overline{F} = \underline{wX} + \underline{F} - \overline{w}\widehat{X} + \frac{1}{\delta}\left(\overline{E\pi^U} - \Gamma^U\right) \text{ with } \widehat{X} := X(\overline{p}, \overline{q}, \underline{\theta}). \tag{17}$$

Employing (17) and maximizing (12) with respect to $\overline{w}$, $\underline{w}$ and $\underline{F}$, we get that $\underline{w}^* = 0$ continues to hold, while $\overline{w}^*$ is implicitly given by

$$\rho_e \frac{\partial e^*}{\partial \overline{w}}(\Delta - \Delta\pi^U) = -\rho \frac{\partial(\overline{p}\overline{X} + \overline{q}\overline{Y})}{\partial \overline{w}}. \tag{18}$$

Turning to the target quality and analyzing the expected profit of the downstream firm, the optimal target quality $\overline{\theta}^*$ satisfies[12]

$$\rho_e \frac{\partial e^*}{\partial \overline{\theta}}(\Delta - \Delta\pi^U) = -\left[\rho_{\overline{\theta}}\Delta + \rho(\overline{p}\overline{X}_{\overline{\theta}} + \overline{q}\overline{Y}_{\overline{\theta}})\right]. \tag{19}$$

[12] Note again that the same first order condition is obtained when both firms negotiate simultaneously the terms of trade and the target quality.

Combining (18) and (19) and restricting the analysis to $\overline{w}^* < \overline{w}^k := \arg\max w(\overline{X} - \widehat{X})$, we get:

Proposition 2 *If the incentive constraint is binding, the bargaining solution is characterized by inefficiently low upstream investments and* $\underline{w}^* = 0 < \overline{w}^*$. *The optimal target quality* $\overline{\theta}^*$ *may be either too low or too high as compared to the fully efficient solution. The target quality* $\overline{\theta}^*$ *is more likely to be inefficiently low (high), the lower (higher)* $\overline{w}$ *or the lower (higher) the marginal effect of* $\overline{\theta}$ *on* $\overline{X}$.

Proof. See appendix. ■

With unconstrained bargaining wholesale prices maximize joint surplus, while the fixed fees are used to divide the joint surplus between the firms and to achieve an efficient allocation of risk. However, when the upstream firm's incentive constraint is binding, one of these instruments must be used to ensure truthful announcement. Since it turns out that the fixed fees are used to allocate the joint surplus and to ensure truthful announcements, the allocation of risk and thus the upstream firm's effort decisions become inefficient. To ameliorate the implied inefficiencies, $\overline{w}$ as well as $\overline{\theta}$ have to be distorted. Since a higher $\overline{w}$ leads to a higher effort as long as $\overline{w}$ is sufficiently small (see (10)), the optimal $\overline{w}^*$ is strictly positive. Considering $\overline{\theta}^*$ and taking into account that an increase in $\overline{\theta}$ may have ambiguous effects on e^* (see (11)), the optimal distortion with respect to $\overline{\theta}$ can be either negative or positive. A careful analysis of (11) reveals that $\overline{\theta}^*$ is more likely to be inefficiently high the higher $\overline{w}^*$.

Combining these results with the observation that the upstream firm's incentives constraint is more likely to be binding the higher the firms' outside options, we get:

Corollary 2 *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.*

A low value of Γ^U implies that the upstream firm has little alternatives to distribute her product to final consumers. In other words, the downstream firm has a high level of gatekeeper control towards final consumer markets. Thus, interpreting Γ^U as an inverse measure of buyer power we find that buyer power may not only cause lower wholesale and retail prices it may also lead to more efficient quality decisions. Similarly, (relatively) 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. Finally, note that these results are perfectly in line with Corollary 1 which refers to the relation between the firms' overall gains from trade and the marginal profits of increased qualities.

