The Strategic Use of Private Quality Standards in Food Supply Chains*

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May 2012

Abstract

We explore the strategic role of private quality standards in food supply chains. Considering two symmetric retailers that are exclusively supplied by a finite number of producers and endogenizing the suppliers' delivery choice, we show that there exist two asymmetric equilibria in the retailers' quality requirements. Our results reveal that the retailers use private quality standards to improve their bargaining position in the intermediate goods market. This is associated with inefficiencies in the upstream production, which can be mitigated by enforcing a minimum quality standard.

JEL Classification: L15, L42, Q13

Keywords: private quality standards, vertical relations, buyer power, food supply chain

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*We would like to thank David Hennessy and two anonymous referees for their valuable comments. Furthermore, we are grateful to Pio Baake, Özlem Bedre-Defolie, Stéphane Caprice, Claire Chambolle, Clémence Christin and Vincent Réquillart, as well as participants of the Annual Conference of the GeWiSoLa (Halle, 2011), of the EAAE Congress (Zurich, 2011), of the Verein für Socialpolitik (Kiel, 2010), and seminar participants at DIW Berlin, Humboldt-Universität zu Berlin, Toulouse School of Economics and INRA-ALISS Paris for helpful discussions and suggestions. Financial support from the Deutsche Forschungsgemeinschaft (FOR 986 and "Market Power in Vertically Related Markets") is gratefully acknowledged.

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Food scandals, like the British BSE[1] crisis, the melamine found in Chinese milk in 2008, and the dioxin contamination of animal feed in Germany in 2010, tend to cause serious consumer concerns about food quality. These crises have encouraged both governments and the food industry to tighten food safety regulations. In particular, food retailers have implemented private quality standards in the area of fresh fruits, vegetables, meat, and fish products, e.g. Tesco's Nature's Choice and Carrefour's Filière Qualité, which are above and beyond public regulations. Quality standards clarify product and process specifications, stipulate how these specifications are met and define each trading partner's responsibilities. While product standards refer to physical properties of the final products, such as maximum residue levels (MRLs) for pesticides and herbicides, threshold values for additives and requirements for packaging material, process standards relate to properties of the production process, including hygiene, sanitary and pest-control measures, the prohibition of child labor, animal-welfare standards and food quality management systems. Moreover, quality standards may vary widely among the individual retailers.[2] Even when adopting collective private standards, such as the British Retail Consortium (BRC) Global Standard for Food Safety and GlobalGAP, retailers tend to supplement them with individual requirements (OECD 2006).[3] This has triggered strong debates as to whether retailers

[1] Bovine spongiform encephalopathy (BSE).

[2] In Germany, for example, the MRLs for pesticides established by some large retail chains in 2008 ranged from 80% of the public MRL (Aldi, Norma), to 70% (REWE, Edeka, Plus), to as low as 33% (Lidl) (PAN Europe 2008). The British retailer Marks & Spencer plans to have all of its fruits, vegetables and salads free of any pesticide residues by 2020 (Marks & Spencer 2010).

[3] In the U.S., for example, collective private standards were first adopted by Wal-Mart on a nation-wide basis in 2008 (Wal-Mart 2008a). In addition, Wal-Mart implemented steps towards reduced packaging by its suppliers (Wal-Mart 2008b) and a more sustainable global supply chain (Wal-Mart 2011).

use private quality standards as a strategic instrument to gain buyer power in procurement markets.[4] So far, this conjecture has not been formally analyzed.[5] We intend to narrow this gap by investigating the retailers' quality choice in a vertical bargaining setting.

More precisely, we consider a vertical structure with two downstream retailers that are supplied by a finite number of upstream producers with increasing marginal costs of production. The retailers are assumed to impose private quality requirements that must be fulfilled by their respective suppliers. Taking the retailers' quality standards as given, the upstream producers decide which retailer they exclusively supply and, thus, which quality standard they meet. Compliance with a higher quality standard is associated with higher quality costs.[6] Furthermore, the suppliers are not

[4] Further incentives for retailers to set private quality standards might be to prevent a potential decrease in revenue due to reputation losses (OECD 2006), to respond to public minimum standards (e.g., Valletti 2000; Crampes and Hollander 1995; Ronnen 1991), to pre-empt or influence public regulation (e.g., McCluskey and Winfree 2009; Lutz, Lyon and Maxwell 2000), to counter producers' lobbying for low public minimum quality standards (Vandemoortele 2011), to substitute for inadequate public regulation in developing countries (e.g., Marcoul and Veyssiere 2010), or to safeguard against liability claims (e.g., Giraud-Héraud, Hammoudi and Soler 2006; Giraud-Héraud et al. 2008). There is also a fierce debate on whether increasing quality requirements by large retailers may impose entry barriers for suppliers in developing countries, in particular for small-scale producers (e.g., OECD 2007, 2006; García Martinez and Poole 2004; Balsevich et al. 2003; Boselie, Henson and Weatherspoon 2003).

[5] Hammoudi, Hoffmann and Surry (2009) even state that the understanding of the strategic aspects of private quality standards in vertical relations is still underdeveloped.

[6] Production costs in the food sector are increasing in quality due to the necessary replacement of pesticides, herbicides or fertilizer by more expensive raw materials, increased management duties and higher labor inputs. Further quality-related cost increases are associated with the development and implementation of quality-management systems, stricter testing and documentation, changes in the production processes, and certification requirements.

able to adjust the quality of their production in the short-term since the product quality depends on the underlying production processes. Given the retailers' quality requirements and the suppliers' delivery decision, both retailers enter into bilateral negotiations with their respective suppliers about the delivery conditions. If a supplier fails to find an agreement with its selected retailer, it is able to switch the delivery to the other retailer as long as it complies with the respective quality requirements. Upon successful completion of the negotiations, each supplier produces and delivers its product to the retailer. Each retailer transforms the received inputs into a final good and sells it to consumers in a perfectly competitive market.

We find that there exist two asymmetric equilibria in the retailers' quality choice. If one retailer sets a relatively high quality standard, the other retailer has an incentive to undercut this quality requirement. The reason is that the suppliers cannot adjust their product quality in the short-term. Accordingly, the suppliers complying with the lower quality standard lose their outside option, which improves the bargaining position of the low-quality retailer. In turn, if one retailer sets a relatively low quality standard, the other retailer has an incentive to implement stricter quality requirements. By increasing its quality standard, the high-quality retailer weakens the outside option of its suppliers since they incur the production costs for the high quality standard but are rewarded for the lower quality only when supplying the low-quality retailer. This improves the bargaining position of the high-quality retailer. In equilibrium, more suppliers decide to deliver to the high-quality retailer than to the low-quality retailer. This induces inefficiencies in the upstream market as an efficient production structure requires that both retailers set the same quality standard and the suppliers split equally between the retailers. Overall, our analysis reveals that the retailers use the private quality standards as a strategic instrument to improve their bargaining position in the intermediate goods market, resulting in inefficient upstream production.

Although quality standards are receiving growing attention, few articles address retailers' private standards in vertical relations.[7] Insights can be found in studies on premium private labels (PPLs). Considering a vertical chain with a finite number of upstream producers delivering to a finite number of local retail monopolies via a spot market, Giraud-Héraud, Rouached and Soler (2006) analyze the incentive of a retailer to establish a PPL, which is based on direct contracting between the retailer and its PPL suppliers. They find that the incentive for a retailer to differentiate its business via a PPL is the higher the lower the public minimum quality standard (MQS). In a similar framework, Bazoche, Giraud-Héraud and Soler (2005) analyze the interest of producers to commit to a retailer's PPL. They show that fewer producers have an incentive to deliver the PPL when the quality of the MQS is increasing. Furthermore, they find that the introduction of a PPL results in higher prices in the intermediate goods market. In contrast to our findings, however, both articles show that the aim of a PPL is not to increase the bargaining power of the retailer.[8]

Our analysis is also related to the large theoretical literature on the sources of buyer power. Potential sources of buyer power include credible threats to vertically integrate or to support market entry at the upstream level (e.g., Katz 1987; Sheffman

[7]For example, Valletti (2000), Crampes and Hollander (1995) and Ronnen (1991) analyze private standard setting in response to the introduction of a public minimum standard. Focussing on product differentiation, private quality decisions of firms are also studied by Motta (1993) and Gal-Or (1985, 1987). However, all these papers neglect vertical supply structures.

[8]Collective standard setting of retailers is analyzed by Giraud-Héraud, Hammoudi and Soler (2006) as well as Giraud-Héraud et al. (2008). Both articles analyze the introduction of a collective standard for a given public MQS, assuming that retailers are price takers in the procurement market. In their models, the retailers' incentive to implement a collective standard depends on the existence of a legal liability rule.

and Spiller 1992), potential delisting strategies after downstream mergers (e.g., Inderst and Shaffer 2007), producers' differentiation (Chambolle and Berto Villas-Boas 2010) as well as a greater degree of retailers' differentiation compared to producers' differentiation (Allain 2002).[9] We show that downstream firms' quality requirements may constitute an additional source of buyer power.

The remainder of the article is organized as follows. First, we present our model. Subsequently, we conduct the equilibrium analysis and investigate the private quality standards of the retailers under perfect competition. To check the robustness of our results, we further extend our analysis to imperfect competition. Finally, we conclude and derive the relevant policy implications.

The Model

We consider a food supply chain with two symmetric downstream retailers D_i, $i = 1, 2$, and $N \geq 2$ symmetric upstream suppliers. Each retailer implements a private quality standard q_i, which has to be met by their respective suppliers. The higher q_i, the more demanding the quality requirements. Taking as given the retailers' private quality standards, the N upstream firms decide which retailer they supply and, thus, which quality standard they comply with. Let U_{ij} denote the suppliers that deliver to retailer D_i. Without loss of generality, we assume that the N_1 upstream firms $U_{11}, ..., U_{1N_1}$ sell exclusively to the downstream firm D_1, while the remaining $N_2 = N - N_1$ upstream firms $U_{2N_1+1}, ..., U_{2N}$ deliver exclusively to the downstream firm D_2. The delivery conditions are based on bilateral and simultaneous negotiations between the retailers and their respective suppliers, specifying the quantity to be delivered and a fixed

[9] For extended surveys on buyer power, see Inderst and Mazzarotto (2008) as well as Inderst and Shaffer (2008).

payment to be made in return.

Each retailer transforms the received inputs on a one-to-one basis into a single consumer good. The total quantity X_i retailer D_i sells of good i consists of the sum of intermediate inputs delivered by its upstream suppliers, i.e.

$$X_i = \sum_{j=a_i}^{A_i} x_{ij} \text{ with: } \begin{cases} a_i = 1,\ A_i = N_1 & \text{for } i = 1 \\ a_i = N_1 + 1,\ A_i = N & \text{for } i = 2 \end{cases}, \tag{1}$$

where x_{ij} denotes the quantity delivered by each individual supplier. The retailers are assumed to incur costs $K(X_i)$ for distributing the products to the final consumers. The retailers' cost functions are twice continuously differentiable, increasing and strictly convex in X_i, i.e. $K'(X_i),\ K''(X_i) > 0$ and $K(0) = 0$. These assumptions refer to retailers' scarce shelf space and limited storage capacities.

Moreover, each supplier incurs total costs of $C(x_{ij}, q_i)$ for producing the quantity x_{ij} at the quality level q_i, where $C(0, q_i) = 0$ and $C_{x_{ij}}(0, q_i) = 0$.[10] The suppliers' cost functions are twice continuously differentiable, increasing and strictly convex in both x_{ij} and q_i. For all $x_{ij}, q_i > 0$, we, thus, have $C_\tau(x_{ij}, q_i),\ C_{\tau\tau}(x_{ij}, q_i), C_{x_{ij}q_i}(x_{ij}, q_i) > 0$ for $\tau = x_{ij}, q_i$. The convexity in quantities reflects decreasing returns to scale and approximates suppliers' capacity constraints, while the convexity in qualities characterizes decreasing marginal effects from quality investments.

