Ownership Structure and Endogenous Quality Choice

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Abstract

This paper examines how ownership structure affects quality choice and the subsequent equilibrium outcomes within a duopoly framework. Specifically, investor owned firms and cooperatives are analyzed in a closed market setting where these firms may coexist in the economy. The conditions under which ownership structure matters are identified. We conclude that ownership structure matters if the cost of quality at farm level is fixed or if there is a variable cost exhibiting non-constant returns to scale. Two farm level cost functions, a fixed cost function that is increasing and convex in quality, and a variable cost function that is increasing and convex in quantity are analyzed. The two processing firms play a two-stage game where each of the firms produces either high or low quality goods. In the first stage they decide the level of quality to produce, and in the second stage they compete in prices. In the case of a fixed cost function only cooperatives consider the costs incurred at farm level in the first stage of the game. Hence, investor owned firms produce higher levels of qualities at lower prices and generates a larger consumer surplus than cooperatives. The high quality market share is constant in all scenarios. In the case of a variable cost function at farm level, the cooperative has a cost advantage, as the investor owned processor has to pay farm level marginal cost for all farm inputs. It is found that cooperatives generate higher levels and larger quantities of the high quality good at lower prices. This results in higher profits and a larger market share of the high quality good. The cooperative structure also generates a larger consumer surplus and a higher total welfare than the investor owned structure.

1. Introduction

Changing consumer preferences, negative publicity pertaining to food safety/quality, and increased international competition as a result of deregulation has resulted in an increased focus on food quality in recent years.[1] In response, the food marketing chain has developed various quality assurance schemes and private labels to be communicated to consumers.[2] By developing quality assurance schemes and requiring suppliers (e.g. farmers) to implement these, companies downstream (e.g. process industry) are able to control the quality of the final product and ultimately to gain consumer trust, increased market shares, and increased profits.

There exists an extensive literature on quality choice and the effects thereof. The literature varies pertaining to the type of market condition, type of competition, cost of quality (none, fix, or variable), consumer information, type of quality (consumer or cost driven), type of game etc. Despite the extensive literature, the incentive structure for investments in quality assurance schemes given different ownership structures is to a large extent a theoretically and empirically overlooked issue.

Farmer cooperatives exist worldwide. However, recent events indicate that the cooperative organizational structure is facing some problems, especially in the presence of fierce international competition (Nilsson, 1994). Problems associated with the decision making process and the equity formation for long term investments within the cooperative entity are well known and have been subject to extensive analysis in the literature. In this literature, the incentive structure for investments in quality assurance schemes given the cooperative management structure is an overlooked issue. This is especially true in the context of markets where various forms of organizational structures appear. Lambertini (1997) analyzed quality choice in a setting including a cooperative structure. Lambertini, however, examines the special case of a monopolist producing one type of quality. He compares the outcome of a labor-managed and a profit-maximizing monopolist and concludes that the produced output is the same but the labor-managed monopolist produces a significantly lower quality. Quality choice and vertical integration has been examined by Economides (1999). He analyzed and compared two vertically related monopolists and a sole integrated monopolist and found that the latter produced higher

[1] GATT- and WTO has had a general impact on economic conditions and policy developments world wide. Within the EU the creation of the internal market has further enhanced competition.
[2] In this study quality assurance schemes refers to schemes communicated to consumers, as opposed to internal schemes improving efficiency etc without being directly communicated to consumers.

quality, and larger consumer as well as producer surplus. The question is then how vertical integration affects the quality choice and the relative position of firms with different ownership structures in an oligpolistic setting.

This paper focus on how and to what extent quality choice and the subsequent equilibrium outcomes are affected by different ownership structures. Specifically, different mixtures of investor owned firms (IOFs) and cooperatives (COOPs) are analyzed in a duopoly setting. The following questions are examined:

(i) Under which circumstances is it relevant to consider ownership structure in analyzing quality choice? As cooperatives and investor owned firms differ in how the maximization problem is specified, this is a question of which farm level cost functions that produce different outcomes for COOPs and IOFs.

(ii) Given different ownership structures in the market, what are the equilibrium outcomes of quality levels, prices, quantities, welfare effects and high-quality market share? Is any specific ownership structure more or less favorable to society as a whole and are there any economic advantages/disadvantages with a vertically integrated cooperative structure.

This study contributes to the existing literature in that it focus on ownership structure and includes cooperatives in the analysis of endogenous quality choice. Furthermore, the starting point for the analysis is a general cost function and from this, the cost functions that yield different outcomes depending on ownership structure are identified and examined. As opposed to previous work, one of the cost functions examined allows for diminishing returns to scale. The presented model draws on Tennbakk's (1995) work of a closed mixed duopoly economy including cooperatives and investor owned firms where these firms may coexist in the economy. This approach is expanded to incorporate endogenous quality choice where two firms play a two stage game where each firm first simultaneously chooses their quality level and then compete in prices in the second stage of the game (see e.g. Motta, 1993). The economic effects of the four possible scenarios described in Table 1 are examined and compared and the stability of each is tested.

Table 1. Scenarios of Duopolistic Market Structures Analyzed

		High-quality producer	
	Ownership structure	IOF	COOP
Low-quality producer	IOF	Scenario (II)	Scenario (CI)
	COOP	Scenario (IC)	Scenario (CC)

The outline of the paper is as follows. In the next section the methodology is presented and in section 3 the cost functions generating different outcomes for different ownership structures are identified. It is found that fixed as well as variable costs of quality matters. The latter case requires non-constant returns to scale. In section 4 the case with fixed cost of quality is examined assuming Bertrand competition and in section 5 the case with variable cost of quality is analyzed. The results are summarized and some conclusions are presented in section 6. In the case of a fixed farm level cost function, we find that as investor owned firms does not consider the farm level cost function when choosing quality level, IOFs underestimate the actual cost of quality thereby producing higher levels of quality at lower prices implying a larger consumer surplus. On the other hand cooperatives promote higher producer surplus and for high quality costs also a higher total welfare. In the case of a variable farm level cost function, the result show that the cooperative structure generates a larger quality spread and a larger total volume than does an investor owned structure. A high-quality producing COOP generates a higher level of quality, lower price, larger quantity, larger profits and larger share of the high quality good. In addition, COOPs produce larger consumer surplus and higher total welfare.

2. Methodology

The presented model draws on Tennbakk's (1995) work of a closed mixed duopoly economy including cooperatives and investor owned firms where these firms may coexist in the economy. This approach is expanded to incorporate endogenous quality choice where each firm chooses to produce either high or low quality (see e.g. Motta, 1993). Consumers as well as producers are assumed to have perfect information. Consumers have the same indirect utility function, $U(\theta, v_i) = \theta v_i - p_i$, if they buy product i, and zero utility otherwise. v_i denotes the level of quality and p_i the price of product i. Consumers differ in their tastes represented by the parameter θ. A continuum of consumers is uniformly distributed with density one over the interval $\theta \in [\theta^{+}, \theta^{-}]$. In accordance with the standard literature on product differentiation, each consumer is assumed to either buy one unit of the good or not buy at all (Tirole, 1988; Motta, 1993). In a model of vertical product differentiation all consumers unambiguously rank the goods the same. However, only consumers with a higher θ will be willing to pay more to acquire a product of higher quality.[3] Hence, the industry is facing a downward sloping demand curve.

In the present duopoly setting, there are two processing firms (*a* and *b*) and a large number of independent farmers supplying the raw material. The two firms play a two stage game where each firm first chooses quality level v_i and then compete in prices in the second stage of the game (see e.g. Metrick & Zeckhauser (1999), Lehmann-Grube (1997), Ueng (1997), Aoki & Prusa (1996)). One of the processors will produce high quality, denoted v_H, and the other low quality, denoted v_L.[4] By assumption $v_H \geq v_L \geq 1$. Setting a lower bound to the quality level can be interpreted as a minimum quality standard required by law or by the market forces (Motta, 1993). Farmers supplying the raw material are assumed to hold no market power on their own and to have identical cost functions. Dividing the population into two equally sized groups, farmers belong to either group *A* or to group *B*, supplying to processing firm *a* and firm *b* respectively (Tennbakk, 1995).

Each of the two processing firms can be either a cooperative or an investor owned firm. Following the approach by Wann and Sexton (1992), a fixed proportions technology is assumed between the intermediate raw material (i.e. the farm product) and the processed product. For expository ease, the cost function related to production at farm level and the costs incurred at process level are treated as separable. Denote the type of quality with subscript *i*, where $i = H, L$, referring to high and low quality respectively and let subscript *k* refer to the individual farmer. Prices and quantities are denoted *p* and *q*. Then, at farm level the cost function for farmer *k* producing quality *i* is denoted $c^F_{ki}(.)$ while the cost function for costs specific for the process level is described by $c^P_i(.)$.[5] The investor owned firm will pay the farm level marginal cost for inputs and, hence, the maximization problem of the IOF can be formulated as in (2.1).

$$\pi^{IOF}_i = p_i q_i - c^P_i(.) - [\partial c^F_{ki}(.) / \partial q_{ki}] q_i \tag{2.1}$$

[3] Alternatively, θ can be interpreted as the marginal rate of substitution, see eg. Tirole (1988).
[4] The possibility of entry is ignored.
[5] The quantity of quality *i* produced by a processing firm is denoted q_i and the quantity of quality *i* produced by farmer *k* is denoted q_{ki}.