5 Example

In order to illustrate our results and to characterize the potential inefficiencies due to imperfect information in more detail, we now turn to a simple example. Using a standard Dixit utility function we analyze the comparative statics with respect to the complementarity between products as well as the upstream firm's outside option. While higher complementarities increase overall gains from trade and thus soften the upstream firm's incentive constraint, increasing Γ^U leads to ambiguous effects with respect to the chosen target quality $\overline{\theta}^*$. More specifically, while $\overline{\theta}^*$ may well decrease in Γ^U, the target quality turns out to be the highest when Γ^U approaches the value above which the firms' gains from trade are lower than their outside options.

Consumers' utility is given by

$$U(x,y,\theta) = (1 + \frac{1}{4}\sqrt{\theta})x + y - \frac{1}{2}(x^2 + y^2 - 2\sigma xy) - px - qy, \tag{20}$$

where σ indicates the degree of complementarity between goods x and y. Differentiating $U(x,y,\theta)$ with respect to x and y and focusing on interior solutions for y, we obtain the respective demand functions $X(\cdot)$ and $Y(\cdot)$ with

$$X(p,q,\sigma,\theta) = \begin{cases} \frac{1+\sigma-p-\sigma q+\sqrt{\theta}/4}{1-\sigma^2} & \text{for } p \leq 1+\sigma-\sigma q+\sqrt{\theta}/4 \\ 0 & \text{otherwise} \end{cases} \tag{21}$$

and

$$Y(p,q,\sigma,\theta) = \begin{cases} \frac{1+\sigma-\sigma p-q+\sigma\sqrt{\theta}/4}{1-\sigma^2} & \text{for } p \leq 1+\sigma-\sigma q+\sqrt{\theta}/4 \\ 1-q & \text{otherwise} \end{cases}. \tag{22}$$

Furthermore, we normalize $\underline{\theta}$ to zero and assume that the probability $\rho(e,\theta)$ and the upstream firm's costs $c(e)$ are given by

$$\rho(e,\theta) = \min\left\{\frac{e}{1+\theta}, 1\right\} \text{ and } c(e) = \frac{e^2}{2}. \tag{23}$$

Assuming first that the upstream firm's incentives constraints are not binding and using (9), (13) as well as (15), we get that the optimal target quality $\overline{\theta}^*$ decreases in σ (see Figure 1). This result is based on two countervailing effects. On the one hand, the marginal revenue from higher $\overline{\theta}$ is increasing in σ. On the other hand, (11) reveals that the effort level chosen by the upstream firm is decreasing in $\overline{\theta}$ as long as $\overline{w} = 0$. Therefore, a higher $\overline{\theta}$ implies a lower probability of $\overline{\theta}$. Comparing this negative effect with the direct effect of σ on marginal revenues, we find that the negative effect dominates. That is, a higher degree of complementarity leads to a lower target quality $\overline{\theta}^*$. Furthermore, analyzing the upstream firm's incentive constraint (7) it is easy to show that there exist a critical value $\Gamma^K(\sigma)$ with $\Gamma^{K\prime}(\sigma) > 0$ such that (7) is binding for all $\Gamma^U > \Gamma^K(\sigma)$ (see Figure 1). As the firms' expected joint surplus and thus their mutual dependencies are increasing in σ, the critical value $\Gamma^K(\sigma)$ must be also increasing in σ (see Corollary 2).