For ease of exposition, we assume that the retailers sell their products in perfectly competitive markets, regardless of their individual quality decision.[11] In other words,

[10] Subscripts denote partial derivatives.

[11] The assumption of perfect competition allows us to minimize the complex role of downstream market features. Later, we relax this assumption by considering imperfect competition in the downstream market.

we consider perfect competition for each quality level q_i.[12] Hence, each retailer acts as a price taker in the downstream market, facing a perfectly elastic inverse demand curve[13] $P(q_i)$ with $P'(q_i) > 0$ and $P''(q_i) < 0$.[14]

The game consists of four stages:

1. In stage one, each retailer implements a private quality standard, q_i.

2. In stage two, the N upstream firms decide which retailer they supply and, thus, which quality standard they comply with.

3. In stage three, the two retailers negotiate simultaneously and bilaterally with their respective suppliers about a quantity-forcing delivery contract. Production takes place upon successful completion of the negotiations.

4. In stage four, the retailers sell to final consumers.

The delivery contracts are assumed to be short-term, which corresponds to the observation that contracts in the agrifood sector tend to be single-season (Jang and Olson 2010). Additionally, we assume that the suppliers cannot adjust the quality of their products in the short-term. The rationale for this assumption is that quality

[12] For simplicity, we assume that the quality levels are continuously distributed. In reality, however, the quality levels are often discrete.

[13] Note, however, that the aggregated inverse demand for any quality level is downward sloping in quantity.

[14] These assumptions reflect the observation that consumers are willing to pay a premium for high-quality products (i.e. $P'(q_i) > 0$), such as eco-labeled food (Bougherara and Combris 2009), organic products (Gil, Gracia and Sánchez 2000) or high-quality attributes of milk (Bernard and Bernard 2009; Brooks and Lusk 2010; Kanter, Messer and Kaiser 2009) and beef (Gao and Schroeder 2009). However, the higher the quality level the less consumers are willing to pay for additional quality, i.e. $P''(q_i) < 0$.

adjustments often require changes in the underlying production process (Codron, Giraud-Héraud and Soler 2005) and the adoption of different production technologies (Mayen, Balagtas and Alexander 2010), which are based on long-term investments in specific technologies, production facilities or the implementation of a particular quality-management system.

Furthermore, we make the following bargaining assumptions:

- *Simultaneous and Efficient Bargaining.* Each retailer bargains simultaneously and bilaterally with its respective suppliers about quantity-forcing delivery contracts $T_{ij}(x_{ij}, F_{ij})$, determining the quantity x_{ij} to be delivered by the supplier U_{ij} and the fixed payment F_{ij} to be made in return by the retailer D_i.[15] This could, for instance, reflect a situation where the retailer delegates representatives that negotiate in parallel with the suppliers (see, e.g., Inderst and Wey 2003). Thereby, any retailer-supplier pair $D_i - U_{ij}$ chooses the quantity x_{ij} so as to maximize their joint profit, taking as given the outcome of all other simultaneous negotiations. The fixed fee F_{ij} serves to divide the joint profit such that each party gets its disagreement payoff plus half of the incremental gains from trade, which refer to the joint profit minus the disagreement payoffs. This approach is consistent with the commonly used bargaining solutions, such as the symmetric Nash bargaining solution (Nash 1953) and the Kalai-Smorodinsky bargaining solution (Kalai and Smorodinsky 1975).[16]

[15] Non-linear tariffs in the form of quantity-forcing contracts account for the fact that relations between sellers and buyers are often based on more complex contracts than simple linear pricing rules (Rey and Vergé 2008). Empirical evidence is provided by Bonnet and Dubois (2010) and Berto Villas-Boas (2007).

[16] The cooperative approach described can also be interpreted in terms of a non-cooperative bargaining approach, such as the alternating-offers bargaining proposed by Rubinstein (1982). If

- *Non-Contingent Contracts.* We assume that the terms of delivery are not contingent on the negotiation outcome of a rival pair. Likewise, we do not allow for renegotiation in the case of negotiation breakdown between any retailer-supplier pair (see, e.g., Horn and Wolinsky 1988, O'Brien and Shaffer 1992, McAfee and Schwartz 1994, 1995). This might be the case when a breakdown in the negotiations between the retailer and one of the suppliers is observable but not verifiable (in court) and, therefore, cannot be contracted upon (Caprice 2006).

- *Disagreement Payoffs.* If the negotiations between the retailer D_i and one of its suppliers U_{ij} fail, the retailer D_i is left to sell the quantities obtained from the remaining suppliers. In turn, the supplier U_{ij} can switch to the retailer D_k, $k = 1, 2$, $k \neq i$, when complying with the respective quality requirements q_k. Note that a switching supplier cannot change its product quality and, thus, its quality-related production costs. However, it is able to adjust the quantity to be produced since production starts only after successful completion of the negotiations.

Using our assumptions, the downstream firms' profits refer to[17]

$$(2)\quad \Pi^{D_i}(\cdot) = R(X_i, q_i) - K(X_i) - \sum_{j=a_i}^{A_i} F_{ij} \text{ with: } \begin{cases} a_i = 1,\ A_i = N_1 & \text{for } i = 1 \\ a_i = N_1 + 1,\ A_i = N & \text{for } i = 2 \end{cases},$$

where $R(X_i, q_i) := P(q_i)X_i$ denotes the revenue of retailer D_i. Our assumptions

the time interval between offers becomes relatively small, the solution of the dynamic non-cooperative process converges to the symmetric Nash bargaining solution (Binmore, Rubinstein and Wolinsky 1986).

[17] In order to simplify the notation, we omit the arguments of the functions where this does not lead to any confusion.

on the retailers' costs and the inverse demand faced by each retailer guarantee that the profit $\Pi^{D_i}(\cdot)$ is strictly concave in X_i. For the upstream firm U_{ij} supplying the downstream firm D_i, the profit is given by

$$\Pi^{U_{ij}}(\cdot) = F_{ij} - C(x_{ij}, q_i). \tag{3}$$

Negotiation Outcomes and Delivery Choice

Since our solution concept is subgame perfection, we solve the game by backward induction. In the last stage of the game, each retailer sets its quantity so as to maximize its profit given the delivery contracts negotiated before. Hence, the quantity choice of the downstream retailers is constrained by the negotiation outcomes with the upstream suppliers, such that the retailers cannot sell more than they get from their suppliers.[18] Proceeding further backwards, we solve for the negotiation outcomes in the intermediate goods market. We then turn to the delivery choice of the suppliers. The retailers' decision about their private quality standards is examined in the next section.

Intermediate Goods Market. To analyze the negotiation outcomes in the intermediate goods market, we have to specify the players' disagreement payoffs. In the case of negotiation breakdown with supplier U_{ij}, the retailer D_i is left to sell the deliveries made by the other suppliers. The supplier U_{ij}, however, can enter into negotiations with the other retailer D_k as long as it complies with the respective quality requirements q_k. Otherwise, the supplier's disagreement payoff equals zero.

[18] Note that the retailers always have an incentive to sell a larger quantity in the final consumer market than they receive from the suppliers as they do not account for the suppliers' production costs.

We denote an upstream firm U_{ij} that switches from D_i to D_k by $\widetilde{U}_{kj}$.

(i) *Disagreement Payoffs.* Assuming without loss of generality $q_1 \geq q_2$, a supplier U_{1j} initially delivering to D_1 can switch its delivery to D_2 when the negotiations with retailer D_1 fail. Then, the switching supplier $\widetilde{U}_{2j}$ negotiates with D_2 about a quantity-forcing delivery tariff $\widetilde{T}_{2j}(\widetilde{x}_{2j}, \widetilde{F}_{2j})$, taking the contracts $T_{2j}(x_{2j}, F_{2j})$ between D_2 and all its initial suppliers U_{2j} as given. Since the suppliers cannot adjust their product quality in the short-term, the switching supplier still incurs the variable costs associated with the higher quality requirements q_1. However, it is able to adjust the quantity as production starts after successful completion of the negotiations. Thus, the profit of the switching supplier $\widetilde{U}_{2j}$ refers to

$$\widetilde{\Pi}^{\widetilde{U}_{2j}}(\cdot) = \widetilde{F}_{2j} - C\left(\widetilde{x}_{2j}, q_1\right). \tag{4}$$

The profit of the downstream retailer D_2 in the negotiations with $\widetilde{U}_{2j}$ is given by

$$\widetilde{\Pi}^{D_2}(\cdot) = R(X_2 + \widetilde{x}_{2j}, q_2) - K(X_2 + \widetilde{x}_{2j}) - \sum_{l=N_1+1}^{N} F_{2l} - \widetilde{F}_{2j}. \tag{5}$$

For given contracts between D_2 and suppliers U_{2j}, the retailer and the switching supplier choose a quantity that maximizes their joint profit denoted by

$$\begin{aligned} \widetilde{\Pi}_2(\cdot) &= \widetilde{\Pi}^{D_2}(\cdot) + \widetilde{\Pi}^{\widetilde{U}_{2j}}(\cdot) \\ &= R(X_2 + \widetilde{x}_{2j}, q_2) - K(X_2 + \widetilde{x}_{2j}) - \sum_{l=N_1+1}^{N} F_{2l} - C\left(\widetilde{x}_{2j}, q_1\right). \end{aligned} \tag{6}$$

Accordingly, the equilibrium quantity $\widetilde{x}^*_{2j}$ of the switching supplier is implicitly determined by the solution of

$$\text{(7)} \qquad \frac{\partial \widetilde{\Pi}_2(\cdot)}{\partial \widetilde{x}_{2j}} = P(q_2) - K'(X_2 + \widetilde{x}^*_{2j}) - \frac{\partial C(\widetilde{x}^*_{2j}, q_1)}{\partial \widetilde{x}_{2j}} = 0.$$

The equilibrium quantity $\widetilde{x}^*_{2j}(X_2, q_1, q_2)$ is decreasing in q_1 due to higher production costs for higher qualities. In contrast, $\widetilde{x}^*_{2j}(X_2, q_1, q_2)$ is increasing in q_2 as consumer willingness-to-pay is increasing in the product quality. Moreover, $\widetilde{x}^*_{2j}(X_2, q_1, q_2)$ is increasing in N_1 (decreasing in N_2). That is, the equilibrium quantity to be delivered by the switching supplier $\widetilde{U}_{2j}$ is the lower the more suppliers are already delivering to D_2 due to the convexity of the cost functions.