Following Sexton (1986) the cooperative firm is viewed as horizontally integrated across farms. In addition, the cooperative is vertically integrated between the primary farm production and the process industry up until the wholesale level. The maximization problem of the cooperative is formulated as a joint maximization problem of the cooperative processing firm and the individual members/owners (Sexton, 1986). Hence, introduction of quality assurance schemes by this industry group may serve a dual purpose by increasing volume at the farm level as well as the profits at the processing level thereby contributing towards an increase of joint profits. The cost structure of the vertically integrated firm accounts for the integral of the supply function at the farm/primary industry level and the processing cost function. A cooperative producing quality *i* will earn the profit

$$\pi^{COOP}_i = p_i q_i - c^P_i(.) - \Sigma_k c^F_{ki}(.) = p_i q_i - c^P_i(.) - c^F_i(.) \qquad (2.2)$$

The functional form of the farm level cost function will be decisive for the outcome since cooperatives and IOFs differ in how the maximization problem is specified. Hence, before analyzing the outcomes of different combinations of ownership structures, we will focus on the cost function and address the first objective: When is it relevant to consider ownership structure in analyzing quality choice?

3. The Relevance of Ownership Structure

As cooperatives and investor owned firms differ in how the maximization problem is specified, the functional form of the farm level cost function will be decisive for the outcome. On the contrary, the functional form of the processing quality costs incurred is not sensitive for our results. However, it seems reasonable to assume that the process level incur some fixed costs in developing a scheme. Furthermore, as pointed out by Lehmann-Grube (1997), the quality choice has to be, at least partially, irreversible in order for the proposed two-stage game to be relevant. As higher quality is likely to demand a more comprehensive and costly scheme, we model this cost function as increasing and convex in quality, $c^P_i(v_i) = \gamma v_i^2$. Henceforth, we refer to all costs not related to quality as "non-quality" costs while costs related to quality are referred to as "quality" costs. To maintain the focus on the relevance of ownership structure, all non-quality costs are assumed to be zero.

Different specifications of the cost functions have been used in the previous literature. Some studies assume the quality costs to be zero (Shaked & Sutton, 1982; Tirole, 1988; Choi &

Shin, 1992; Donnenfeld & Weber, 1992; Wauthy, 1996; Metrick & Zeckhauser, 1999). As pointed out by e.g. Lehmann-Grube (1997), the assumption that quality can be obtained at no cost is unreasonable. Other studies consider the cost of quality as a variable cost given constant returns to scale (Motta, 1993; Bijl, 1997; Bonnano & Haworth, 1998; Ueng, 1997) or assume a fixed cost (Motta, 1993; Lehmann-Grube, 1997).

Assume that farmers have a quality cost function that includes both a fixed and a variable component. The cost function for farmer *k* producing quality of type *i* is defined as in (3.1), being a function of the level of quality and the quantity produced. Assuming that all farmers have identical cost functions $q_{ki} \equiv K^{-1} q_i$ ($K = \Sigma k$, $k \in A, B$). Consequently, the cost function relevant for the COOP is obtained by summing over all farmers delivering to the COOP, $k \in A$, and is denoted $c^F{}_i\,(q_i, v_i)$. Then, the profit functions for the COOP firm and the IOF firm can be defined as in (3.3) and (3.4) respectively.

$$c^F{}_{ki}(q_{ki}, v_i) = \alpha\, v_i^h\, q_{ki}^n + \beta_k v_i^m \tag{3.1}$$
$$c^F{}_i(q_i, v_i) = \Sigma_k^K\, c^F{}_{ki}(.) = \Sigma_k^K\, [\alpha\, v_i^h\, K^{-n}\, q_i^n + \beta_k v_i^m] = \alpha v_i^h K^{-(n-1)} q_i^n + \beta v_i^m \tag{3.2}$$

$$\pi^{IOF}{}_i = p_i q_i - c^P{}_i(\cdot) - [\partial c^F{}_{ki}(\cdot)/\,\partial q_{ki}]\, q_i = p_i q_i - \gamma v_i^g - n\,\alpha\, v_i^h\, K^{-(n-1)}\, q_i^n \tag{3.3}$$
$$\pi^{COOP}{}_i = p_i q_i - c^P{}_i(\cdot) - c^F{}_i(\cdot) = p_i q_i - \gamma v_i^g - \alpha v_i^h\, K^{-(n-1)} q_i^n - \beta v_i^m \tag{3.4}$$

First consider the case with only fix costs, i.e. $\alpha = 0$ and $\beta \neq 0$. Taking the derivatives of (3.3) & (3.4) w.r.t. the level of quality, v_i, we find that $\beta \neq 0$ is a sufficient condition for the equilibrium quality levels and profits to depend on ownership structure (see Appendix 1). In the subsequent sections it is assumed that the farm level cost function associated with fixed costs of quality is increasing and convex in the level of quality and specified as $c^F{}_{ki}(.) = \beta_k\, v_i^2/2$. This cost function is the same as in Motta (1993) and similar to the cost functions specified in e.g. Aoki *et al* (1996) and Lehmann-Grube (1997).[6]

Secondly, consider the case with only variable costs, i.e. $\alpha \neq 0$ and $\beta = 0$. Taking the derivatives of the profit functions w.r.t. prices it is evident that the equilibrium quantities and prices will depend on ownership structure IFF $|n| > 1$, i.e. given that the cost function does not exhibit CRS (see Appendix 1). As a consequence, $|n| > 1$ is a necessary and sufficient condition for quality levels and profits etc to be dependent on ownership structure given $\beta = 0$. This finding is not surprising as the case without product differentiation, assuming the same cost

[6] Transformed to the notation used in this paper, the cost functions are $c_i(v_i) = \beta v_i$ in Aoki (1996); $c_i(v_i) = \beta v_i^2$ in Lehmann-Grube (1997), and $c_i(v_i, q_i) = \beta v_i^2/2$ in Motta (1993).

function, yield the same result. In the subsequent sections, the variable farm level cost function is assumed to be increasing (rather than decreasing) and convex in quantity, and of the form $c^F{}_{ki}(v_i,q_{ki}) = \alpha\, v_i\, q_{ik}{}^2$. Hence, the IOF fraction of the industry faces an upward sloping supply function accounted for in the maximization problem for each firm. In the literature, variable cost of quality with technology exhibiting CRS has been examined by e.g. Ueng (1997), Bonnano *et al* (1998), and Motta (1993).[7] In some cases it may be relevant to specify the farm level cost function as exhibiting CRS. However, it follows from equations (3.3) and (3.4) that ownership structure is not an issue in that case and hence we refer the reader to the mentioned references.

In conclusion, ownership structure affects the equilibrium outcomes in all cases except when we have a variable cost function exhibiting CRS. In the next section, the case with fixed cost of quality is examined assuming Bertrand competition. The cost function includes only a fixed component, is increasing and convex in quality, and is specified as $c^F{}_{ki}(v_i) = \beta_k\, v_i^2/2$. The sub-game perfect Nash equilibrium is obtained by backwards induction. Taking quality levels as fixed we start by solving the price setting sub-game. Once we have solved the price setting second stage of the game we can solve for the optimal level of qualities in the first stage of the game. In section 5, the case of variable cost of quality is examined assuming the cost function consists only of a variable component, is increasing and convex in quantity, and is specified as $c^F{}_{ki}(q_i,\, v_i\,) = \alpha v_i\, q_i^2$.[8]

4. Fixed Cost of Quality

In this section the case with fixed cost of quality is examined. As IOFs underestimate the actual cost of quality by not considering the farm level cost in the quality stage of the game, IOFs promote higher levels of quality, lower prices, higher consumer surplus and, for small quality costs, higher total welfare than COOPs. Cooperatives promote higher producer surplus and for large quality costs also a higher total welfare while the market share of the high-quality good is unaffected by the ownership structure.

Taking quality levels as fixed we start by solving the price setting sub-game. As previously mentioned, consumers have the same indirect utility function $U(\theta,\, v_i) = \theta v_i - p_i$. The

[7] In our notation, the cost functions used are $c_i(v_i,q_i) = \alpha v_i^2 q_i$ in Ueng (1997); $c_i(v_i,q_i) = \alpha v_i q_i$ in Bonnano et al (1998), and $c_i(v_i,q_i) = \alpha v_i^2 q_i/2$ in Motta (1993).