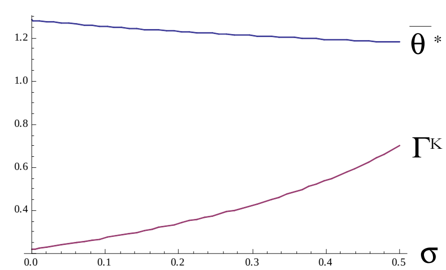

Figure 1: Optimal target quality and critical outside option of firm U

If constraint (7) is binding, i.e. $\Gamma^U > \Gamma^K(\sigma)$, the equilibrium values for $\overline{w}^*$ and $\overline{\theta}^*$ can be calculated by using (17)—(19). Figure (2) shows the graphs of $\overline{w}^*(\sigma, \Gamma^U)$ and $\overline{\theta}^*(\sigma, \Gamma^U)$ for $\sigma = 0.2$ and $\sigma = 0.5$. The upper bound $\Gamma^M(\sigma)$ for Γ^U corresponds to the value of Γ^U above which gains from trade become negative. While a higher Γ^U unambiguously increases the optimal wholesale price $\overline{w}^*$ if $\Gamma^U > \Gamma^K(\sigma)$ holds, the relation between Γ^U and the optimal target quality $\overline{\theta}^*$ is not monotone. Starting from $\Gamma^U = \Gamma^K(\sigma)$ an increase in Γ^U first reduces $\overline{\theta}^*$, while relative high values of Γ^U imply that $\overline{\theta}^*$ is increasing in Γ^U. This non-monotonic relation traces back to the observation that $\overline{w}^*$ and $\overline{\theta}^*$ are distorted in order to enhance the upstream firm's effort and thus to mitigate efficiency losses due to inefficient risk sharing between both firms. (11) implies that the upstream firm's effort will decrease in $\overline{\theta}$ as long as $\overline{w}$ is relatively low. Thus, in order to avoid inefficiently low effort levels, the optimal target quality $\overline{\theta}^*$ first decreases in

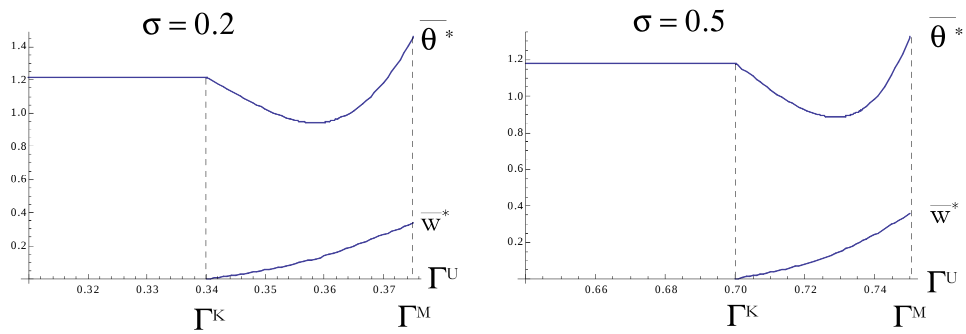

Figure 2: Optimal target quality for $\sigma = 0.2$ and $\sigma = 0.5$

Γ^U. However, the lower $\overline{\theta}$ the higher the marginal revenues from increasing $\overline{\theta}$. Additionally, the higher Γ^U the higher $\overline{w}^*$ and thus the more likely the upstream firm will increase her effort if $\overline{\theta}$ is high. Therefore, the optimal target quality $\overline{\theta}^*$ increases in Γ^U if Γ^U is high enough. Finally, extending our results from Corollary 2 to the analysis of social welfare, we define expected social welfare EW as the sum of expected consumers' surplus and firms' profits, i.e.

$$EW = \rho \left[U(\overline{x}, \overline{y}, \overline{\theta}) + \overline{p}\overline{X} + \overline{q}\overline{Y} \right] + (1 - \rho) \left[U(\underline{x}, \underline{y}, \underline{\theta}) + \underline{p}\underline{X} + \underline{q}\underline{Y} \right] - c(e^*). \tag{24}$$

Figure (3) shows that EW is unambiguously decreasing in Γ^U for all $\Gamma^U > \Gamma^K(\sigma)$. Obviously, positive wholesale prices $\overline{w}$ as well as low target qualities tend to reduce the firms' expected profits as well the expected surplus of the consumers. Furthermore, although relatively high values