The joint profit is divided by the fixed fee such that each party gets its disagreement payoff plus half of the incremental gains from trade, i.e. the joint profit minus the respective disagreement payoffs. While the switching upstream firm $\widetilde{U}_{2j}$ has no further outside option in the case of negotiation breakdown with D_2, the retailer D_2 can still sell the quantities of suppliers U_{2j} it has already made an agreement with. Accordingly, the disagreement payoff of retailer D_2 is given by

$$\text{(8)} \qquad \Pi^{D_2}(\cdot) = R(X_2, q_2) - K(X_2) - \sum_{l=N_1+1}^{N} F_{2l}.$$

Using (6) and (8), the incremental gains from trade are obtained as

$$\text{(9)} \quad \widetilde{G}_2(\cdot) = R(X_2 + \widetilde{x}^*_{2j}, q_2) - R(X_2, q_2) - \big(K(X_2 + \widetilde{x}^*_{2j}) - K(X_2)\big) - C(\widetilde{x}^*_{2j}, q_1).$$

Thus, the equilibrium fixed fee $\widetilde{F}^*_{2j}$ is chosen such that

$$\text{(10)} \qquad \widetilde{\Pi}^{\widetilde{U}_{2j}}(\cdot) = \widetilde{F}^*_{2j} - C(\widetilde{x}^*_{2j}, q_1) = \frac{1}{2}\widetilde{G}_2(\cdot),$$

implying

$$\widetilde{F}_{2j}^{*}(X_2,q_1,q_2)=\frac{\Delta R(X_2+\widetilde{x}_{2j}^{*},q_2)-\Delta K(X_2+\widetilde{x}_{2j}^{*})+C(\widetilde{x}_{2j}^{*},q_1)}{2}, \tag{11}$$

where we denote the difference in revenues by $\Delta R(X_2+\widetilde{x}_{2j}^{*},q_2):=R(X_2+\widetilde{x}_{2j}^{*},q_2)-R(X_2,q_2)$ and the difference in retail costs by $\Delta K(X_2+\widetilde{x}_{2j}^{*}):=K(X_2+\widetilde{x}_{2j}^{*})-K(X_2)$.

Due to our assumption $q_1\geq q_2$, an upstream firm U_{2j}, initially negotiating with retailer D_2, can switch its delivery to retailer D_1 in the case of disagreement with D_2 only if $q_1=q_2$. By the same argument as above, we get $\widetilde{x}_{1j}^{*}(X_1,q_1,q_2)$ and $\widetilde{F}_{1j}^{*}(X_1,q_1,q_2)$.

Lemma 1 *For given X_i and $T_{ij}(x_{ij},F_{ij})$, there exists an equilibrium delivery contract specified as $\widetilde{T}_{ij}(\widetilde{x}_{ij}^{*},\widetilde{F}_{ij}^{*})$ with $i,k=1,2$, $i\neq k$, where $\widetilde{x}_{ij}^{*}(X_i,q_1,q_2)$ maximizes the joint profit of each retailer-supplier pair $D_i-\widetilde{U}_{ij}$ and the fixed fee $\widetilde{F}_{ij}^{*}(X_i,q_1,q_2)$ shares the joint profit. Comparative statics reveal that $\widetilde{x}_{ij}^{*}(X_i,q_1,q_2)$ is increasing in q_i, while it is decreasing in q_k and N_i.*

Proof. See Appendix A. ■

(ii) *Negotiations.* Using our above results, the disagreement payoff of the upstream firm U_{1j} when negotiating with its initially selected retailer D_1 is given by

$$\widehat{\Pi}^{U_{1j}}(\cdot):=\widetilde{\Pi}^{\widetilde{U}_{2j}*}(\cdot)=\widetilde{F}_{2j}^{*}-C(\widetilde{x}_{2j}^{*},q_1). \tag{12}$$

Correspondingly, the disagreement payoff of the upstream firm U_{2j}, initially negotiating with the retailer D_2, is given by

$$\widehat{\Pi}^{U_{2j}}(\cdot)=\begin{cases}0 & \text{if } q_1>q_2\\ \widetilde{F}_{1j}^{*}-C(\widetilde{x}_{1j}^{*},q_2) & \text{if } q_1=q_2\end{cases}. \tag{13}$$

The retailers, in turn, can still sell the quantities delivered by the remaining suppliers in the case of disagreement. Thus, the retailers' disagreement payoffs are given by

$$\widehat{\Pi}^{D_i}(\cdot) = R(X_i - x_{ij}, q_i) - K(X_i - x_{ij}) - \sum_{l=a_i, l\neq j}^{A_i} F_{il}, \tag{14}$$

where a_i and A_i are defined as in (2).

In the negotiations, the retailer D_i agrees with each supplier U_{ij} on a delivery quantity that maximizes their joint profit given by

$$\Pi_i(\cdot) = \Pi^{D_i}(\cdot) + \Pi^{U_{ij}}(\cdot) = R(X_i, q_i) - K(X_i) - \sum_{l=a_i, l\neq j}^{A_i} F_{il} - C(x_{ij}, q_i). \tag{15}$$

Accordingly, the symmetric equilibrium quantity $x_{ij}^* = x_i^*(N_i, q_i)$ each supplier U_{ij} delivers to D_i is implicitly given by the solution of

$$\frac{\partial \Pi_i(\cdot)}{\partial x_{ij}} = P(q_i) - K'(X_i^*) - \frac{\partial C(x_i^*, q_i)}{\partial x_{ij}} = 0, \tag{16}$$

where the total equilibrium quantity sold by retailer D_i refers to $X_i^* = N_i x_i^*$.

The fixed fee divides the joint profit such that each party gets its disagreement payoff plus half of the incremental gains from trade. Using (12), (14) and (15), the incremental gains from trade of retailer D_1 and supplier U_{1j}, i.e. $G_1(\cdot) := \Pi_1(\cdot) - \widehat{\Pi}^{D_1}(\cdot) - \widehat{\Pi}^{U_{1j}}(\cdot)$, can be written as

$$G_1(\cdot) = \Delta R(X_1^*, q_1) - \Delta K(X_1^*) - C(x_1^*, q_1) - \left(\widetilde{F}_{2j}^* - C(\widetilde{x}_{2j}^*, q_1)\right), \tag{17}$$

where we denote the difference in revenues by $\Delta R(X_1^*, q_1) := R(X_1^*, q_1) - R(X_1^* - x_1^*, q_1)$ and the difference in retail costs by $\Delta K(X_1^*) := K(X_1^*) - K(X_1^* - x_1^*)$. Thus, the symmetric equilibrium fixed fees $F_{1j}^* = F_1^*$ are chosen such that

$$\Pi^{U_{1j}}(\cdot) = F_1^* - C(x_1^*, q_1) = \widehat{\Pi}^{U_{1j}}(\cdot) + \frac{1}{2} G_1(\cdot), \tag{18}$$

implying

$$F_1^*(N_1, q_1, q_2) = \frac{\Delta R(X_1^*, q_1) - \Delta K(X_1^*) + C(x_1^*, q_1) + \widetilde{F}_{2j}^* - C(\widetilde{x}_{2j}^*, q_1)}{2}, \tag{19}$$

where $\widetilde{F}_{2j}^* - C(\widetilde{x}_{2j}^*, q_1)$ refers to the value of the supplier's outside option (see 12). Analogously, the incremental gains from trade of retailer D_2 and supplier U_{2j} are given by

(20)

$$G_2(\cdot) = \begin{cases} \Delta R(X_2^*, q_2) - \Delta K(X_2^*) - C(x_2^*, q_2) & \text{if } q_1 > q_2 \\ \Delta R(X_2^*, q_2) - \Delta K(X_2^*) - C(x_2^*, q_2) - \left(\widetilde{F}_{1j}^* - C(\widetilde{x}_{1j}^*, q_2)\right) & \text{if } q_1 = q_2 \end{cases},$$

where we denote the difference in revenues by $\Delta R(X_2^*, q_2) := R(X_2^*, q_2) - R(X_2^* - x_2^*, q_2)$ and the difference in retail costs by $\Delta K(X_2^*) := K(X_2^*) - K(X_2^* - x_2^*)$. The symmetric equilibrium fixed fees $F_{2j}^* = F_2^*$ are chosen such that

$$\Pi^{U_{2j}}(\cdot) = F_2^* - C(x_2^*, q_2) = \widehat{\Pi}^{U_{2j}}(\cdot) + \frac{1}{2} G_2(\cdot), \tag{21}$$

implying

$$F_2^*(N_2, q_1, q_2) = \begin{cases} \frac{\Delta R(X_2^*, q_2) - \Delta K(X_2^*) + C(x_2^*, q_2)}{2} & \text{if } q_1 > q_2 \\ \frac{\Delta R(X_2^*, q_2) - \Delta K(X_2^*) + C(x_2^*, q_2) + \widetilde{F}_{1j}^* - C(\widetilde{x}_{1j}^*, q_2)}{2} & \text{if } q_1 = q_2 \end{cases}. \tag{22}$$

It turns out that the suppliers get a larger share of the joint profit if they deliver to the high-quality retailer than if they supply the low-quality retailer.

Lemma 2 *For given N_i, q_1 and q_2, there exists a symmetric equilibrium delivery contract $T_i(x_i^*, F_i^*)$ $\forall i, k = 1, 2$, $i \neq k$, where $x_i^*(N_i, q_i)$ maximizes the joint profit of the retailer-supplier pair $D_i - U_{ij}$ and the fixed fee $F_i^*(N_i, q_1, q_2)$ shares the joint profit. Comparative statics reveal that $x_i^*(N_i, q_i)$ is decreasing (increasing) in N_i (N_k), while the overall quantity X_i^* is increasing (decreasing) in N_i (N_k). Furthermore, $x_i^*(N_i, q_i)$ is decreasing in q_i as long as $P'(q_i) - (\partial^2 C(x_i^*, q_i)/\partial x_{ij} \partial q_i) < 0$.*

Proof. See Appendix A. ■

Our results reveal that $x_i^*(N_i, q_i)$ is decreasing in N_i due to the convexity of both production and distribution costs. The increase of $x_i^*(N_i, q_i)$ in N_k is just a mirror image of its decrease in N_i since $N_k = N - N_i$. Furthermore, $x_i^*(N_i, q_i)$ is decreasing in q_i as long as the marginal costs of production are sufficiently high, i.e. $\partial^2 C(x_i^*, q_i)/\partial x_{ij} \partial q_i > P'(q_i)$.

Using our previous results and taking into account the discontinuity in the equilibrium fixed fees (see 22), the retailers' reduced profit functions are given by

$$\Pi^{D_i *}(\cdot) = R(X_i^*, q_i) - K(X_i^*) - N_i F_i^*. \tag{23}$$

Correspondingly, the reduced profit functions of the suppliers are obtained as

$$\Pi^{U_{1j} *}(\cdot) = \frac{\Delta R(X_1^*, q_1) - \Delta K(X_1^*) - C(x_1^*, q_1) + \widetilde{F}_{2j}^* - C(\widetilde{x}_{2j}^*, q_1)}{2} \tag{24}$$

and

$$\Pi^{U_{2j} *}(\cdot) = \begin{cases} \frac{\Delta R(X_2^*, q_2) - \Delta K(X_2^*) - C(x_2^*, q_2)}{2} & \text{if } q_1 > q_2 \\ \frac{\Delta R(X_2^*, q_2) - \Delta K(X_2^*) - C(x_2^*, q_2) + \widetilde{F}_{1j}^* - C(\widetilde{x}_{1j}^*, q_2)}{2} & \text{if } q_1 = q_2 \end{cases}. \tag{25}$$

Delivery Choice of Upstream Firms. Taking the retailers' quality requirements

q_1 and q_2 as given, the upstream suppliers decide whether they deliver to retailer D_1 or D_2. Any upstream supplier has an outside option if both retailers impose the same quality standards. Hence, for $q_1 = q_2$, half of the suppliers would opt for retailer D_1, while the other half would opt for retailer D_2. If, in turn, the retailers' quality requirements differ, i.e. $q_1 > q_2$, only the suppliers delivering to the high-quality retailer D_1 have an outside option in the case of negotiation breakdown. This makes adherence to the higher quality standard more attractive at first. However, as the retailers' marginal costs of distribution are increasing, i.e. $K'(X_i) > 0$, not all upstream firms decide to supply the high-quality retailer.[19]

In equilibrium, the upstream firms are indifferent as to which retailer they supply. Considering $q_1 > q_2$ and using the reduced profit functions given in (24) and (25), it must hold in equilibrium that

$$\Pi^{U_{1j}*}(N_1, q_1, q_2) = \Pi^{U_{2j}*}(N - N_1, q_2). \tag{26}$$

Lemma 3 *For $q_1 > q_2$, equation (26) has a unique solution $N_1^*(q_1, q_2)$, indicating the equilibrium number of suppliers that deliver to retailer D_1. Correspondingly, the equilibrium number of upstream firms delivering to D_2 is obtained as $N_2^*(q_1, q_2) = N - N_1^*(q_1, q_2)$.*

Proof. See Appendix A. ■

Denoting $x_i^{**}(q_1, q_2) := x_i^*(N_i^*(\cdot), q_i)$, $X_i^{**}(q_1, q_2) := N_i^*(\cdot)\, x_i^{**}(q_1, q_2)$ and

[19] Note that we would get a similar effect without considering convex retail costs if there was imperfect competition in the downstream market. Under imperfect competition, retailers can affect the market price of their goods by their output decisions. Since the market price is decreasing in the overall quantity of the good sold in the market, the marginal contribution of the individual suppliers is decreasing in the number of suppliers delivering to the same retailer.