[8] $c^F{}_i(q_i,\, v_i\,) = \Sigma_k^K\, c^F{}_{ki}(q_i,\, v_i\,) = \alpha\, v_i\, K^{-1} q_i^2$. For notational convenience, and without loss of generality, α is normalized and redefined such that $\alpha \equiv \alpha K^{-1}$. $\beta = \Sigma_k^K\, \beta_k$.

consumer will buy the high quality good if $U(\theta, v_H) \geq U(\theta, v_L)$ and $U(\theta, v_H) \geq 0$, and she will buy the low-quality good if $U(\theta, v_L) > U(\theta, v_H)$ and $U(\theta, v_L) \geq 0$.[9] The consumer indifferent between the two goods has the taste parameter $\theta_{LH} = (p_H - p_L)/(v_H - v_L)$ and the consumer indifferent between buying the low quality good and not buying at all has the taste parameter $\theta_{\varnothing L} = p_L/v_L$. The demand functions can then be constructed using these results and noting that any consumer getting the same utility from a high and a low quality good at a certain price unambiguously prefer the high-quality good. The demand for the high quality good is represented by the consumers that have a taste parameter in the interval $\theta^+ \geq \theta \geq \theta_{HL}$ while the demand for the low quality good is represented by the consumers with a taste parameter $\theta_{HL} > \theta \geq \theta_{L\varnothing}$. Consumers with a taste parameter $\theta < \theta_{L\varnothing}$ will not buy at all. Hence, we get demand functions for the two goods as defined by (4.1) and (4.2).With a fixed farm level cost function, $c^F_{ki}(.) = \beta_k v_i^2/2$, the profit functions for COOP and IOF are defined as in (4.3) and (4.4):

$$q_H = \theta^+ - (p_H - p_L)/(v_H - v_L) \tag{4.1}$$
$$q_L = (p_H - p_L)/(v_H - v_L) - p_L / v_L \tag{4.2}$$

$$\pi^{IOF}_i = p_i q_i - c^P_i(\cdot) - [\partial c^F_{ki}(\cdot)/\partial q_{ki}]\, q_i = p_i q_i - v_i^2/2 \tag{4.3}$$
$$\pi^{COOP}_i = p_i q_i - c^P_i(\cdot) - \Sigma_k c^F_{ki}(\cdot) = p_i q_i - (1+\alpha)\, v_i^2/2 \tag{4.4}$$

For each scenario, the demand equations (4.1) and (4.2) are substituted into the profit functions (4.3) and (4.4). Differentiating the obtained profits with respect to prices we can solve for the optimal quantities, prices and profits. As the first order conditions do not depend on ownership structure, we can state the equilibrium prices ((4.7) and (4.8)), quantities ((4.9) and (4.10)), and revenue functions ((4.11) and (4.12)) as general cases independent of ownership structure.

$$\partial\pi_H/\partial p_H = [\theta v_L(v_H - v_L) - v_L(2p_H - p_L)]/[v_L(v_H - v_L)] = 0 \tag{4.5}$$
$$\partial\pi_L/\partial p_L = [v_L p_H - 2v_H p_L]/[v_L(v_H - v_L)] = 0 \tag{4.6}$$

$$q_H(v_H, v_L) = 2\theta v_H / [4v_H - v_L] = 2\theta z / [4z - 1] = 2q_L^j \tag{4.7}$$
$$q_L(v_H, v_L) = \theta v_H / [4v_H - v_L] = \theta z / [4z - 1] \tag{4.8}$$

$$p_H(v_H, v_L) = 2\theta v_H(v_H - v_L)/ [4v_H - v_L] = 2\theta z v_L(z-1)/ [4z - 1] = (v_H - v_L)q_H^j \tag{4.9}$$
$$p_L(v_H, v_L) = \theta v_L(v_H - v_L) / [4v_H - v_L] = \theta v_L(z-1)/[4z-1] = v_L(v_H - v_L)q_L^j / v_H \tag{4.10}$$

$$R_H(v_H, v_L) = 4\theta^2 v_H^2(v_H - v_L)/ [4v_H - v_L]^2 = 4\theta^2 z^2 v_L(z-1)/ [4z - 1]^2 \tag{4.11}$$
$$R_L(v_H, v_L) = \theta^2 v_H v_L(v_H - v_L) / [4v_H - v_L]^2 = \theta^2 z v_L(z-1) / [4z - 1]^2 \tag{4.12}$$

[9] A consumer buy the high quality good if (i) $U(\theta,v_H) = \theta v_H - p_H \geq \theta v_L - p_L = U(\theta,v_L)$, i.e. if $\theta \geq (p_H - p_L)/(v_H - v_L)$ and (ii) $U(\theta,v_H) = \theta v_H - p_H \geq 0$, i.e. if $\theta \geq p_H/v_H$. A consumer buy a low quality good if (i) $U(\theta, v_H) = \theta v_H - p_H < \theta v_L - p_L = U(\theta,v_L)$, i.e. if $\theta < (p_H - p_L)/(v_H - v_L)$, and (ii) $U(\theta,v_L) = \theta v_L - p_L \geq 0$, i.e. if $\theta \geq p_L/v_L$ (Metrick et al, 1999).

Substituting the equilibrium prices and quantities into the profit functions (4.3) and (4.4) we obtain the equilibrium profits as functions of the quality levels for the four different scenarios respectively. In solving the first stage of the game, the optimal profits are differentiated w.r.t. the level of quality. Substituting for $v_H = zv_L$, we can solve for the quality spread z. By substituting z into optimal profits we can solve for the optimal quality levels of v_H and v_L and by specifying a value of the cost parameter α we can then get explicit solutions in terms of θ. Using these values we can explicitly solve for profits, prices, quantities and calculate welfare effects and market shares. In Table 2 the profit functions, the equilibrium quality spread and quality levels for each of the four scenarios are presented.

Table 2. Equilibrium Outcomes - Fixed Cost of Quality

Scenario (II): The Case with two IOFs

$\pi^{II}{}_H = 4\theta^2 v_H{}^2(v_H\text{-}v_L) / [4v_H - v_L]^2 - v_H{}^2 / 2$ (4:13a)

$\pi^{II}{}_L = \theta^2 v_H v_L(v_H\text{-}v_L) / [4v_H - v_L]^2 - v_L{}^2 / 2$ (4:14a)

$\partial\pi^{II}{}_i / \partial v_i$; $v_H \equiv z\, v_L$; $z \geq 1 \Longrightarrow \quad 4z^3\text{-}23z^2\text{+}12z\text{-}8 = 0$ (4:15a)

$v_L{}^{II} = [\theta^2 v_H{}^2(4v_H\text{-}7v_L)]/[4v_H\text{-}v_L]^3 \quad = [\theta^2 z(4z^2\text{-}7z)]/[4z\text{-}1]^3$ (4:16a)

$v_H{}^{II} = 4\theta^2 v_H(4v_H{}^2\text{+}2v_L{}^2\text{-}3v_Hv_L)/[4v_H\text{-}v_L]^3 \quad = 4\theta^2 z(4z^2\text{+}2\text{-}3z)/[4z\text{-}1]^3$ (4:17a)

Scenario (CC): The Case with two COOPs

$\pi^{CC}{}_H = 4\theta^2 v_H{}^2(v_H\text{-}v_L) / [4v_H - v_L]^2 - (1+\beta)v_H{}^2 / 2$ (4:13b)

$\pi^{CC}{}_L = \theta^2 v_H v_L(v_H\text{-}v_L) / [4v_H - v_L]^2 - (1+\beta)v_L{}^2 / 2$ (4:14b)

$\partial\pi^{CC}{}_i/\partial v_i$; $v_H \equiv z\, v_L$; $z \geq 1 \Longrightarrow \quad 4z^3\text{-}23z^2\text{+}12z\text{-}8 = 0$ (4:15b)

$v_L{}^{CC} = [\theta^2 v_H{}^2(4v_H\text{-}7v_L)]/\{(1+\beta)[4v_H\text{-}v_L]^3\} \quad = v_L{}^{II} / (1+\beta)$ (4:16b)

$v_H{}^{CC} = 4\theta^2 v_H(4v_H{}^2\text{+}2v_L{}^2\text{-}3v_Hv_L)/[(1+\beta)[4v_H\text{-}v_L]^3] = v_H{}^{II} /(1+\beta)$ (4:17b)

Scenario (IC): The Case with a high-quality IOF and a low-quality COOP

$\pi^{IC}{}_H = 4\theta^2 v_H{}^2(v_H\text{-}v_L) / [4v_H - v_L]^2 - v_H{}^2 /2$ (4:13c)

$\pi^{IC}{}_L = \theta^2 v_H v_L(v_H\text{-}v_L) / [4v_H - v_L]^2 - (1+\beta)v_L{}^2 / 2$ (4:14c)

$\partial\pi_i/\partial v_i$; $v_H \equiv z\, v_L$; $z \geq 1 \Longrightarrow \quad (4z^3\text{-}7z^2)\text{-}4(1+\beta)(4z^2\text{+}2\text{-}3z) = 0$ (4:15c)

$v_L{}^{IC} = [\theta^2 v_H{}^2(4v_H\text{-}7v_L)]/\{(1+\beta)[4v_H\text{-}v_L]^3\} \quad = \{v_L{}^{II} \mid z = z^{IC}\} / (1+\beta)$ (4:16c)