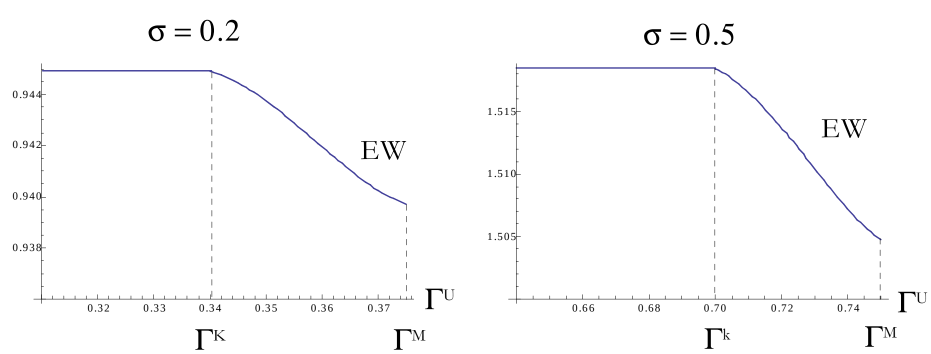

Figure 3: Expected Welfare in Γ for $\sigma = 0.2$ and $\sigma = 0.5$

of Γ^U may lead to higher target qualities, the implied distortions due to positive wholesale prices $\overline{w}^*$ and inefficiently low effort levels lead to overall lower expected social welfare. Hence, mutual dependency between upstream and downstream firms does not only induce higher expected profits it also leads to higher expected social welfare.

6 Conclusion

We have analyzed a simple vertical structure with one upstream firm selling a consumer good or an essential input to a downstream firm over an infinite number of periods. The good's quality is stochastically determined and private information of the upstream firm. The delivery contracts which are contingent on the upstream firm's quality announcement are negotiated between both firms according to the Nash bargaining solution. Within this framework we have shown that both the delivery conditions as well as the quality are distorted when the upstream firms incentives to deviate from truthful announcement are high enough. Relating these results to the firms' outside options we get that delivery contracts and quality decisions are more likely to be efficient the higher the mutual dependency between the downstream and upstream firm. That is, higher gains from trade imply stronger incentives for the upstream firm to rely on truthful announcements and thus lead to more efficient qualities and delivery contracts.

Applying this result to the analysis of buyer power we find that high buyer power and thus a low outside option of the upstream firm may well lead to lower wholesale and retail prices as well to more efficient qualities. Accordingly, relation specific investments by upstream firms can not only enhance the bargaining position of the downstream firm, they can also increase the efficiency of the firms' interaction. Note that this also implies that outsourcing may become more attractive the more both firms depend on their interaction. In turn, we find similar results with respect to the downstream firm's outside option. The higher the complementarity between the products the downstream offers the relatively lower is her outside option and thus the higher the efficiency of negotiated delivery contracts. Correspondingly, as long as consumers' beliefs about the qualities of the product offered by the downstream are positively correlated, higher reputation losses due to umbrella branding induce relatively low outside options and may thus enhance efficiency.

Appendix

Proof of Proposition 1 Maximizing (12) with respect to the tariff $\underline{w}, \underline{F}$ and $\overline{w}, \overline{F}$, using the envelope theorem with respect to $e^*(\cdot)$ and analyzing the respective first order conditions, we first obtain

$$\frac{\partial N}{\partial \overline{F}} = 0 \Leftrightarrow \frac{\rho_e \frac{\partial e^*}{\partial \overline{F}} \Delta\pi^D - \rho}{\rho} = -\frac{\left[E\pi^D + \frac{1}{\delta}\overline{E\pi^D} - \frac{1+\delta}{\delta}\Gamma^D\right]}{\left[E\pi^U + \frac{1}{\delta}\overline{E\pi^U} - \frac{1+\delta}{\delta}\Gamma^U\right]} \tag{25}$$