$\widetilde{x}_{kj}^{**}(q_1, q_2) := \widetilde{x}_{kj}^{*}(N_k^*(\cdot), q_1, q_2)$, the comparative statics of $N_1^*(q_1, q_2)$ are as follows:

Lemma 4 *For $q_1 > q_2$, comparative statics reveal that $N_1^*(q_1, q_2)$ is increasing in q_1 if $\partial C(x_1^{**}, q_1)/\partial q_1 < \left(P'(q_1)x_1^{**} - \partial C(\widetilde{x}_{2j}^{**}, q_1)/\partial q_1 - K''(X_1^{**})(N_1^* - 1)x_1^{**}\left(\partial x_1^{**}/\partial q_1\right)\right)$. Moreover, $N_1^*(q_1, q_2)$ is decreasing in q_2 if $\partial C(x_2^{**}, q_2)/\partial q_2 < P'(q_2)\left(x_2^{**} - \widetilde{x}_{2j}^{**}/2\right)$ $- K''(X_2^{**})\left[(N_2^* - 1)x_2^{**} - N_2^*\widetilde{x}_{2j}^{**}/2\right]\left(\partial x_2^{**}/\partial q_2\right)$.*

Proof. See Appendix A. ■

Considering $q_1 > q_2$, an increase in q_1 has two countervailing effects on the profits of suppliers U_{1j} given in (24). First, it results in a higher gross profit, i.e. $\partial\left[\Delta R(X_1^{**}, q_1) - \Delta K(X_1^{**}) - C(x_1^{**}, q_1)\right]/\partial q_1 > 0$. Second, it implies a decline in the suppliers' outside option, i.e. $\partial\left[\widetilde{F}_{2j}^*(N_2^*, q_1, q_2) - C(\widetilde{x}_{2j}^{**}, q_1)\right]/\partial q_1 < 0$. As long as the first effect dominates the second, a higher q_1 results in a larger number of suppliers delivering to the high-quality retailer and, thus, in fewer suppliers delivering to D_2. This is the case if the production costs are not increasing too strongly in q_1 (see lemma 4).

A rise in q_2, however, results in a higher profit for the suppliers U_{2j} delivering to the low-quality retailer D_2, i.e. $\partial\left[\Delta R(X_2^{**}, q_2) - \Delta K(X_2^{**}) - C(x_2^{**}, q_2)\right]/\partial q_2 > 0$. At the same time, it improves the outside option of the suppliers U_{1j} delivering to the high-quality retailer D_1. Again, if the first effect dominates the second, a higher q_2 leads to a lower number of suppliers delivering to the high-quality retailer, implying a larger number of suppliers opting for the low-quality retailer. This holds if the production costs are not increasing too strongly in q_2 (see lemma 4).

Private Quality Standards

In this section, we analyze the retailers' choice of quality requirements. Both retailers set their private quality standards so as to maximize their respective profit functions. Denoting $F_i^{**} := F_i^*(N_i^*, q_1, q_2)$, the equilibrium quality requirements are, thus, given by

$$
\begin{aligned}
(27) \qquad q_i^* &: = \arg\max_{q_i} \Pi^{D_i**}(\cdot) \\
\text{with} &: \Pi^{D_i**}(\cdot) = \left[R\left(X_i^{**}, q_i\right) - K(X_i^{**}) - N_i^* F_i^{**}\right].
\end{aligned}
$$

Equilibrium Analysis. In our setting, there exists no symmetric equilibrium in the retailers' quality requirements.[20]

Considering $q_1 = q_2$, the upstream firms can deliver to both retailers when complying with the respective quality standard. Thus, all suppliers have an outside option in the case of disagreement with their initially chosen retailer.

If retailer D_1 increases its quality requirements by an arbitrarily small amount to $q_1 = q_2 + \varepsilon$, two effects emerge: The suppliers U_{2j} delivering to D_2 lose their outside option and the outside option of the suppliers U_{1j} becomes less valuable. The reason for the latter is that the suppliers still incur the production costs associated with q_1 when switching to D_2, while they are only rewarded for supplying q_2. As long as ε is sufficiently small, the first effect dominates the second. Accordingly, delivery to D_1 becomes more attractive, resulting in a higher N_1^*. A larger number of suppliers delivering to the high-quality retailer, in turn, induces the following trade-off: First, the higher N_1^* results in a lower quantity delivered by each supplier (see lemma 2),

[20] If the suppliers generally have no possibility to switch their delivery to the other retailer, there will be a symmetric equilibrium in qualities (see von Schlippenbach and Teichmann 2011).

such that the joint profit of retailer D_1 and any of its suppliers is increasing. Second, a higher N_1^* implies a lower N_2^*, which improves the disagreement payoff of suppliers U_{1j}. In other words, the marginal contribution of the switching supplier $\widetilde{U}_{2j}$ to the joint profit with the retailer D_2 is increasing if N_2^* is decreasing (lemma 1). As the first effect dominates the second, the retailers have an incentive to deviate from the symmetric candidate equilibrium.

Proposition 1 *There exists no symmetric equilibrium in the retailers' quality requirements as the retailers always have an incentive to deviate from the symmetric candidate equilibrium.*

Proof. See Appendix A. ■

To ensure the existence of an asymmetric equilibrium in the retailers' quality choice, the marginal costs of production need to be sufficiently convex in quality and quantity as this eliminates the incentive for retailers to leapfrog each other. Consistent with our above assumptions, we apply the following inverse demand functions $P(q_i) = \sqrt{q_i}$, production-cost functions $C(x_{ij}, q_i) = q_i^3 x_{ij}^2/3$ and retail-cost functions $K(X_i) = X_i^2$ for $i = 1, 2$ to illustrate our results numerically.[21]

Result 1 *Numerical analysis shows that there exists an asymmetric equilibrium in the retailers' quality choice, i.e. $q_1^* > q_2^*$, if the suppliers' production costs are sufficiently convex in quality and quantity.*

< Insert figure 1 >

[21] Numerical results for the equilibrium quantities, fixed fees and the number of suppliers delivering to D_i can be found in Appendix B.

Considering a relatively low value of q_2^*, the best response of retailer D_1 is to raise its quality requirements above q_2^* (figure 1, upper panel). As described above, an increase in q_1, starting from $q_1 = q_2^*$, leads to more suppliers delivering to D_1 and, thus, to a larger joint profit of the retailer D_1 and any of its suppliers U_{1j} due to the lower quantity delivered by each supplier. However, for very high values of q_1, the rise in the quality-related production costs dominates the favorable quantity effect. This puts limits to the rise in q_1.

Taking now a relatively high quality standard q_1^* as given, the best response of retailer D_2 is to considerably undercut the quality requirements of D_1 (figure 1, lower panel). If q_2 drops just below q_1^*, i.e. $q_2 = q_1^* - \varepsilon$, the suppliers U_{2j} lose their outside option. This makes delivery to the now low-quality retailer less attractive than supplying the high-quality retailer. Furthermore, a lower number of upstream firms supplying the same retailer leads to a larger quantity to be delivered by each of these suppliers (lemma 2). This results in a disproportionately strong increase in the production costs since these are strictly convex in quantity. Retailer D_2, therefore, has an incentive to considerably undercut q_1^*: First, lower quality requirements result in lower quality-related production costs. Second, a lower q_2 relative to q_1^* reduces the outside option of suppliers U_{1j}, making delivery to D_1 less attractive. Note, however, that the retailer D_2 has no incentive to decrease its quality requirements unlimitedly since the reduced quality implies lower prices in the final consumer market and, thus, decreases the retailer's revenue.

Result 2 *Numerical analysis further reveals that the quality requirements q_1^* and q_2^* as well as the difference $q_1^* - q_2^*$ are increasing in N.*

< Insert figure 2 >

The higher N, the more suppliers decide to deliver to the high-quality retailer D_1 since $N_1^* \geq N/2$. This results in a decrease in the quantity delivered by each supplier U_{1j} (lemma 2), leading to a reduction in the quantity-related production costs. On this basis, the retailer D_1 is able to increase its quality requirements in order to strengthen its bargaining position by weakening the suppliers' outside option. A higher q_1^*, in turn, enables the retailer D_2 to increase its quality requirements q_2^* as well, resulting in a higher joint profit with the suppliers. Due to the disproportionate increase of N_1^* in N, a relatively higher quantity is produced by each supplier delivering to the low-quality retailer. This implies that the quality requirement of the low-quality retailer is less increasing in N than the quality requirement of the high-quality retailer. Hence, the spread between q_1^* and q_2^* is increasing in N (figure 2).

Under the assumption of perfect competition, the retailers' choice of private quality standards is not affected by downstream market features. In other words, the retailers do not differentiate in quality in order to soften the competition in final consumer markets. The only reason to differentiate in quality is driven by the retailers' incentive to improve their bargaining position vis-à-vis their suppliers and, thus, to gain buyer power in the intermediate goods market. We find that the joint profit of the low-quality retailer with any of its suppliers is smaller than the respective joint profit obtained by the high-quality retailer as long as the quality requirements have a stronger impact on the retailers' revenue than on production costs. Referring to the above-described outside-option effect, the low-quality retailer gets a larger share of a smaller pie, while the high-quality retailer gets a smaller share of a larger pie. Note that the suppliers make the same profit in equilibrium, no matter which retailer they supply.

The implementation of private quality standards induces inefficiencies in the upstream production. Due to the convexity of the production and distribution costs, the industry profit is maximized if both retailers implement the same quality requirements and the suppliers split equally between the retailers.[22] However, from proposition 1 we know that there is no symmetric equilibrium in the retailers' profit-maximizing quality choice. Hence, we get:

Proposition 2 *The strategic use of private quality standards by retailers results in an inefficient production structure. The inefficiency rises in N since the spread between q_1^* and q_2^* is increasing in N.*[23]

Extension: Imperfect Competition

In the following, we relax the assumption of perfect competition to account for the highly concentrated retail sector in many European countries (Dobson, Waterson and Davies 2003; OECD 2006). Leaving the underlying bargaining mechanism unchanged, we now assume that the retailers are horizontally differentiated and compete in quantities in the final consumer market. This allows us to analyze the impact of downstream market features on the retailers' quality choice. We consider a representative consumer with the utility function[24]

$$U(X_1, X_2) = \sum_{i=1}^{2} \sqrt{q_i} X_i - \frac{1}{2} \left(\sum_{i=1}^{2} X_i^2 + 2\sigma X_1 X_2 \right) - \sum_{i=1}^{2} P_i X_i, \ \forall i = 1, 2, \tag{28}$$

[22] Note that under our assumptions the quality level that maximizes industry profit equals the socially optimal quality level.