$v_H{}^{IC} = 4\theta^2 v_H(4v_H{}^2\text{+}2v_L{}^2\text{-}3v_Hv_L)/[4v_H\text{-}v_L]^3 \quad = \{v_H{}^{II} \mid z = z^{IC}\}$ (4:17c)

Scenario (CI): The Case with a high-quality COOP and a low-quality IOF

$\pi^{CI}{}_H = 4\theta^2 v_H{}^2(v_H\text{-}v_L) / [4v_H - v_L]^2\text{-}(1+\beta)v_H{}^2 / 2$ (4:13d)

$\pi^{CI}{}_L = \theta^2 v_H v_L(v_H\text{-}v_L) / [4v_H - v_L]^2\text{-}v_L{}^2/ 2$ (4:14d)

$\partial\pi^{CC}{}_i/\partial v_i$; $v_H \equiv z\, v_L$; $z \geq 1 \Longrightarrow \quad (1+\beta)(4z^3\text{-}7z^2) \text{-}4(4z^2\text{+}2\text{-}3z) = 0$ (4:15d)

$v_L{}^{CI} = [\theta^2 v_H(4v_H{}^2\text{-}7v_Hv_L)]/[4v_H\text{-}v_L]^3 \quad = \{v_L{}^{II} \mid z = z^{CI}\}$ (4:16d)

$v_H{}^{CI} = 4\theta^2 v_H(4v_H{}^2\text{+}2v_L{}^2\text{-}3v_Hv_L)/\{(1+\beta)[4v_H\text{-}v_L]^3\} = \{v_H{}^{II} \mid z = z^{CI}\} / (1+\beta)$ (4:17d)

Using equations (4.3) and (4.4) we define the total cost as $TC^{IOF}=c^{P}_{i}(.)+[\partial c^{F}_{ki}(.)/\partial q_{ki}]q_i$ and $TC^{COOP} = c^{P}_{i}(.) + \Sigma_k c^{F}_{ki}(.)$ for IOFs and COOPs respectively. The second derivatives are both negative given the assumption that $v_H \geq v_L$.[10] Hence, the solutions given by equations (4.16) - (4.17) represents local maxima. In order for these to be Nash equilibria, we have to prove that the solutions are stable, i.e. that they represent the optimal response so that neither firm has an incentive to deviate. Following Motta (1993), we assume firm 1 produce the high-quality v_H, and firm 2 produce the low-quality v_L. For the solutions to be Nash equilibria we have to be sure that (i) there is no other $v_H \neq v_H*$ ($v_L \neq v_L*$) that is more profitable to firm 1 (firm 2), and (ii) there is no incentive for firm 1 (firm 2) to leapfrog the rival firm and itself produce the lower (higher) quality. Formally, the following conditions have to be satisfied in order for our solutions to be Nash equilibria:

$$\pi_1(v_H*, v_L*) \geq \pi_1(v_H, v_2 = v_L*) \text{ for } v_H \geq v_L* \qquad (4.18)$$
$$\pi_1(v_H*, v_L*) \geq \pi_1(v_L, v_2 = v_L*) \text{ for } v_L \leq v_L* \qquad (4.19)$$

$$\pi_2(v_L*, v_H*) \geq \pi_2(v_L, v_1 = v_H*) \text{ for } v_L \leq v_H* \qquad (4.20)$$
$$\pi_2(v_L*, v_H*) \geq \pi_2(v_H, v_1 = v_H*) \text{ for } v_H \geq v_H* \qquad (4.21)$$

In solving equations (4.15) we found that there is only one possible solution that satisfies the assumption that $v_H \geq v_L$ (i.e. $z \geq 1$). Hence, conditions (4.18) and (4.20) are satisfied.[11] The condition that there is no incentive to leapfrog the rival and switch type of quality for neither of the firms is represented in (4.19) and (4.21). In Appendix 2 it is shown that these conditions are satisfied for scenario (II), (CC), and (IC) for all values of β while in the scenario (CI) the conditions are fulfilled for all $\beta < 0.59$.

The revenue functions are defined as in equations (4.11) and (4.12) and are independent of the cost parameter β. Differentiating equations (4.11) and (4.12) we find that the revenue functions have the following properties $\partial R_H*/\partial v_H > 0$; $\partial R_H*/\partial v_L* < 0$; $\partial R_L*/\partial v_L > 0$; $\partial R_L*/\partial v_H* > 0$.[12] Naturally, the slope of the revenue function has to equal the slope of the cost function for each firm in equilibrium. The cost functions have the property $\partial C_i^{COOP}/\partial v_i = (1+\beta)v_i$ for cooperatives and $\partial C_i^{IOF}/\partial v_i = v_i$ for IOFs. Hence, a fixed cost of quality at farm level does not

[10] $\partial^2 \pi_H/\partial v_H^2 = -8\theta^2 v_L^2(5v_H+v_L)/[4v_H-v_L]^4 - \partial^2 TC/\partial v_H^2 < 0$; $\partial^2 \pi_L/\partial v_L^2 = -2\theta^2 v_H^2(8v_H+7v_L)/[4v_H-v_L]^4 - \partial^2 TC/\partial v_L^2 < 0$. For an IOF, $\partial^2 TC/\partial v_i^2 = -1 < 0$, and for a $COOP\ \partial^2 TC/\partial v_i^2 = -(1+\beta) < 0$.
[11] For the high-quality firm i to produce any other level of quality such that $v_H \geq v_L*$ would yield a lower profit than producing v_H*, i.e. condition (4.18) is satisfied. Correspondingly, for the low-quality firm j to produce any other level of quality such that $v_L \leq v_H*$ would yield a lower profit than producing v_L*, i.e. condition (4.20) is satisfied.
[12] This has been shown by eg Aoki et al (1996).

directly affect behavior of the IOF and, as a consequence, the equilibrium solution in scenario (II) is unaffected by changes in β. In the remaining scenarios, an increase in β implies an increase in the cost of production for at least one of the producers, which will affect the equilibrium solutions. For example, assume that the firm producing low quality is a cooperative and the firm producing high quality is an IOF, i.e. the (IC) scenario. As β increases, the cost function of the cooperative becomes more convex, while the revenue function is unaffected. Hence, by concavity of the revenue function and convexity of the cost function, the firm would earn a higher profit producing a lower quality as β increases. This reduction in v_L shift the revenue curve of the high-quality producing firm upwards as $\partial R_H^*(v_H, v_L^*)/\partial v_L^* < 0$. Unless the high-quality producing IOF decreases their quality level, $\partial R_H^*/\partial v_H > \partial C_H/\partial v_H$. Hence, it is optimal to reduce v_H which reduce the revenue of the low-quality producing COOP as $\partial R_L^*/\partial v_H > 0$, i.e. it is optimal for the IOF to decrease the level of quality. Equilibrium is reached in (v_H^*, v_L^*) where $\partial R_i^*/\partial v_i = \partial C_i/\partial v_i$ is achieved for both firms.

In the case where $\beta = 0$, the same outcome is generated in all scenarios. This reference outcome is principally the same as in Motta (1993). Motta examines one level of the chain and includes a fixed cost as specified in this paper for the process level. In the scenario with only investor owned firms, an increase in β will not affect the equilibrium outcomes. As the cost increase the producer surplus decrease and, hence, total welfare decrease as well. In the scenario with only cooperatives higher costs of production associated affects both firms proportionally such that the relative cost remains constant. Hence, the optimal response is to retain the same relative quality levels, i.e. a constant quality spread. A higher cost imply lower levels of quality, which in turn implies lower prices, revenues and profits. Producer and consumer surplus decreases as β increases. As both firms are affected proportionally, quality levels, prices and profits for the cooperatives equals that of a market with only IOFs adjusted by the cost increase.[13]

In the mixed scenarios, the relative competitiveness of the COOP decreases as β increases due to a more convex cost function. In the (IC) scenario, higher costs of production affects only the low-quality cooperative which implies that the level of quality decreases. As the high-quality level remains approximately constant, the quality spread increases, the high-quality

[13] $v_i^{CC} = v_i^{II}/(1+\beta)$; $q_L^{CC} = q_L^{II}$; $q_H^{CC} = 2q_L^{CC} = 2q_L^{II}$; $p_i^{CC} = p_i^{II}/(1+\alpha)$; $\pi_i^{CC} = \pi_i^{II}/(1+\alpha)$

price increases and the low-quality price decreases. Furthermore, quantities decreases slightly, profits increase for the IOF and decreases for the COOP and overall producer surplus decreases as β increases. Increased production costs imply a smaller consumer surplus and a smaller total welfare. In scenario (CI), higher costs of production implies that the cooperative decreases the level of high quality. This increases the competition between the goods and the quality spread decreases, which imply larger quantities of both qualities. The prices decrease as the low-quality level and the quality spread decreases. Profits decreases for the IOF as well as for the COOP and overall producer surplus decreases as do consumer surplus and total welfare.