$$\frac{\partial N}{\partial \underline{F}} = 0 \Leftrightarrow \frac{-\rho_e \frac{\partial e^*}{\partial \underline{F}} \Delta\pi^D - (1-\rho)}{(1-\rho)} = -\frac{\left[E\pi^D(\cdot) + \frac{1}{\delta}\overline{E\pi^D} - \frac{1+\delta}{\delta}\Gamma^D\right]}{\left[E\pi^U(\cdot) + \frac{1}{\delta}\overline{E\pi^U} - \frac{1+\delta}{\delta}\Gamma^U\right]} \tag{26}$$

with $\Delta\pi^D := \overline{\pi}^D - \underline{\pi}^D$. (25), (26) and $\partial e^* / \partial \overline{F} = - \partial e^* / \partial \underline{F}$ imply that we must have

$$\frac{\rho_e}{\rho}\Delta\pi^D = \frac{\rho_e}{(1-\rho)}\Delta\pi^D \tag{27}$$

and therefore $\Delta\pi^D = 0$ as well as (see (25))

$$E\pi^D(\cdot) + \frac{1}{\delta}\overline{E\pi^D} - \frac{1+r}{\delta}\Gamma^D = E\pi^U(\cdot) + \frac{1}{\delta}\overline{E\pi^U} - \frac{1+\delta}{\delta}\Gamma^U. \tag{28}$$

Employing (28) and again $\Delta\pi^D = 0$, the first order conditions with respect to $\overline{w}$ and $\underline{w}$ can be written as

$$\frac{\partial N}{\partial \overline{w}} = \rho\frac{\partial \overline{\pi}^D}{\partial \overline{w}} + \rho\frac{\partial \overline{\pi}^U}{\partial \overline{w}} = -\rho\overline{X} + \rho\left[\overline{X} + \overline{w}\frac{d\overline{X}}{d\overline{w}}\right] = 0 \tag{29}$$

$$\frac{\partial N}{\partial \underline{w}} = (1-\rho)\frac{\partial \underline{\pi}^D}{\partial \underline{w}} + (1-\rho)\frac{\partial \underline{\pi}^U}{\partial \underline{w}} = -(1-\rho)\underline{X} + (1-\rho)\left[\underline{X} + \underline{w}\frac{d\underline{X}}{d\underline{w}}\right] = 0 \tag{30}$$

which leads to $\overline{w}^* = \underline{w}^* = 0$. Hence, $\Delta\pi^D = 0$ also implies that we have $\overline{F}^* - \underline{F}^* = \overline{p}\overline{X} + \overline{q}\overline{Y} - (\underline{p}\underline{X} + \underline{q}\underline{Y})$. Solving (28) for $\overline{F}^*$ and substituting into the downstream firm's expected profit leads to (14).

Proof of Corollary 1 First, using $E\pi^D(\cdot) = \overline{E\pi^D}$ and $E\pi^U(\cdot) = \overline{E\pi^U}$, it is easy to show that the equilibrium payments $\overline{F}^*$ and $\underline{F}^*$ are given by

$$\overline{F}^* = \frac{1}{2}\left[(2-\rho)(\overline{p}\overline{X}+\overline{q}\overline{Y})-(1-\rho)(\underline{p}\underline{X}+\underline{q}\underline{Y})+c(e^*)+\Gamma^U-\Gamma^D\right] \tag{31}$$

$$\underline{F}^* = \frac{1}{2}\left[(1+\rho)(\underline{p}\underline{X}+\underline{q}\underline{Y})-\rho(\overline{p}\overline{X}+\overline{q}\overline{Y})+c(e^*)+\Gamma^U-\Gamma^D\right]. \tag{32}$$

employing (31) and (32), we get (16) which is equivalent to

$$\delta \leq \frac{1}{2\Delta}\left[\rho\Delta+(\underline{p}\underline{X}+\underline{q}\underline{Y})-c(e^*)-\Gamma^U-\Gamma^D\right]. \tag{33}$$