[23] The negative impact of private quality standards on the production structure can be limited by enforcing a binding public MQS (see Appendix C).

[24] This utility function is based on the symmetric, additively separable utility function proposed by Dixit and Stiglitz (1977).

where $\sigma \in [0, 1)$ indicates the degree of substitutability between the retailers 1 and 2. The closer σ approaches one, the more the retailers are substitutable. The differentiation is based on parameters associated with the retail outlet, such as store atmosphere, product range and location. Differentiating (28) with respect to X_i, the inverse demand functions refer to $P_i(q_i, X_i, X_k) = \max\left\{\sqrt{q_i} - X_i - \sigma X_k, 0\right\}$, with $i, k = 1, 2$, $i \neq k$. That is, the inverse demand functions are twice continuously differentiable in q_i with $\partial P_i(q_i, \cdot)/\partial q_i > 0$ and $\partial^2 P_i(q_i, \cdot)/\partial q_i^2 < 0$ for $P_i(q_i, \cdot) > 0$. The production-cost functions and the retail-cost functions remain the same as under perfect competition with $C(x_{ij}, q_i) = q_i^3 x_{ij}^2/3$ and $K(X_i) = X_i^2$. Moreover, we still assume that $q_1 \geq q_2$.

Equilibrium Analysis. Solving the third stage of the game, we get the equilibrium quantities $\underline{\widetilde{x}}_{kj}^*(X_i, q_1, q_2)$ and $\underline{x}_i^*(N_i, q_1, q_2)$ as well as the fixed fees $\underline{\widetilde{F}}_{kj}^*(X_i, q_1, q_2)$ and $\underline{F}_i^*(N_i, q_1, q_2)$. In the second stage of the game, we obtain $\underline{N}_i^*$, which leads us to the reduced forms $\underline{x}_i^{**} := \underline{x}_i^*(\underline{N}_i^*, q_1, q_2)$, $\underline{X}_i^{**} := \underline{N}_i^* \underline{x}_i^{**}$ and $\underline{F}_i^{**} := \underline{F}_i^*(\underline{N}_i^*, q_1, q_2)$.[25] Finally, in the first stage, we analyze the equilibrium quality choice of the retailers. There is an asymmetric equilibrium in the retailers' quality requirements as in the case of perfect competition (figure 3). The reasoning is as before: Retailer D_1 strengthens its quality requirements to attract more suppliers and, at the same time, to improve its bargaining position in the negotiations with the suppliers. The best response of retailer D_2 is to reduce its quality requirements. However, the prevalence of imperfect competition gives rise to an additional effect as the quantities sold by the retailers now affect the overall market outcome. By increasing its quality requirements, D_1 commits itself to sell a higher quantity to final consumers. The reason is that the retailer attracts more suppliers by increasing q_1, resulting in a larger $\underline{X}_1^{**}$ (lemma 2).

[25] Numerical results for the equilibrium quantities, fixed fees and the number of suppliers delivering to D_i can be found in Appendix B.

As quantities are strategic substitutes in our setting, the best response of the competitor D_2 is to decrease its quantity in the final consumer market. D_2 is able to do so by reducing its quality requirements. This effect becomes less pronounced the more differentiated the retailers are and, thus, the softer downstream competition. This also implies that the inefficiency induced by the retailers' private standard setting is decreasing in the degree of retail differentiation.

< Insert figure 3 >

Result 3 *The results obtained under perfect competition in the downstream market do not qualitatively change when imperfect downstream competition is considered.*

Minimum Quality Standard. The inefficiency in upstream production induced by the retailers' quality choice under imperfect competition can be limited by enforcing a binding public MQS. Under such a MQS, the retailer with the lower quality requirements cannot unrestrictedly reduce its quality standard in response to increasing quality requirements of the other retailer. As a consequence, the high-quality retailer has less incentive to increase its quality standard, such that the spread in the high and low quality requirements is reduced.[26]

[26] Under perfect competition, the low-quality retailer also increases its quality requirements when a public MQS is enforced. In contrast to the case of imperfect competition, the best response of the high-quality retailer is to increase its quality requirements as well. Overall, the first effect dominates the second, such that a public MQS also mitigates the unfavorable effects of private quality standards under perfect competition (see Appendix C).

Conclusion

Our analysis indicates that retailers use private quality standards to improve their buyer power in the food supply chain, leading to inefficient production structures in the upstream market. The inefficiency in the upstream production is increasing in both the number of upstream suppliers and, in the case of imperfect competition, the degree of substitutability among retailers. We find that the implementation of a binding public MQS mitigates the unfavorable effects from the retailers' strategic use of quality standards.

These results hold for both perfect and imperfect competition in the downstream retail market. However, our findings are limited to production costs that are sufficiently convex in quality and quantity. Moreover, it is required that suppliers cannot easily change their production process to comply with different quality requirements. This refers mainly to industries where producers face high quality-related production costs and are locked in their production processes in the short-term, such as in the production of fruits and vegetables.

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Appendix A

Proof of lemma 1. To determine the comparative statics of $\widetilde{x}_{ij}^{*}(\cdot)$, we apply the implicit-function theorem and use

$$\begin{aligned}
\widetilde{\Pi}_i(\cdot) &= \widetilde{\Pi}^{D_i}(\cdot)+\widetilde{\Pi}^{\widetilde{U}_{ij}}(\cdot)=R(X_i+\widetilde{x}_{ij},q_i)-K(X_i+\widetilde{x}_{ij})-\sum_{l=a_i}^{A_i}F_{il}-C\left(\widetilde{x}_{ij},q_k\right)\\
\text{with} &: \begin{cases} a_i=1,\ A_i=N_1 & \text{for } i=1\\ a_i=N_1+1,\ A_i=N & \text{for } i=2\end{cases}.
\end{aligned}$$

Since

$$\partial^2\widetilde{\Pi}_i(\cdot)/\partial\widetilde{x}_{ij}^2=-\left(K''(X_i+\widetilde{x}_{ij}^{*}(\cdot))+\partial^2 C(\widetilde{x}_{ij}^{*}(\cdot),q_k)/\partial\widetilde{x}_{ij}^2\right)<0, \tag{29}$$

the comparative statics of $\widetilde{x}_{ij}^{*}(\cdot)$ are given by $sign\left(\partial\widetilde{x}_{ij}^{*}(\cdot)/\partial\alpha\right) = sign\left(\partial^2\widetilde{\Pi}_i(\cdot)/\partial\widetilde{x}_{ij}\partial\alpha\right)$ for $\alpha=q_i,q_k,N_i$. Thus, it holds that

$$sign\left(\frac{\partial\widetilde{x}_{ij}^{*}(\cdot)}{\partial q_k}\right) < 0 \text{ since } \frac{\partial^2\widetilde{\Pi}_i(\cdot)}{\partial\widetilde{x}_{ij}\partial q_k}=-\frac{\partial^2 C(\widetilde{x}_{ij}^{*}(\cdot),q_k)}{\partial\widetilde{x}_{ij}\partial q_k}<0, \tag{30}$$

$$sign\left(\frac{\partial\widetilde{x}_{ij}^{*}(\cdot)}{\partial q_i}\right) > 0 \text{ since } \frac{\partial^2\widetilde{\Pi}_i(\cdot)}{\partial\widetilde{x}_{ij}\partial q_i}=P'(q_i)>0, \tag{31}$$

$$sign\left(\frac{\partial\widetilde{x}_{ij}^{*}(\cdot)}{\partial N_i}\right) < 0 \text{ since } \frac{\partial^2\widetilde{\Pi}_i(\cdot)}{\partial\widetilde{x}_{ij}\partial N_i}=-K''(X_i+\widetilde{x}_{ij}^{*})\widetilde{x}_{ij}^{*}<0. \tag{32}$$

Proof of lemma 2. To determine the comparative statics of $x_i^{*}(\cdot)$, we apply the implicit-function theorem. Denoting $H(N_i,x_i^{*}(N_i,q_i))=0$ the first-order condition given in (16) and using $\partial H(\cdot)/\partial x_{ij}=-\left(N_iK''(X_i^{*}(\cdot))+\partial^2 C(x_i^{*}(\cdot),q_i)/\partial x_{ij}^2\right)<0$, we get

$$
\begin{aligned}
(33) \quad sign\left(\frac{\partial x_i^*(\cdot)}{\partial N_i}\right) &= sign\left(\frac{\partial H(N_i, x_i^*(\cdot))}{\partial N_i}\right) = -K''(X_i^*(\cdot))x_i^*(\cdot) < 0 \ , \\
(34) \quad sign\left(\frac{\partial x_i^*(\cdot)}{\partial N_k}\right) &= sign\left(\frac{\partial H(N_i, x_i^*(\cdot))}{\partial N_k}\right) = K''(X_i^*(\cdot))x_i^*(\cdot) > 0.
\end{aligned}
$$

Considering the overall quantity, we have

$$\frac{\partial X_i^*(\cdot)}{\partial N_i} = x_i^*(\cdot)\left(1 - \frac{N_i K''(X_i^*(\cdot))}{N_i K''(X_i^*(\cdot)) + \partial^2 C(x_i^*(\cdot), q_i)/\partial x_{ij}^2}\right) > 0.$$

Correspondingly, it holds that $\partial X_i^*(\cdot)/\partial N_k < 0$. Furthermore, we have

$$
\begin{aligned}
(35) \ sign\left(\frac{\partial x_i^*(\cdot)}{\partial q_i}\right) &= sign\left(\frac{\partial H(N_i, x_i^*(\cdot))}{\partial q_i}\right) = P'(q_i) - \frac{\partial^2 C(x_i^*(\cdot), q_i)}{\partial x_{ij}\partial q_i} \gtrless 0, \\
(36) \ sign\left(\frac{\partial x_i^*(\cdot)}{\partial q_k}\right) &= 0 \text{ since } \frac{\partial H(N_i, x_i^*(\cdot))}{\partial q_k} = 0.
\end{aligned}
$$

Proof of lemma 3. To prove the existence of $N_1^*(\cdot)$, we first show that the difference in the upstream firms' profits, $\Delta\Pi^U(\cdot) = \Pi^{U_{1j}*}(N_1, q_1, q_2) - \Pi^{U_{2j}*}(N - N_1, q_2)$ is monotonically decreasing in N_1. That is, we show that $\partial\Delta\Pi^U(\cdot)/\partial N_1 < 0$, i.e.

$$(37) \qquad \frac{\partial \Delta\Pi^U(\cdot)}{\partial N_1} = -\frac{1}{2}\left[\Gamma_1 + \Gamma_2 - \Gamma_3\right] < 0$$

with

$$
\begin{aligned}
\Gamma_1 &= \left(K'(X_1^*(\cdot)) - K'(X_1^*(\cdot) - x_1^*(\cdot))\right)\left(x_1^*(\cdot) + (N_1 - 1)\frac{\partial x_1^*(\cdot)}{\partial N_1}\right), \\
\Gamma_2 &= \frac{1}{2}\left(K'(X_2^*(\cdot) + \widetilde{x}_{2j}^*(\cdot)) - K'\left(X_2^*(\cdot)\right)\right)\left(-x_2^*(\cdot) + (N - N_1)\frac{\partial x_2^*(\cdot)}{\partial N_1}\right), \\
\Gamma_3 &= \left(K'(X_2^*(\cdot)) - K'\left(X_2^*(\cdot) - x_2^*(\cdot)\right)\right)\left(-x_2^*(\cdot) + (N - N_1 - 1)\frac{\partial x_2^*(\cdot)}{\partial N_1}\right).
\end{aligned}
$$

From lemma 2, we immediately get $x_1^*(\cdot) + (N_1 - 1)\left(\partial x_1^*(\cdot)/\partial N_1\right) > 0$, which implies $\Gamma_1 > 0$. Analogously, we obtain

$$
\left(-x_2^*(\cdot) + (N - N_1 - 1)\frac{\partial x_2^*(\cdot)}{\partial N_1}\right) < \left(-x_2^*(\cdot) + (N - N_1)\frac{\partial x_2^*(\cdot)}{\partial N_1}\right) < 0. \tag{38}
$$

It remains to show that $\Gamma_2 - \Gamma_3 > 0$, which holds as long as

$$
\frac{1}{2}\left(K'(X_2^*(\cdot) + \widetilde{x}_{2j}^*(\cdot)) - K'\left(X_2^*(\cdot)\right)\right) - \left(K'(X_2^*(\cdot)) - K'\left(X_2^*(\cdot) - x_2^*(\cdot)\right)\right) < 0. \tag{39}
$$

Since $\widetilde{x}_{2j}^*(\cdot) < x_2^*(\cdot)$ due to the comparison of (7) and (16), we can consider $\widetilde{x}_{2j}^*(\cdot) = x_2^*(\cdot)$ and get that (39) is obviously fulfilled for $K'''(\cdot) = 0$. However, condition (39) is likewise fulfilled if $K''(\cdot)$ is not too large, i.e. the retailers' costs are not too convex in quantity.