Results

In Table 3 the comparison between the four scenarios are summarized and within brackets it is shown, in each scenario, how the variables are affected as the cost of quality increases. Only the cooperative structure considers the fixed cost of quality at farm level when choosing the level of quality. Hence, investor owned firms underestimate the actual cost of quality in the first stage of the game. Consequently, it is natural that the case with only investor owned firms produce the highest levels of quality, the case with only cooperatives produce the lowest and that scenario (IC) produces a higher level of high quality and a lower level of low quality than scenario(CI).

The difference in the degree of convexity of the cost function between the scenarios imply that the quality levels in each scenario are affected differently as previously explained. In the scenarios with only one type of ownership structure, the relative cost of production is independent of β, and the quality spread is the same and constant in these scenarios. In the mixed scenarios, the relative cost advantage of the investor owned firm is larger if the IOF is the high-quality producer. Hence, the quality spread is largest, and increasing, in scenario (IC) and lowest, and decreasing, in scenario (CI).

Quantities only depend on the quality spread and, hence the quantities produced in a setting with only one type of ownership structure are constant. The mixed scenario with a high-quality cooperative has the smallest quality spread and consequently produces the largest volumes of both quantities while the opposite is true for the mixed scenarios with a low-quality cooperative. Furthermore, it is evident from equation (4.7)-(4.8) that the high-quality firm produces twice the quantity of the low-quality firm, i.e. the market share of the high-quality good is consistently 2/3. This is in accordance with previous literature not incorporating the aspect of ownership structure, which has concluded that the high-quality firm produces a larger quantity than the low-quality firm (Motta, 1993; Aoki, 1996; Lehmann-Grube, 1997; Metrick & Zeckhauser, 1999).[14]

Table 3: Summary - Fixed Cost of Quality [a)]

z		IC(↑)	>	II(=)	=	CC (=)	>	CI (↓)	
v_L		II (=)	>	CI(↓)	>	IC (↓)	>	CC (↓)	
v_H		II (=)	>	IC (↓)[b)]	>	CI (↓)	>	CC (↓)	
q_L		CI(↑)	>	II (=)	=	CC(=)	>	IC (↓)	
q_H		CI(↑)	>	II (=)	=	CC(=)	>	IC (↓)	
q_T		CI (↑)	>	II (=)	=	CC(=)	>	IC (↓)	
p_L		II (=)	>	CI (↓)	>	IC (↓)	>	CC(↓)	
p_H		IC (↑)	>	II (=)	>	CC(↓)	>	CI (↓)	
π_L		II (=)	>	CI(↓)	>	IC (↓)	>	CC (↓)	
π_H		IC (↑)	>	II (=)	>	CC (↓)	>	CI (↓)	
Producer Surplus [c)]		CC(↓)	>	CI (↓)	<>	IC (↓)	>	II (↓)	
Consumer Surplus		II (=)	>	IC(↓)	>	CI (↓)	>	CC (↓)	
Total Welfare [d)]	>	II (↓)	>	IC (↓)	>	CI (↓)	>	CC(↓)	>
High Quality Market share		IC (=)	=	II (=)	=	CC (=)	=	CI (=)	

Within brackets the direction of the change within each scenario as β increases is shown. [a)] As pointed out in the text, in the (CI) scenario a Nash Equilibrium only exists for $\beta < 0.59$. [b)] Small changes. [c)] IC > CI for $\beta < 0.15$, and CI > IC for $\beta \geq 0.15$. [d)] Switches such that for $\beta > 2$ CC>IC>II.

The market can be considered to be more competitive the smaller the quality spread, i.e. the less differentiated the products are. A more competitive market will have smaller price differences and larger quantities than a less competitive market. From equations (4.9) and (4.10) it is evident that in equilibrium it is always optimal to have relative price equal to $2z$, i.e. the price spread increases the less competitive the market is. Equations (4.7) and (4.8) show that the total quantity will be $q_T = 3\theta z/(4z-1)$ which is decreasing in z. Hence, we conclude that (CI) is the most competitive scenario, with the smallest quality spread, the smallest price spread and the largest total quantity while (IC) is the least competitive scenario. The unmixed markets are equally competitive and less competitive than the (CI) scenario but more competitive than the (IC) scenario.

[14] This has been shown to be true both for simultanous and sequential games.

A well-established result in the literature on vertical product differentiation is that the high-quality firm earns higher profits than the low-quality firm (Shaked & Sutton, 1982; Tirole, 1988; Choi & Shin, 1992; Donnenfeld & Weber, 1992; Motta, 1993; Aoki & Prusa, 1996; Metrick & Zeckhauser, 1999). Lehmann-Grube (1997) has shown that in a duopoly setting not taking ownership structure into account, the high-quality firm will earn higher profits for all fixed cost functions that are increasing and convex in quality. We find that this is true for all scenarios for all Nash equilibria (see Appendix 3).

All scenarios have the same cost structure but they differ in the quality levels choosen by the processors. As investor owned firm does not consider the fixed farm level cost in the choice of quality, the producer surplus incorporating profits at farm level is smallest in the case with only IOFs, and largest in the case with only cooperatives. The consumer surplus is lowest in the market with only cooperative firms, which has the lowest levels of quality and highest quality costs. Highest consumer surplus is generated in the market with only investor owned firms, where the reverse is true. If the cost of quality is low, the total social welfare is highest in scenario (II) and lowest in scenario (CC), as the consumer surplus. If the costs are high, the producer surplus becomes more dominant and eventually total social welfare is highest in (CC) and lowest in (II).

5. Variable Cost of Quality

In this section we analyze the case were the cost of quality is assumed to be variable instead of fixed. We find that a high-quality producing cooperative promote a higher level of quality, lower prices, larger volumes, larger profits and larger market share of the high-quality good. The cooperative structure also implies a larger quality spread and larger total quantity. In addition, COOPs implies larger consumer surplus and higher total welfare.

The demand side is as described in section 4, and the direct demand as shown in equations (4.1) and (4.2). In the case of variable quality cost, ownership structure will only matter when there are non-constant returns to scale, as noted in section 3. With a variable farm level cost function defined as $c^F_{ki}(q_{ki}, v_i) = \alpha\, v_i\, q_{ki}^2$, the profit functions for COOP and IOF respectively are:

$$\pi^{IOF}_i = p_i q_i - c^P_i(.) - [\partial c^F_{ki}(.)/\partial q_{ki}]q_i = p_i q_i - v_i/2 - 2\alpha\, v_i\, q_i^2 \quad (5.1)$$

$$\pi^{COOP}_i = p_i q_i - c^P_i(.) - \Sigma_k c^F_{ki}(.) = p_i q_i - v_i/2 - \alpha\, v_i\, q_i^2 \quad (5.2)$$

In the first stage of the game, the firms choose their level of quality and in the second stage of the game they compete in prices. Following the procedure presented in section 4, the solution can be found by backwards induction. Hence, we start by solving the second stage of the game by substituting the demand equations (4.1) and (4.2) into the profit functions (5.1) and (5.2) and differentiating the obtained profits with respect to prices. It is then possible to solve for the optimal quantities, prices and profits in terms of the quality levels. As the first order conditions depend on ownership structure and hence the equilibrium prices, quantities, profit and revenue functions are unique for each scenario. Therefore, it is necessary to specify the solutions for each scenario. Once we have obtained the profits as a function of the levels of quality for each specific scenario, we differentiate the optimal profits by the level of quality, substitute for $v_H = zv_L$ and solve for the quality spread z. The optimal quality levels of v_H and v_L are obtained by substituting z into the optimal profits, and by specifying a value of the cost parameter α, explicit numerical solutions in terms of θ are derived. Using these values we can explicitly solve for profits, prices, quantities and calculate welfare effects and market shares etc. In Table 4 prices, quantities, the profit functions, and the equilibrium quality levels for each of the four scenarios are presented.

Given the assumption that $v_H \geq v_L$, all the second derivatives of profits with respect to the level of quality are negative. Hence, we can conclude that the solutions in equations (5.9) and (5.10) represents local maxima.[15] If neither firm has an incentive to deviate, the solutions are stable and represent Nash equilibria, i.e. the conditions represented by equations (4.18) - (4.21) are satisfied. Conditions (4.18) and (4.20) are satisfied as we, in solving for z, found that there is only one possible solution that satisfies the assumption that $v_H \geq v_L$ (i.e. $z \geq 1$). Conditions (4.19) and (4.21) represent the condition that there is no incentive to "leapfrog" the rival and "switch" type of quality for neither of the firms. In Appendix 4 it is shown that these conditions are satisfied for all α's in scenarios (II) and (CC), for $\alpha \leq 0.3448$ in scenario (CI) and for $\alpha \leq 0.6564$ in scenario (CI).