Introducing α as a shift parameter for the marginal revenues from increasing θ, the first order condition for $\overline{\theta}$ can be written as

$$\rho\alpha\left[\overline{p}\overline{X}_{\overline{\theta}}+\overline{q}\overline{Y}_{\overline{\theta}}\right]+\rho_{\overline{\theta}}\left[\overline{F}^*-\underline{F}^*\right]=0. \tag{34}$$

Using (34) simple comparative statics with respect to α leads to

$$sign\frac{d\overline{\theta}}{d\alpha}=sign[\rho(\overline{p}\overline{X}_{\overline{\theta}}+\overline{q}\overline{Y}_{\overline{\theta}})]>0. \tag{35}$$

Furthermore, differentiating the RHS of (33) with respect to $\overline{\theta}$, using the envelope theorem with respect to e^* and evaluating at $\alpha = 1$, we obtain

$$sign\frac{d}{d\alpha}\left[\frac{1}{2\Delta}\left[\rho\Delta+(\underline{p}\underline{X}+\underline{q}\underline{Y})-c(e^*)-\Gamma^U-\Gamma^D\right]\right] \tag{36}$$

$$= sign\left[\frac{\partial\Delta}{\partial\overline{\theta}}\left[c(e^*)+\Gamma^U+\Gamma^D-(\underline{p}\underline{X}+\underline{q}\underline{Y})\right]+\Delta^2\rho_{\overline{\theta}}\right]. \tag{37}$$

Finally, using $\rho\left(\overline{p}\overline{X}+\overline{q}\overline{Y}\right)+(1-\rho)\left(\underline{p}\underline{X}+\underline{q}\underline{Y}\right)-c(e^*)>\Gamma^U+\Gamma^D$ and again (34) we obtain

$$\frac{\partial\Delta}{\partial\overline{\theta}}\left[c(e^*)+\Gamma^U+\Gamma^D-(\underline{p}\underline{X}+\underline{q}\underline{Y})\right]+\Delta^2\rho_{\overline{\theta}}<0. \tag{38}$$

Proof of Proposition 2 Using (17) note first that the firms' profits for $\theta = \overline{\theta}$ and $\theta = \underline{\theta}$

can be written as

$$\begin{aligned}
\overline{\pi}^D &= (\overline{p}-\overline{w})\overline{X}+\overline{p}_y\overline{Y}-\underline{wX}-\underline{F}+\overline{w}\widehat{X}-\frac{1}{r}\left(\overline{E\pi^U}-\Gamma^U\right) && (39)\\
\underline{\pi}^D &= (\underline{p}-\underline{w})\underline{X}+\underline{p}_y\underline{Y}-\underline{F} && (40)\\
\overline{\pi}^U &= \overline{w}\overline{X}+\underline{wX}+\underline{F}-\overline{w}\widehat{X}+\frac{1}{\delta}\left(\overline{E\pi^U}-\Gamma^U\right) && (41)\\
\underline{\pi}^U &= \underline{wX}+\underline{F}. && (42)
\end{aligned}$$

Employing (39)—(42) and considering first $\underline{F}$ and $\underline{w}$, we again get

$$\begin{aligned}
\frac{\partial N}{\partial \underline{F}} &= 0 \Leftrightarrow E\pi^D(\cdot)+\frac{1}{\delta}\overline{E\pi^D}-\frac{1+\delta}{\delta}\Gamma^D = E\pi^U(\cdot)+\frac{1}{\delta}\overline{E\pi^U}-\frac{1+\delta}{\delta}\Gamma^U && (43)\\
\frac{\partial N}{\partial \underline{w}} &= (1-\rho)\left[\underline{pX}+\underline{p}_y\underline{Y}\right]_{\underline{w}}=0 \Rightarrow \underline{w}^*=0. && (44)
\end{aligned}$$