Second, we show that $\Pi^{U_{1j}*}(1, \cdot) > \Pi^{U_{2j}*}(N - 1, \cdot)$. Considering $q_1 = q_2 + \varepsilon$ and $N_1 = N_2 = 1$ for given $N = 2$, we get $\Pi^{U_{1j}*}(1, \cdot) > \Pi^{U_{2j}*}(1, \cdot)$ as supplier U_{1j} has a strictly positive outside option in contrast to supplier U_{2j}. $\Pi^{U_{2j}*}(N_2, \cdot)$ is decreasing in N_2 since the marginal contribution of any individual supplier is the lower the more suppliers deliver to the same retailer. Accordingly, it holds that $\Pi^{U_{1j}*}(1, \cdot) > \Pi^{U_{2j}*}(N - 1, \cdot)$ for any $N \geq 2$. For N sufficiently large, it holds analogously that $\Pi^{U_{1j}*}(N - 1, \cdot) < \Pi^{U_{2j}*}(1, \cdot)$. Thus, there exists an equilibrium $N_1^*(\cdot)$.

Proof of lemma 4. To determine the comparative statics of $N_1^*(q_1, q_2)$ in q_1 and q_2, i.e. $\partial N_1^*(\cdot)/\partial q_1 > 0$ and $\partial N_1^*(\cdot)/\partial q_2 < 0$ for $q_1 > q_2$, we apply the implicit-function theorem. Since $\partial \Delta \Pi^U(\cdot)/\partial N_1 < 0$, we have $sign\left(\partial N_1^*(\cdot)/\partial \tau\right) = sign\left(\partial \Delta \Pi^U(\cdot)/\partial \tau\right)$ for $\tau = q_1, q_2$. We write the suppliers' profits given in (24) and (25) as $\Pi^{U_{1j}*}(\cdot) = GP_1 + DP_1$ and $\Pi^{U_{2j}*}(\cdot) = GP_2$ with

$$GP_1 = \frac{\Delta R(X_1^{**}(\cdot), q_1) - \Delta K(X_1^{**}(\cdot)) - C(x_1^{**}(\cdot), q_1)}{2}, \tag{40}$$

$$GP_2 = \frac{\Delta R(X_2^{**}(\cdot), q_2) - \Delta K(X_2^{**}(\cdot)) - C(x_2^{**}(\cdot), q_2)}{2} \tag{41}$$

and

$$DP_1 = \frac{\Delta R(X_2^{**}(\cdot) + \widetilde{x}_{2j}^{**}(\cdot), \cdot) - \Delta K(X_2^{**}(\cdot) + \widetilde{x}_{2j}^{**}(\cdot)) - C(\widetilde{x}_{2j}^{**}(\cdot), q_1)}{4}. \tag{42}$$

If $P'(q_1) - (\partial^2 C(x_1^{**}(\cdot), q_1)/\partial x_{1j}\partial q_1) < 0$ and $P'(q_1)x_1^{**}(\cdot) - \partial C(x_1^{**}(\cdot), q_1)/\partial q_1 > 0$, we have

$$\frac{\partial GP_1}{\partial q_1} = \underbrace{P'(q_1)x_1^{**}(\cdot) - \frac{\partial C(x_1^{**}(\cdot), q_1)}{\partial q_1}}_{>0} \tag{43}$$
$$\underbrace{-(N_1^*(\cdot) - 1)\left(K'(X_1^{**}(\cdot)) - K'(X_1^{**}(\cdot) - x_1^{**}(\cdot))\right)\frac{\partial x_1^{**}(\cdot)}{\partial q_1}}_{<0} > 0$$

and analogously $\partial GP_2/\partial q_2 > 0$. Furthermore, we have

$$\frac{\partial DP_1}{\partial q_2} = P'(q_2)\widetilde{x}_{2j}^{**}(\cdot) \tag{44}$$
$$\underbrace{-N_2^*(\cdot)\left(K'(X_2^{**}(\cdot) + \widetilde{x}_{2j}^{**}(\cdot)) - K'\left(X_2^{**}(\cdot)\right)\right)\frac{\partial x_2^{**}(\cdot)}{\partial q_2}}_{<0} > 0$$

and

$$\frac{\partial DP_1}{\partial q_1} = -\frac{\partial C(\widetilde{x}_{2j}^{**}(\cdot), q_1)}{\partial q_1} < 0. \tag{45}$$

Turning to the comparative static results, we get

$$sign\left(\frac{\partial N_1^*(\cdot)}{\partial q_1}\right) = sign\left(\frac{\partial \Delta\Pi^U(\cdot)}{\partial q_1}\right) = sign\left(\frac{\partial GP_1}{\partial q_1} + \frac{\partial DP_1}{\partial q_1}\right) > 0 \tag{46}$$

and

$$sign\left(\frac{\partial N_1^*(\cdot)}{\partial q_2}\right) = sign\left(\frac{\partial \Delta\Pi^U(\cdot)}{\partial q_2}\right) = sign\left(\frac{\partial DP_1}{\partial q_2} - \frac{\partial GP_2}{\partial q_2}\right) < 0. \tag{47}$$

Condition (46) is fulfilled if

$$\begin{aligned} \frac{\partial C(x_1^{**}(\cdot), q_1)}{\partial q_1} &< P'(q_1)x_1^{**}(\cdot) - \frac{\partial C(\widetilde{x}_{2j}^{**}(\cdot), q_1)}{\partial q_1} \\ &-(N_1^*(\cdot)-1)\left(K'(X_1^{**}(\cdot)) - K'(X_1^{**}(\cdot) - x_1^{**}(\cdot))\right)\frac{\partial x_1^{**}(\cdot)}{\partial q_1}. \end{aligned} \tag{48}$$

Applying the first-order Taylor approximation, (48) can be rewritten as

$$\begin{aligned} \frac{\partial C(x_1^{**}(\cdot), q_1)}{\partial q_1} &< P'(q_1)x_1^{**}(\cdot) - \frac{\partial C(\widetilde{x}_{2j}^{**}(\cdot), q_1)}{\partial q_1} \\ &\quad -K''(X_1^{**}(\cdot))(N_1^*(\cdot)-1)x_1^{**}(\cdot)\frac{\partial x_1^{**}(\cdot)}{\partial q_1}. \end{aligned} \tag{49}$$

Likewise, condition (47) is fulfilled if

$$\begin{aligned} \frac{\partial C(x_2^{**}(\cdot), q_2)}{\partial q_2} &< P'(q_2)(x_2^{**}(\cdot) - \widetilde{x}_{2j}^{**}(\cdot)/2) \\ &-\frac{2(N_2^*(\cdot)-1)\Delta K'(X_2^{**}(\cdot)) - N_2^*(\cdot)\,\Delta K'(X_2^{**}(\cdot) + \widetilde{x}_{2j}^{**}(\cdot))}{2}\frac{\partial x_2^{**}(\cdot)}{\partial q_2}, \end{aligned} \tag{50}$$

$$\text{with} \;:\; \Delta K'(X_2^{**}(\cdot)) = K'(X_2^{**}(\cdot)) - K'\left(X_2^{**}(\cdot) - x_2^{**}(\cdot)\right)$$

$$\text{and} \;:\; \Delta K'(X_2^{**}(\cdot) + \widetilde{x}_{2j}^{**}(\cdot)) = K'(X_2^{**}(\cdot) + \widetilde{x}_{2j}^{**}(\cdot)) - K'\left(X_2^{**}(\cdot)\right).$$

Applying the first-order Taylor approximation, (50) can be rewritten as

$$\begin{aligned} \frac{\partial C(x_2^{**}(\cdot), q_2)}{\partial q_2} &< P'(q_2)\frac{2x_2^{**}(\cdot) - \widetilde{x}_{2j}^{**}(\cdot)}{2} \\ -K''(X_2^{**}(\cdot)) &\left[(N_2^*(\cdot) - 1)x_2^{**}(\cdot) - \frac{N_2^*(\cdot)}{2}\widetilde{x}_{2j}^{**}(\cdot)\right]\frac{\partial x_2^{**}(\cdot)}{\partial q_2}. \end{aligned} \tag{51}$$

Proof of proposition 1. To prove that there exists no symmetric equilibrium in the retailers' quality choice, we show that the retailers always have an incentive to deviate from the symmetric candidate equilibrium. We, thus, compare the profit of retailer D_1 in the case of equal quality requirements, i.e. $q_1 = q_2$, with its profit in the case of $q_1 = q_2 + \varepsilon$. If retailer D_1 exceeds the quality requirements of retailer D_2 by an arbitrarily small amount ε, delivery to D_1 becomes more attractive as the suppliers delivering to D_2 lose their outside option. Accordingly, $N_1^*(\cdot)$ is increasing. Neglecting any quality effect from the small increase in q_1, we show that $\partial \Pi^{D_1**}(\cdot)/\partial N_1 > 0$ in order to prove proposition 1.

First, we show that the overall profit of retailer D_1 and all its $N_1^*(\cdot)$ suppliers U_{1j}, i.e. $\Omega(\cdot) = P(q_1)X_1^{**}(\cdot) - K(X_1^{**}(\cdot)) - N_1^*(\cdot)C(x_1^{**}(\cdot), q_1)$, is increasing in N_1. Applying the envelope theorem, we have

$$\frac{\partial \Omega(\cdot)}{\partial N_1} = \left(P(q_1) - K'(X_1^{**}(\cdot))\right)x_1^{**}(\cdot) - C(x_1^{**}(\cdot), q_1). \tag{52}$$

By using (16), (52) can be rewritten as

$$\frac{\partial \Omega(\cdot)}{\partial N_1} = \frac{\partial C(x_1^{**}(\cdot), q_1)}{\partial x_{1j}}x_1^{**}(\cdot) - C(x_1^{**}(\cdot), q_1) > 0. \tag{53}$$

Condition (53) is fulfilled due to the assumed convexity of production costs $C(x_{1j}, q_1)$.