[15] $\partial^2(\pi_H{}^{II})/\partial(v_H{}^{II})^2 = \partial^2(v_H{}^{IC})/\partial(v_H{}^{IC})^2 = -2\{(1+2\alpha)v_H - v_L\}/\{v_H-v_L\}^2 < 0$; $\partial^2(\pi_L{}^{II})/\partial(v_L{}^{II})^2 = \partial^2(v_L{}^{CI})/\partial(v_L{}^{CI})^2 = -2v_H\{(1+2\alpha)v_H - v_L\}/\{v_L(v_H-v_L)^2\} < 0$; $\partial^2(\pi_H{}^{CC})/\partial(v_H{}^{CC})^2 = \partial^2(\pi_H{}^{CI})/\partial(v_H{}^{CI})^2 = -2\{(1+\alpha)v_H - v_L\}/\{v_H-v_L\}^2 < 0$; $\partial^2(\pi_L{}^{CC})/\partial(v_L{}^{CC})^2 = \partial^2(\pi_H{}^{IC})/\partial(v_H{}^{IC})^2 = -2v_H\{(1+\alpha)v_H - v_L\}/\{v_L(v_H-v_L)^2\} < 0$

Table 4. Equilibrium Outcomes – Variable Cost of Quality

Scenario (II): The Case with two IOFs

$q_H^{II} = 2\theta v_H[v_H(1+2\alpha)-v_L] / [4(1+2\alpha)^2 v_H^2 - (5+8\alpha)v_H v_L + v_L^2]$ (5.3a)

$q_L^{II} = \theta v_H(v_H(1+4\alpha)-v_L) / [4(1+2\alpha)^2 v_H^2 - (5+8\alpha)v_H v_L + v_L^2]$ (5.4a)

$p_H^{II} = 2\theta v_H(v_H(1+2\alpha)-v_L)(v_H(1+4\alpha)-v_L)/[.] \quad = (v_H(1+4\alpha)-v_L)q_H$ (5.5a)

$p_L^{II} = \theta\, v_L(v_H(1+4\alpha)-v_L)^2 / [.] \quad = v_L(v_H(1+4\alpha)-v_L)q_L / v_H$ (5.6a)

$\pi_H^{II} = 4\theta^2 v_H^2[v_H(1+2\alpha)-v_L]^3/[.]^2-v_H^2/2 \quad = [(v_H(1+2\alpha)-v_L)]q_H^2-v_H^2/2$ (5.7a)

$\pi_L^{II} = \theta^2 v_H v_L[v_H(1+2\alpha)-v_L][v_H(1+4\alpha)-v_L]^2/[.]^2-v_L^2/2 = v_L[(v_H(1+2\alpha)-v_L)]q_L^2/v_H - v_L^2/2$ (5.8a)

$v_L^{II}=z^2\theta^2\{(z(1+4\alpha)-1)(-7-6\alpha+z(1+2\alpha)(18+28\alpha+4z^2(1+4\alpha)(1+2\alpha)^2-z(15+68\alpha+80\alpha^2)))\}/[.]^3$ (5.9a)

$v_H^{II} = 4\theta^2 z\{(z(1+2\alpha)-1)^2(z(1+2\alpha)(z(4z(1+2\alpha)^2-7-8\alpha)+5)-2)\}/[.]^3$ (5.10a)

Scenario (CC): The Case with two COOPs

$q_H^{CC} = 2\theta v_H[v_H(1+\alpha)-v_L] / [4(1+\alpha)^2 v_H^2 - (5+4\alpha)v_H v_L + v_L^2]$ (5.3b)

$q_L^{CC} = \theta v_H(v_H(1+2\alpha)-v_L) / [4(1+\alpha)^2 v_H^2 - (5+4\alpha)v_H v_L + v_L^2]$ (5.4b)

$p_H^{CC} = 2\theta v_H(v_H(1+\alpha)-v_L)(v_H(1+2\alpha)-v_L)/[.] \quad = (v_H(1+2\alpha)-v_L)q_H$ (5.5b)

$p_L^{CC} = \theta\, v_L(v_H(1+2\alpha)-v_L)^2 / [.] \quad = v_L(v_H(1+2\alpha)-v_L)q_L / v_H$ (5.6b)

$\pi_H^{CC} = 4\theta^2 v_H^2[(v_H(1+\alpha)-v_L)]^3/ [.]^2 - v_H^2/2 \quad = [v_H(1+\alpha)-v_L]q_H^2 - v_H^2/2$ (5.7b)

$\pi_L^{CC} = \theta^2 v_H v_L(v_H(1+2\alpha)-v_L)^2[(v_H(1+\alpha)-v_L)]/[.]^2-v_L^2/2= v_L[v_H(1+\alpha)-v_L]q_L^2/v_H-v_L^2/2$ (5.8b)

$v_L^{CC} =\theta^2 z^2(z(1+2\alpha)-1)\{(-7-3\alpha+z(1+\alpha)(18+14\alpha+4z^2(1+\alpha)^2(1+2\alpha)-2\alpha z(17+10\alpha)-15z))\}/[.]^3$ (5.9b)

$v_H^{CC} = 4\theta^2 z\{(z(1+\alpha)-1)^2(z(1+\alpha)(4z^2(1+\alpha)^2-z(7+4\alpha)+5)-2)\}/[1-z(5+4\alpha)+4z^2(1+\alpha)^2)]^3$ (5.10b)

Scenario (IC): The Case with a High-Quality IOF and a Low-Quality COOP

$q_H^{IC} = 2\theta v_H[v_H(1+\alpha)-v_L] / [4v_H(1+\alpha)-v_L)(v_H(1+2\alpha)-v_L]$ (5.3c)

$q_L^{IC} = \theta v_H[v_H(1+4\alpha)-v_L] / [4v_H(1+\alpha)-v_L)(v_H(1+2\alpha)-v_L]$ (5.4c)

$p_H^{IC} = 2\theta v_H\{v_H(1+4\alpha)-v_L\}[v_H(1+\alpha)-v_L]/[.] = \{v_H(1+4\alpha)-v_L\}q_H^{IOF}$ (5.5c)

$p_L^{IC} = \theta v_L\{v_H(1+4\alpha)-v_L\}(v_H(1+2\alpha)-v_L)/[.] = v_L(v_H(1+2\alpha)-v_L)q_L^{COOP}/v_H$ (5.6c)

$\pi_H^{IC} = 4\theta^2 v_H^2[(1+\alpha)v_H-v_L]^2((1+2\alpha)v_H-v_L)/[(4(1+\alpha)v_H-v_L)^2((1+2\alpha)v_H-v_L)^2]-v_H^2/2$ (5.7c)

$\pi_L^{IC} = \theta^2 v_H v_L[(1+\alpha)v_H-v_L][(1+4\alpha)v_H-v_L]^2/[(4(1+\alpha)v_H-v_L)^2((1+2\alpha)v_H-v_L)^2]-v_L^2/2$ (5.8c)

$v_L^{IC}=\theta^2 z^2(z(1+4\alpha)-1)(-7-3\alpha+z(1+\alpha)(18+26\alpha+4z^2(1+\alpha)(1+2\alpha)(1+4\alpha)-2\alpha z(29+32\alpha)-15z)))$
$/[(2z(1+\alpha)-1)^3(4z(1+\alpha)-1)^3]$ (5.9c)

$v_H^{IC} = 4\theta^2 z\{(z(1+\alpha)-1)^2(z(1+\alpha)(4z^2(1+\alpha)(1+2\alpha)-z(7+6\alpha))+z(5+6\alpha)-2)\}/[.]^3$ (5.10c)

Scenario (CI): The Case with a High-Quality COOP and a Low-Quality IOF

$q_H^{CI} = 2\theta v_H / [4v_H(1+\alpha)-v_L)]$ (5.3d)

$q_L^{CI} = \theta v_H / [4v_H(1+\alpha)-v_L)]$ (5.4d)

$p_H^{CI} = 2\theta v_H\{v_H(1+2\alpha)-v_L\} / [.] = \{v_H(1+2\alpha)-v_L\}q_H^{COOP}$ (5.5d)

$p_L^{CI} = \theta\, v_L\{v_H(1+4\alpha)-v_L\} / [.] = v_L(v_H(1+4\alpha)-v_L)\, q_L^{IOF} / v_H$ (5.6d)

$\pi_H^{CI} = 4\theta^2 v_H^2[(1+\alpha)v_H-v_L]/[4(1+\alpha)v_H-v_L]^2-v_H^2/2$ (5.7d)

$\pi_L^{CI} = \theta^2 v_H v_L[(1+2\alpha)v_H-v_L]/[4(1+\alpha)v_H-v_L]^2-v_L^2/2$ (5.8d)

$v_L^{CI} = \theta^2 z^2[-7-6\alpha+4z(1+\alpha)(1+2\alpha)]/[4z(1+\alpha)-1]^3$ (5.9d)

$v_H^{CI} = 4\theta^2 z[2+z(1+\alpha)(-3+4z(1+\alpha))]/[4z(1+\alpha)-1]^3$ (5.10d)

Results

The four scenarios are summarized and compared in Table 5. Within brackets it is shown how the variables are affected in each scenario as the cost of quality increases. Previous literature on endogenous choice, not incorporating the issue of ownership structure and generally assuming CRS, has established that a high-quality advantage exists with respect to profits, prices and quantities (see e.g. Motta, 1993). It is also well known that a cooperative structure, given diminishing returns to scale, implies a cost advantage as investor owned firms have to pay the farm level marginal cost for all inputs (see e.g. Tirole, 1988). These two factors, the high-cost advantage and the advantage of the cooperative structure, are the driving forces in the model. In scenario (II) only the high-quality advantage plays a role while both factors play a role in the scenario with only cooperatives. The two factors are reinforcing each other in scenario (CI) and contradicting in scenario (IC).