Turning to $\overline{w}$, using $\Delta\pi^U=\overline{w}(\overline{X}-\widehat{X})+\frac{1}{\delta}\left(E\pi^U-\Gamma^U\right)$ (see (41) and (42)) as well as $E\pi^D(\cdot)=\overline{E\pi^D}$ and $E\pi^U(\cdot)=\overline{E\pi^U}$ the first order condition for $\overline{w}$ can be written as

$$\begin{aligned}
\frac{\partial N}{\partial \overline{w}} &= \rho_e\frac{\partial e^*}{\partial \overline{w}}\left[\Delta-\Delta\pi^U\right]+\rho\frac{\partial(\overline{p}\overline{X}+\overline{q}\overline{Y})}{\partial\overline{w}}=0 && (45)\\
\text{with} &: \Delta\pi^U=\overline{w}(\overline{X}-\widehat{X})+\frac{1}{2\delta}\left[\rho\Delta+\underline{pX}+\underline{qY}-c(e^*)-\Gamma^U-\Gamma^D\right]. && (46)
\end{aligned}$$

To prove the proposition, note first that $\partial(\overline{p}\overline{X}+\overline{q}\overline{Y})/\partial\overline{w}=0$ for $\overline{w}=0$ and $\partial(\overline{p}\overline{X}+\overline{q}\overline{Y})/\partial\overline{w}<0$ for all $\overline{w}>0$. Furthermore, using (10) we obtain

$$sign\frac{\partial e^*}{\partial\overline{w}}=sign\frac{d}{d\overline{w}}\left[\overline{w}(\overline{X}-\widehat{X})\right]>0 \text{ as long as } \overline{w}<\overline{w}^k. \qquad (47)$$

Considering the sign of $\Delta-\Delta\pi^U$ and assuming $\Delta-\Delta\pi^U\leq 0$, (45) and (47) would imply $\overline{w}=0$. Employing $\overline{w}=0$, we additionally get

$$\Delta-\Delta\pi^U\leq 0\Leftrightarrow\Gamma^D\leq(\rho-2\delta)\Delta+(\underline{pX}+\underline{qY})-c(e^*)-\Gamma^U, \qquad (48)$$

which contradicts the assumption that (16) is binding. Hence we must have $\Delta-\Delta\pi^U>0$ and therefore inefficient risk sharing as well as $\overline{w}^*>0$. Finally, turning to $\overline{\theta}$, using $\underline{F}^*$ as well as the envelope theorem with respect to $e^*(\cdot)$ and $\overline{w}^*$, the optimal target quality $\overline{\theta}^*$ is implicitly given by

$$\frac{dE\pi^D}{d\overline{\theta}} = \rho_{\overline{\theta}}\Delta + \rho_e \frac{\partial e^*}{\partial \overline{\theta}} \left[\Delta - \Delta\pi^U\right] + \rho \left[\overline{p}\overline{X}_{\overline{\theta}} + \overline{q}\overline{Y}_{\overline{\theta}}\right] = 0. \tag{49}$$

Using (49) and (11) reveals that

$$sign\left[\rho_{e\overline{\theta}}\Delta\pi^U + \rho_e \overline{w}\overline{X}_{\overline{\theta}}\right] = -sign(\rho_{\overline{\theta}}\Delta + \rho(\overline{p}\overline{X}_{\overline{\theta}} + \overline{q}\overline{Y}_{\overline{\theta}})) \tag{50}$$

which implies that—for given e^*—the target quality may be either inefficiently low or high. More precisely, $\rho_{e\overline{\theta}}\Delta\pi^U + \rho_e \overline{w}\overline{X}_{\overline{\theta}} \gtreqless 0$ leads to $\rho_{\overline{\theta}}\Delta + \rho(\overline{p}\overline{X}_{\overline{\theta}} + \overline{q}\overline{Y}_{\overline{\theta}} \lesseqgtr 0$. Therefore, the lower (higher) $\overline{w}^*$ or $\overline{X}_{\overline{\theta}}$ the more likely is the target quality inefficiently low (high).

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