Second, denote $\Pi^{U_{ij}**}(\cdot) := \Pi^{U_{ij}*}(N_i^*(\cdot), \cdot)$. Using $\Omega(\cdot) = \Pi^{D_1**}(\cdot) + N_1^*\Pi^{U_{1j}**}(\cdot)$, we compare the overall profit $\underline{\Omega}(\cdot)$ for $q_1 = q_2$ with $\underline{N}_1 := N_1^*(q_2, q_2)$, $\underline{x}_1 := x_1^{**}(q_2, q_2)$ and $\underline{X}_1 := X_1^{**}(q_2, q_2)$ to $\overline{\Omega}(\cdot)$ for $q_1 = q_2 + \varepsilon$ with $\overline{N}_1 := N_1^*(q_2 + \varepsilon, q_2)$, $\overline{x}_1 := x_1^{**}(q_2 + \varepsilon, q_2)$, $\overline{X}_1 := X_1^{**}(q_2 + \varepsilon, q_2)$, $\overline{\widetilde{x}}_{2j} := \widetilde{x}_{2j}^{**}(q_2 + \varepsilon, q_2)$ and $\overline{\widetilde{F}}_{2j} := \widetilde{F}_{2j}^{**}(q_2 + \varepsilon, q_2)$. Denoting $\underline{\Pi}^{D_1} := \Pi^{D_1**}(\underline{N}_1, \cdot)$, $\overline{\Pi}^{D_1} := \Pi^{D_1**}(\overline{N}_1, \cdot)$, $\underline{\Pi}^{U_{1j}} := \Pi^{U_{1j}**}(\underline{N}_1, \cdot)$ and $\overline{\Pi}^{U_{1j}} := \Pi^{U_{1j}**}(\overline{N}_1, \cdot)$, we write $\overline{\Omega}(\cdot) = \overline{\Pi}^{D_1} + \overline{N}_1\left(\overline{\Pi}^{U_{1j}} - \underline{\Pi}^{U_{1j}}\right) + \left(\overline{N}_1 - \underline{N}_1\right)\overline{\Pi}^{U_{1j}}$. Evaluating the difference $\Delta\overline{\Omega}(\cdot) = \overline{\Omega}(\cdot) - \underline{\Omega}(\cdot)$, we get

$$\Delta\overline{\Omega}(\cdot) = \overline{\Pi}^{D_1} - \underline{\Pi}^{D_1} + \left[\overline{N}_1\left(\overline{\Pi}^{U_{1j}} - \underline{\Pi}^{U_{1j}}\right) + \left(\overline{N}_1 - \underline{N}_1\right)\overline{\Pi}^{U_{1j}}\right], \tag{54}$$

which can be rewritten as

$$\overline{\Pi}^{D_1} - \underline{\Pi}^{D_1} = \Delta\overline{\Omega}(\cdot) - \left[\overline{N}_1\left(\overline{\Pi}^{U_{1j}} - \underline{\Pi}^{U_{1j}}\right) + \left(\overline{N}_1 - \underline{N}_1\right)\overline{\Pi}^{U_{1j}}\right]. \tag{55}$$

Note that $\overline{\Pi}^{U_{1j}} - \underline{\Pi}^{U_{1j}} < 0$. This is due to the fact that all the suppliers have an outside option if $q_1 = q_2$. If, instead, q_1 increases by ε to $q_2 + \varepsilon$, the suppliers delivering to D_2 lose their outside option, implying a lower profit $\Pi^{U_{2j}**}(\cdot)$. This implies that more suppliers decide to deliver to D_1, resulting in a higher profit of those suppliers delivering to D_2. As, in equilibrium, the profits of the suppliers delivering to D_1 and D_2 are equal, the profit $\Pi^{U_{1j}**}(\cdot)$ must decrease in $N_1^*(\cdot)$, i.e. $\overline{\Pi}^{U_{1j}} - \underline{\Pi}^{U_{1j}} < 0$.

Furthermore, from (53) we know that $\Delta\overline{\Omega}(\cdot) > 0$. Accordingly, it remains to show that $\Delta\overline{\Omega}(\cdot) \geq \left(\overline{N}_1 - \underline{N}_1\right)\overline{\Pi}^{U_{1j}}$. Using first-order Taylor approximation, we rewrite $\Delta\overline{\Omega}(\cdot) = \overline{N}_1(P(q_1)\overline{x}_1 - C(\overline{x}_1, q_1)) - K(\overline{X}_1) - [\underline{N}_1(P(q_1)\underline{x}_1 - C(\underline{x}_1, q_1)) - K(\underline{X}_1)]$ as $\Delta\widetilde{\Omega}(\cdot) = \left(\overline{N}_1 - \underline{N}_1\right)\left(P(q_1)\overline{x}_1 - C(\overline{x}_1, q_1) - K'(\overline{X}_1)\overline{x}_1\right)$.

Thus, we show that

$$\left(\overline{N}_1 - \underline{N}_1\right)\left(P(q_1)\overline{x}_1 - C(\overline{x}_1, q_1) - K'(\overline{X}_1)\overline{x}_1\right) > \frac{\left(\overline{N}_1 - \underline{N}_1\right)}{2}\left(P(q_1)\overline{x}_1 - K'(\overline{X}_1)\overline{x}_1 - C(\overline{x}_1, q_1) + \overline{\overline{F}}_{2j} - C(\overline{\overline{x}}_{2j}, q_i)\right), \tag{56}$$

which simplifies to

$$P(q_1)\overline{x}_1 - C(\overline{x}_1, q_1) - K'(\overline{X}_1)\overline{x}_1 > P(q_2)\overline{\overline{x}}_{2j} - C(\overline{\overline{x}}_{2j}, q_1) - K'(\overline{X}_2 + \overline{\overline{x}}_{2j})\overline{\overline{x}}_{2j}. \tag{57}$$

The left-hand side of inequality (57) is equal or larger than the incremental gains from trade between D_1 and U_{1j} given in (17). The right-hand side of (57) equals the off-equilibrium incremental gains from trade as given in (9). Therefore, we can conclude that (57) is always fulfilled due to the properties of the bargaining solution. Accordingly, we have $\Delta\overline{\Omega}(\cdot) - \left[\overline{N}_1\left(\overline{\Pi}^{U_{1j}} - \underline{\Pi}^{U_{1j}}\right) + \left(\overline{N}_1 - \underline{N}_1\right)\overline{\Pi}^{U_{1j}}\right] > 0$, such that $\overline{\Pi}^{D_1} - \underline{\Pi}^{D_1}$ cannot be negative.

Appendix B

Numerical Results under Perfect Competition. Plugging the functions $P(q_i) = \sqrt{q_i}$, $C(x_{ij}, q_i) = q_i^3 x_{ij}^2/3$ and $K(X_i) = X_i^2$ into equations (19) and (22), the equilibrium fixed fees $F_1^*(\cdot)$ and $F_2^*(\cdot)$ for $q_1 \geq q_2$ are given by

$$F_1^*(\cdot) = \frac{\sqrt{q_1}x_1^*(\cdot) - (2N_1 - 1)\,x_1^*(\cdot)^2 + \frac{q_1^3}{3}x_1^*(\cdot)^2 + \widetilde{F}_{2j}^*(\cdot) - \frac{q_1^3}{3}\widetilde{x}_{2j}^*(\cdot)^2}{2}, \tag{58}$$

$$
(59) \qquad F_2^*(\cdot) = \begin{cases} \frac{\sqrt{q_2}x_2^*(\cdot)-(2N_2-1)x_2^*(\cdot)^2+\frac{q_2^3}{3}x_2^*(\cdot)^2}{2} & \text{if } q_1 > q_2 \\ \frac{\sqrt{q_2}x_2^*(\cdot)-(2N_2-1)x_2^*(\cdot)^2+\frac{q_2^3}{3}x_2^*(\cdot)^2+\widetilde{F}_{1j}^*(\cdot)-\frac{q_2^3}{3}\widetilde{x}_{1j}^*(\cdot)^2}{2} & \text{if } q_1 = q_2 \end{cases},
$$

with

$$
(60) \quad \widetilde{F}_{kj}^*(\cdot) = \frac{1}{2}\widetilde{x}_{kj}^*(\cdot)\left[\sqrt{q_k} - \left(2N_k x_k^*(\cdot) + \widetilde{x}_{kj}^*(\cdot)\right) + \frac{q_i^3}{3}\widetilde{x}_{kj}^*(\cdot)\right], \ \forall k = 1,2, \ i \neq k.
$$

For the equilibrium quantities $x_i^*(\cdot)$, $i = 1,2$, and $\widetilde{x}_{kj}^*(\cdot)$, $k = 1,2$, $i \neq k$, we have

$$
(61) \qquad x_i^*(\cdot) = \frac{\sqrt{q_i}}{2\left(N_i + \frac{q_i^3}{3}\right)},
$$

$$
(62) \qquad \widetilde{x}_{kj}^*(\cdot) = \frac{3q_k^{7/2}}{2\left(3+q_i^3\right)\left(3N_k+q_k^3\right)}.
$$

Furthermore, the following identity holds for $N_i^*(\cdot)$

$$
\begin{aligned}
(63) \qquad \Theta_1 N_i^*(\cdot) \equiv & \left(\left(1-\frac{q_i^3}{3}\right)x_i^{**}(\cdot)+\sqrt{q_i}\right)\frac{x_i^{**}(\cdot)}{2} \\
& -\left(\left(1-\frac{q_k^3}{3}\right)x_k^{**}(\cdot)+\sqrt{q_k}\right)\frac{x_k^{**}(\cdot)}{2} \\
& -\left(\left(1+\frac{q_i^3}{3}\right)\widetilde{x}_{kj}^{**}(\cdot)-\sqrt{q_k}\right)\frac{\widetilde{x}_{kj}^{**}(\cdot)}{4} \\
& +\left(2x_k^{**}(\cdot)-\widetilde{x}_{kj}^{**}(\cdot)\right)\frac{Nx_k^{**}(\cdot)}{2},
\end{aligned}
$$

with

$$
(64) \qquad \Theta_1 = x_i^{**}(\cdot)^2 - \frac{1}{2}x_k^{**}(\cdot)\,\widetilde{x}_{kj}^{**}(\cdot) + x_k^{**}(\cdot)^2.
$$

Numerical Results under Imperfect Competition. Based on the functions $P_i(q_i) = \max\left\{\sqrt{q_i} - X_i - \sigma X_k, 0\right\}$, $C(x_{ij}, q_i) = q_i^3 x_{ij}^2/3$ and $K(X_i) = X_i^2$, $\forall i, k = 1, 2$, $i \neq k$, the equilibrium fixed fees $\underline{F}_1^*(\cdot)$ and $\underline{F}_2^*(\cdot)$ for $q_1 \geq q_2$ are given by

$$\underline{F}_1^*(\cdot) = \frac{\Delta R(\underline{X}_1^*(\cdot), \cdot) - (2N_1 - 1)\, \underline{x}_1^*(\cdot)^2 + \frac{q_1^3}{3} \underline{x}_1^*(\cdot)^2 + \widetilde{\underline{F}}_{2j}^* - \frac{q_1^3}{3} \widetilde{\underline{x}}_{2j}^*(\cdot)^2}{2}, \tag{65}$$

$$\underline{F}_2^*(\cdot) = \begin{cases} \frac{\Delta R(\underline{X}_2^*(\cdot),\cdot) - (2N_2-1)\underline{x}_2^*(\cdot)^2 + \frac{q_2^3}{3}\underline{x}_2^*(\cdot)^2}{2} & \text{if } q_1 > q_2 \\ \frac{\Delta R(\underline{X}_2^*(\cdot),\cdot) - (2N_2-1)\underline{x}_2^*(\cdot)^2 + \frac{q_2^3}{3}\underline{x}_2^*(\cdot)^2 + \widetilde{\underline{F}}_{1j}^* - \frac{q_2^3}{3}\widetilde{\underline{x}}_{1j}^*(\cdot)^2}{2} & \text{if } q_1 = q_2 \end{cases}, \tag{66}$$