Due to the comparative advantage of the cooperative structure, we expect the cooperative structure to produce a higher level of high quality in the unmixed markets. Correspondingly, the CI scenario produces a higher level than the IC scenario as the comparative advantage is larger for the cooperative producing the high quality. We also expect that, due to the cost advantage of the cooperative structure, v_L is larger in scenario (IC) than in scenario (CI) and larger in scenario (CC) than in scenario (II). The latter is however true only for high costs of quality.[16]

In the mixed scenario with a high-quality cooperative, the cooperative possess both the high-quality advantage and the structural advantage. As a result the relative advantage of the high-quality producer is highest and, hence, the quality spread largest in this scenario. In the other mixed scenario, the quality spread is smallest as the high-quality advantage of the investor owned firm is counteracted by the structural advantage of the low-quality cooperative. Of the unmixed markets, the cooperative structure result in a larger quality spread due to lower costs.

[16] In all scenarios $\partial C_L/\partial v_H < 0 \ \forall \ \alpha$ and $\partial R_L/\partial v_H > 0$ for small α which implies that the optimal response for the low-quality firm is to increase v_L as α increases. However, as α increases the quality spread decreases and eventually $\partial R_L/\partial v_H < 0$ in all scenarios but in (IC). As an investor owned firm pay a higher marginal cost for inputs, it is more sensitive than a cooperative to any change in α. Hence, as the cost of quality increases the low-quality investor owned firm will increase the level of quality more than a low-quality cooperative for small α, and decrease the level more for larger α.

Table 5: Summary - Variable Cost of Quality [a]

z		CI(↓)	>	CC(↓)	>	II(↓)	>	IC(↓)
v_L [b]		IC(↑)	>	II(↑↓)	><	CC(↑↓)	>	CI(↑↓)
v_H [c]		CC(↓)	>	CI(↓)	>	IC(↓)	>	II(↓)
q_L [d]		IC(↑)	>	CC(↑↓)	<>	II(↑↓)	>	CI(↓)
q_H		CI(↓)	>	CC(↓)	>	II(↓)	>	IC(↓)
q_T		CC(↓)	>	IC(↓)	>	CI(↓)	>	II(↓)
p_L [e]	($\alpha \leq 0.15$)	II(↑↓)	>	IC(↑)	>	CI(↑)	>	CC(↑↓)
	($\alpha \geq 1.5$)			CC(↑↓)	>	II(↑↓)		
p_H [f]		CI(↑↓)	>	CC(↓)	>	II(↓)	>	IC(↓)
Farm level, π_F		II(↑↓)	>	IC(↑↓)	>	CI(↑)	>	CC(=0)
π_L [g]		IC(↑)	>	CC(↑↓)	<>	II(↑↓)	>	CI(↑↓)
π_H		CI(↓)	>	CC(↓)	>	II(↓)	>	IC(↓)
Producer Surplus [h]		CI(↓)	>	II(↓)	><	CC(↓)	>	IC(↓)
Consumer Surplus		CC(↓)	>	CI(↓)	>	IC(↓)	>	II(↓)
Total Welfare		CC(↓)	>	CI(↓)	>	IC(↓)	>	II(↓)
High Quality Market share		CI(=)	>	CC(↓)	>	II(↓)	>	IC(↓)

Within brackets the direction of the change within each scenario as α increases is shown. [a] In scenario IC a Nash equilibrium only exists for $\alpha \leq 0.34$ and in scenario IC a Nash equilibrium only exists for $\alpha \leq 0.65$. [b] The level of low quality initially increases as α increases. Except in the IC scenario, v_L starts to decrease as α continues to increase. First in scenario CI, then in II and finally in CC. As a consequence, II > CC $\forall\ \alpha < 0.5$ & CC > II $\forall\ \alpha \geq 0.5$. [c] CC ≈ CI & IC ≈ II. [d] In scenarios II and CC, q_L initially increases before it decreases as α increases. As II increase and decline faster than CC, II > CC $\forall\ \alpha < 0.1$ & CC > II $\forall\ \alpha \geq 0.1$. [e] For $\alpha > 0.15$ CC>CI & for $\alpha \geq 0.25$ IC>II. [f] In scenario CI, p_H initially increase before it decrease at $\alpha > 0.1$. [g] See b), d), e) [h] See e).

The high quality and the cooperative cost advantages promotes larger quantities. This explain why scenario (IC) produces the largest quantity of low quality and the smallest quantity of high quality while the reverse is true for scenario (CI). A market with only cooperatives will produce a larger volume of high-quality goods than a market with only investor owned firms. As in a scenario with a homogenous product we find that a market with only cooperatives produce a larger total quantity than a mixed market which produce a larger total volume than a market with only investor owned firms (see Appendix 5). Of the mixed markets, the scenario including a low-quality cooperative produces a larger volume as this market is more competitive. Due to the high quality and the cooperative cost advantages we find that the high-quality firm produces a larger quantity than the low-quality firm in scenarios (II), (CC) and (CI). With a high quality IOF and a low quality cooperative, however, the contradicting tendencies result in the high-quality firm producing a larger quantity than the low-quality firm only when the cost of quality is small. The market share for the high-quality good is decreasing in α in all scenarios but scenario (CI). Notable is that in scenario (CI) the advantage of the cooperative structure perfectly offsets the increase in relative cost caused by an increase in the cost of quality such that the market share for high quality is constantly 2/3 as in the case with a fixed cost of quality.

The market can be considered to be more competitive the smaller the quality spread, i.e. the less differentiated the products are. We conclude that scenario (IC) is more competitive than the (CI) scenario, having a smaller quality spread, a smaller price spread and a larger total quantity. Furthermore, a market with only investor owned firms is more competitive than a market with only cooperatives as the quality spread and the price spread is smaller.

In the literature on vertical product differentiation it has been established that the high-quality firm earns higher profits than the low-quality firm. In section 3 we found that this is true for all scenarios for all Nash equilibria (as shown by Lehmann-Grube, 1997). In the case of a variable quality cost, we numerically find that this is also generally true in all scenarios but the (IC) scenario. In scenario (IC), the comparative advantage of producing high quality is eventually offset by the advantage of lower production costs associated with the cooperative structure as α increases.

Cooperatives and investor owned firms implicitly have the same overall cost of production although the producer surplus differ as the processors incentive structure differs. The producer surplus is largest in scenario (CI), where the advantage of high quality and the structural advantage is reinforcing, and lowest in scenario (IC), where the factors are contradicting. A market with only IOFs yields a larger (smaller) producer surplus than a market with only cooperatives if the cost of quality is low (high). As cooperatives produce to a lower cost and tend promote larger quantities and cover a larger share of the market, the cooperative structure implies a larger consumer surplus. The total social welfare is as the consumer surplus, highest in scenario (CC) and lowest in scenario (II).

6. Summary and Conclusions

We have found that ownership structure matters if the cost of quality is fixed or if there is a variable cost exhibiting non-constant returns to scale. The latter is not surprising as this is true for homogenous products as well. We examined two farm level cost functions, a fixed cost function that is increasing and convex in quality, and a variable cost function that is increasing and convex in quantity. With a fixed cost function, only cooperatives consider the costs incurred at farm level in the quality stage of the game. Hence, an investor owned firm underestimates the actual cost of quality and thereby chooses higher levels of qualities and lower prices than a cooperative. As a result, the consumer surplus is higher while the producer surplus is lower in a market with only investor owned firms than in market with only cooperatives. If the cost of quality is low (high), a high quality producing IOF generates larger (smaller) total welfare than a high quality producing cooperative. The high quality market share is constant in all scenarios. We also found that in all Nash equilibria the high quality firm produces a larger quantity and earns a higher profit than the low-quality firm. This confirms the findings in previous studies not incorporating the aspect of ownership structure.

In the case of a variable cost function at farm level, the cooperative has a cost advantage as the investor owned processor has to pay farm level marginal cost for all inputs. Of the high quality good, a cooperative produces a larger quantity of a higher level of quality and to a lower price. This results in higher profits and a larger market share for the high quality cooperative. In the mixed scenarios, a cooperative produce a higher level and a larger quantity of the low quality good to a higher price resulting in higher profits. The cooperative structure generates a larger consumer surplus and a higher total welfare than the investor owned structure. In addition, we found that the high quality firm produce a larger volume and earns a higher profit than the low quality firm in scenarios (II), (CC) and (CI). This is in accordance with previous literature not incorporating the aspect of ownership structure. In scenario (IC), this is true only for low costs.