with

$$\begin{aligned} \Delta R(\underline{X}_1^*(\cdot), \cdot) &= \underline{x}_1^*(\cdot)\left(\sqrt{q_1} - N_2 \sigma \underline{x}_2^*(\cdot) + (1 - 2N_1)\, \underline{x}_1^*(\cdot)\right) \\ &\quad + \underline{x}_1^*(\cdot)\,(N_1 - 1)\, \sigma \widetilde{\underline{x}}_{2j}^*(\cdot), \end{aligned} \tag{67}$$

$$\Delta R(\underline{X}_2^*(\cdot), \cdot) = \begin{cases} \underline{x}_2^*(\cdot)\left(\sqrt{q_2} - N_1 \sigma \underline{x}_1^*(\cdot) + (1 - 2N_2)\, \underline{x}_2^*(\cdot)\right) & \text{if } q_1 > q_2 \\ \underline{x}_2^*(\cdot)\left(\sqrt{q_2} - N_1 \sigma \underline{x}_1^*(\cdot) + (1 - 2N_2)\, \underline{x}_2^*(\cdot)\right) & \\ + \underline{x}_2^*(\cdot)\,(N_2 - 1)\, \sigma \widetilde{\underline{x}}_{1j}^*(\cdot) & \text{if } q_1 = q_2 \end{cases} \tag{68}$$

and

$$\widetilde{\underline{F}}_{kj}^*(\cdot) = \frac{1}{2} \widetilde{\underline{x}}_{kj}^*(\cdot) \left[\sqrt{q_k} - 4N_k \underline{x}_k^*(\cdot) + (1 - N_i)\, \sigma \underline{x}_i^*(\cdot) + \left(\frac{q_i^3}{3} - 2\right) \widetilde{\underline{x}}_{kj}^*(\cdot)\right], \tag{69}$$

$\forall k = 1, 2$, $i \neq k$.

For the equilibrium quantities $\underline{x}_i^*(\cdot)$, $i = 1, 2$, and $\widetilde{\underline{x}}_{kj}^*(\cdot)$, $k = 1, 2$, $i \neq k$, we have

$$(70) \qquad \underline{x}_i^*(\cdot) = \frac{2\frac{q_k^3}{3}\sqrt{q_i} + N_k\left(4\sqrt{q_i} - \sigma\sqrt{q_k}\right)}{4\left(\frac{q_i^3}{3} + 2N_i\right)\left(\frac{q_k^3}{3} + 2N_k\right) - N_iN_k\sigma^2},$$

$$(71) \qquad \widetilde{\underline{x}}_{kj}^*(\cdot) = \frac{4\frac{q_k^3}{3}\left(\frac{q_i^3}{3} + 2N_i\right)\sqrt{q_k} + 2\left(\frac{q_k^3}{3} - \frac{q_k^3}{3}N_i + 2N_k\right)\sigma\sqrt{q_i} - N_k\sqrt{q_k}\sigma^2}{2\left(2 + \frac{q_i^3}{3}\right)\left[4\left(\frac{q_i^3}{3} + 2N_i\right)\left(\frac{q_k^3}{3} + 2N_k\right) - N_iN_k\sigma^2\right]}.$$

Furthermore, the following identity holds for $\underline{N}_i^*(\cdot)$

$$(72) \qquad \begin{aligned} \Theta_2\underline{N}_i^*(\cdot) \equiv\ & -2\underline{x}_i^{**}(\cdot)\left(\sqrt{q_i} + \left(2 - \frac{q_i^3}{3}\right)\underline{x}_i^{**}(\cdot)\right) \\ & +2\underline{x}_k^{**}(\cdot)\left(\sqrt{q_k} + \left(2 - \frac{q_k^3}{3} - 4N\right)\underline{x}_k^{**}(\cdot)\right) \\ & +2N\sigma\underline{x}_i^{**}(\cdot)\,\underline{x}_k^{**}(\cdot) + \left(2 + \frac{q_i^3}{3}\right)\widetilde{\underline{x}}_{kj}^{**}(\cdot)^2 \\ & + \left(\sigma\underline{x}_i^{**}(\cdot) + 4N\underline{x}_k^{**}(\cdot) - \sqrt{q_k}\right)\widetilde{\underline{x}}_{kj}^{**}(\cdot), \end{aligned}$$

with

$$(73) \qquad \begin{aligned} \Theta_2 =\ & -8\left(\underline{x}_i^{**}(\cdot)^2 + \underline{x}_k^{**}(\cdot)^2\right) \\ & + \left(4\underline{x}_k^{**}(\cdot) + \sigma\underline{x}_i^{**}(\cdot)\right)\widetilde{\underline{x}}_{kj}^{**}(\cdot) \\ & +4\sigma\underline{x}_i^{**}(\cdot)\,\underline{x}_k^{**}(\cdot). \end{aligned}$$

Appendix C

Due to our assumption of perfect competition, the retailers' quality choice has no impact on the overall quantity in the market. Accordingly, private quality standards only affect the industry profit, i.e. $I(\cdot) = \sum_{i=1}^{2} [P(q_i)X_i^{**} - K(X_i^{**}) - N_i^* C(x_i^{**}, q_i)]$. The industry-optimal quality requirement is then given by $q^I := \arg\max I(\cdot)$, resulting in $q_1^I = q_2^I = q^I$. Accordingly, the suppliers split equally between the retailers. Numerical analysis shows that the industry-optimal quality level q^I is increasing in the total number of suppliers. This is made possible by the decrease in the quantity-related production costs due to the rise in N. Once the number of suppliers reaches the threshold value $\widetilde{N}$, the high-quality retailer D_1 imposes a quality standard q_1^* that exceeds the industry-optimal quality level q^I. Thus, for all $N \leq \widetilde{N}$, a binding MQS leads to a higher industry profit. However, a trade-off emerges for $N > \widetilde{N}$. While a higher q_2^* due to the enforcement of a public MQS approaches the industry-optimal quality level, the quality requirements q_1^* of the high-quality retailer are more likely to exceed q^I. Denoting the best-response function of the high-quality retailer by $r_1(q_2)$, the industry-optimal level of the public MQS, $\overline{q}_2^I$, is obtained by maximizing the industry profit with respect to q_2, i.e.

$$\overline{q}_2^I := \arg\max_{q_2} I(N_1^*(r_1(q_2), q_2), r_1(q_2), q_2). \tag{74}$$

Comparing numerically $\Delta I_1 = I(q^I, q^I) - I(q_1^*, q_2^*)$ and $\Delta I_2 = I(q^I, q^I) - I(r_1(\overline{q}_2^I), \overline{q}_2^I)$, we find that $\Delta I_1 > \Delta I_2$ always holds. That is, the enforcement of a binding public MQS increases the industry profit also for $N > \widetilde{N}$.

Figures

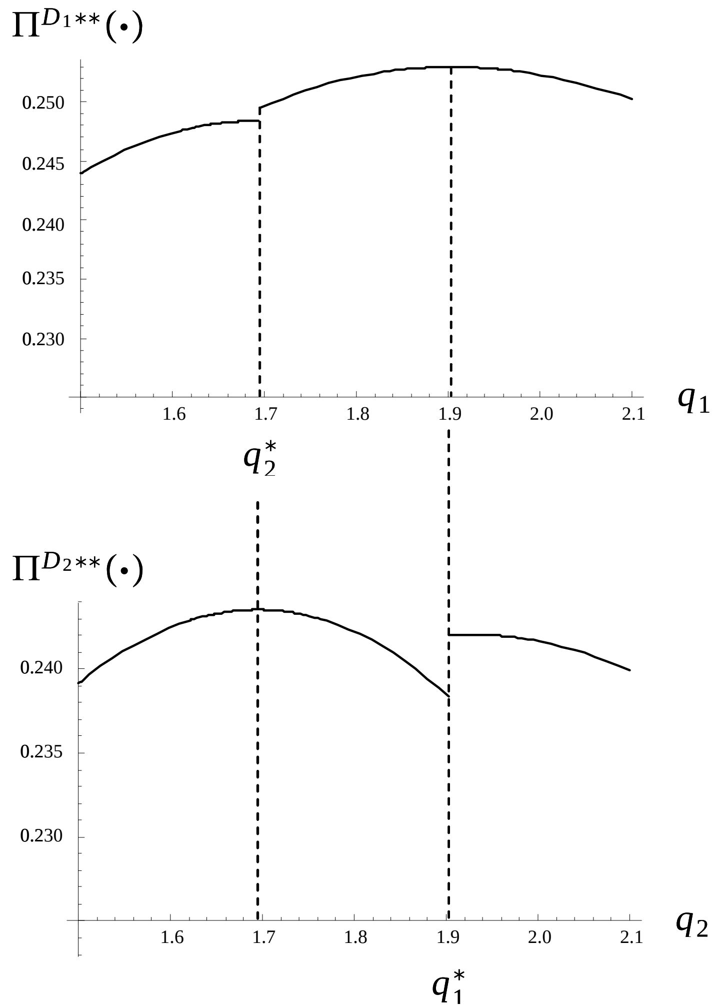

Figure 1. Profit functions and equilibria for $N = 10$

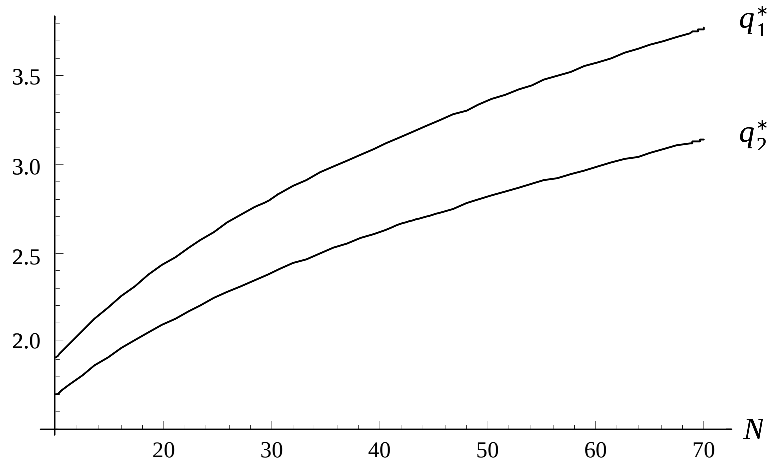

Figure 2. Quality requirements q_1^* and q_2^* in N

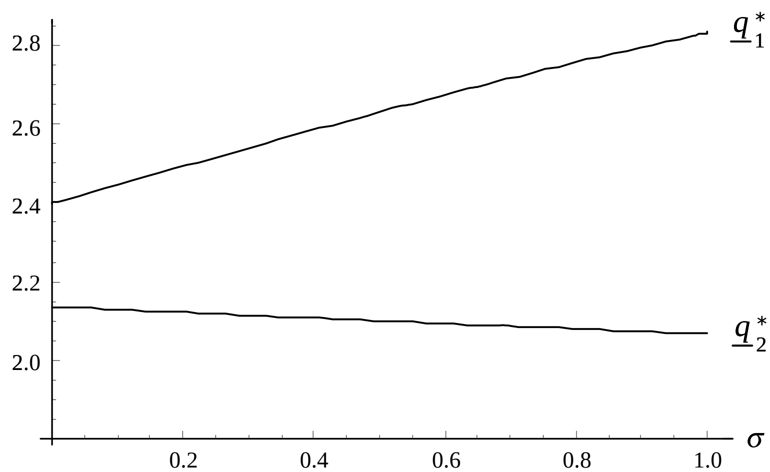

Figure 3. Quality requirements $\underline{q}_1^*$ and $\underline{q}_2^*$ in σ for $N = 10$