From a consumer point of view, investor owned firms are more beneficial than cooperatives if the cost of quality at farm level is fixed as the quality levels are higher and the prices lower. On the other hand, if the farm level cost is variable, cooperatives generates a larger consumer surplus as cooperatives pay a lower price for inputs. From a welfare point of view, the cooperative structure is preferable to society if the farm level quality cost is variable. It may be argued that society, e.g. for safety reasons, may benefit from having a market structure generating a high minimum standard. Then investor owned firms are desirable if the cost is fixed and a low-quality cooperative and a high-quality IOF is desirable if the cost is variable. Another argument may be that society is better of the higher the level of the high quality as this e.g. may imply safer or more nutritional food. Then IOFs are desirable if the cost is fixed and cooperatives are desirable if the cost is variable.

Appendix 1. Relevance of Ownership Structure

The equilibrium quantities and prices will depend on ownership structure IFF $|n| > 1$, i.e. given a "quality" cost function nonlinear in quantities.

$\partial\pi^{IOF}_i / \partial p_i = [\partial(p_i q_i)/\partial p_i] - n\,\alpha\, v_i^h K^{-(n-1)} (\partial q_i^n/\partial p_i) = 0$

$\partial\pi^{COOP}_i / \partial p_i = [\partial(p_i q_i)/\partial p_i] - \alpha\, v_i^h K^{-(n-1)} (\partial q_i^n/\partial p_i)=0$

(i) $\{\{\partial\pi^{IOF}_i/\partial p_i \neq \partial\pi^{COOP}_i/\partial p_i\} \mid \alpha\neq 0; |n|>1; \forall\beta,\gamma; \forall m,g\}$ $\Rightarrow q_i^{IOF} \neq q_i^{COOP};\ p_i^{IOF} \neq p_i^{COOP}$

(iia) $\{\{\partial\pi^{IOF}_i/\partial p_i = \partial\pi^{COOP}_i/\partial p_i\} \mid \alpha\neq 0; |n|=1; \forall\beta,\gamma; \forall m,g\}$ $\Rightarrow q_i^{IOF} = q_i^{COOP};\ p_i^{IOF} = p_i^{COOP}$

(iib) $\{\{\partial\pi^{IOF}_i/\partial p_i = \partial\pi^{COOP}_i/\partial p_i\} \mid \alpha=0; \forall\beta,\gamma; \forall n,m,g\}$ $\Rightarrow q_i^{IOF} = q_i^{COOP};\ p_i^{IOF} = p_i^{COOP}$

The equilibrium quality levels and profits will depend on ownership structure IFF either (1), $|n| > 1$ & $\beta = 0$ (see above), or (2), $\beta \neq 0$, i.e. there is a fixed cost at farm level.

$\partial\pi^{IOF}_i / \partial v_i = [\partial(P_i q_i)/\partial v_i] - g\,\gamma v_i^{(g-1)} - h\, n\,\alpha\, v_i^{(h-1)} K^{-(n-1)} q_i^n - n\,[\alpha\, v_i^h K^{-(n-1)}][\partial q_i^n/\partial v_i] = 0$

$\partial\pi^{COOP}_i / \partial v_i = [\partial(P_i q_i)/\partial v_i] - g\,\gamma\, v_i^{(g-1)} - h\,\alpha v_i^{(h-1)} K^{-(n-1)} q_i^n - [\alpha v_i^h K^{-(n-1)}][\partial q_i^n/\partial v_i] - m\,\beta v_i^{(m-1)} = 0$

(iii) $\{\{\partial\pi^{IOF}_i/\partial v_i \neq \partial\pi^{COOP}_i/\partial v_i\} \mid \alpha\neq 0; |n|>1; \forall\beta,\gamma; \forall m,g\}$ $\Rightarrow v_i^{IOF} \neq v_i^{COOP};\ \pi_i^{IOF} \neq \pi_i^{COOP}$

(iv) $\{\{\partial\pi^{IOF}_i/\partial v_i \neq \partial\pi^{COOP}_i/\partial v_i\} \mid \beta\neq 0; \forall\alpha,\gamma; \forall n,m,g\}$ $\Rightarrow v_i^{IOF} \neq v_i^{COOP};\ \pi_i^{IOF} \neq \pi_i^{COOP}$

Appendix 2. Nash Equilibrium with a Fixed Cost of Quality

<u>Bertrand – fix (II): (NE $\forall\ \alpha$)</u>

<u>Low to high</u>: $\pi_2(v_L^*, v_H^*) \geq \pi_2(v_H, v_1 = v_H^*)$ for $v_H \geq v_H^*$

$\pi^{II}_{LtoH}(v_H, v_1 = v_H^* \mid k \geq 1) = 4\theta^2 v_H^2(v_H - v_H^*) / [4v_H - v_H^*]^2 - v_H^2 / 2$ let $v_H = kx$, $k \geq 1 \Rightarrow$

$= 4\theta^2 k^2 (v_H^*)(k-1) / [4k-1]^2 - k^2 (v_H^*)^2 / 2$

$= k^2 (v_H^*)\{8\theta^2(k-1) - (v_H^*)[4k-1]^2\} / \{2[4k-1]^2\}$

We know that the optimal quality levels are independent of α and that $v_H^* = 0.2533\ \theta^2$. Substitution yields: $\pi^{II}_{LtoH}(v_H, v_1 = v_H^* \mid k \geq 1) = (0.2533)\, k^2\, \theta^2\{8(k-1) - (0.2533)\,[4k-1]^2\} / \{2[4k-1]^2\}$

$< (0.2533)\, k^2\, \theta^2(2k-1)\{4 - (0.2533)\,[8k]\} / \{2[4k-1]^2\}$

$< 0 \Longrightarrow \pi_2(v_L^*, v_H^*) \geq \pi_2(v_H, v_1 = v_H^*) \Longrightarrow$ Nash equilibrium $\forall\ \alpha$

<u>High to low</u>: $\pi_1(v_H^*, v_L^*) \geq \pi_1(v_L, v_2 = v_L^*)$ for $v_L \leq v_L^*$. As the high-quality firm always earns higher profit than the low-quality firm, the issue of backwards leapfrogging is not an issue. Hence, $\pi_1(v_H^*, v_L^*) \geq \pi_1(v_L, v_2 = v_L^*)$ for $v_L \leq v_L^*$ follows from the proof that $\pi_H > \pi_L$ (see Appendix 3)

<u>Bertrand – fix (CC): (NE $\forall\ \alpha$)</u>

<u>Low to high</u>: $\pi_2(v_L^*, v_H^*) \geq \pi_2(v_H, v_1 = v_H^*)$ for $v_H \geq v_H^*$

$\pi^{CC}_{LtoH}(v_H, v_1 = v_H^* \mid k \geq 1) = 4\theta^2 v_H^2(v_H - v_H^*) / [4v_H - v_H^*]^2 - (1+\alpha)(v_H^*)^2 / 2$ let $v_H = kx$, $k \geq 1 \Rightarrow$

$= k^2(v_H^*)\{8\theta^2(k-1) - (1+\alpha)(v_H^*)[4k-1]^2\} / \{2[4k-1]^2\}$

$\pi_2(v_L^*, v_H^*) < \pi_2(v_H, v_1 = v_H^*)$ IFF $[8\theta^2(k-1) - \{(1+\alpha)(v_H^*)[4k-1]^2\} > 0]$. We know that $v_H^{II} = (1+\alpha)v_H^{CC} = 0.2533$. Substitution yields $[8\theta^2(k-1) - \{(1+\alpha)(v_H^*)[4k-1]^2\}] = \theta^2[8(k-1) - (0.2533)[4k-1]^2] < \theta^2(2k-1)[4 - (0.2533)[8k]] < 0$ $\Longrightarrow \pi_2(v_L^*, v_H^*) \geq \pi_2(v_H, v_1 = v_H^*) \Longrightarrow$ Nash eq. $\forall\ \alpha$

<u>High to low</u>: $\pi_1(v_H^*, v_L^*) \geq \pi_1(v_L, v_2 = v_L^*)$ for $v_L \leq v_L^*$ follows from the proof that $\pi_H > \pi_L$.

Bertrand – fix (IC): (NE $\forall$ α)

Low to high: $\pi_2(v_L^*, v_H^*) \geq \pi_2(v_H, v_1 = v_H^*)$ for $v_H \geq v_H^*$

$\pi^{IC}_{LtoH}(v_H, v_1 = v_H^* \mid k \geq 1) = 4\theta^2 v_H^2(v_H - v_H^*) / [4v_H - v_H^*]^2 - (1+\alpha)(v_H^*)^2 / 2$

$\Longrightarrow \pi_2(v_L^*, v_H^*) < \pi_2(v_H, v_1 = v_H^*)$ IFF $[8\theta^2(k-1) - \{(1+\alpha)x[4k-1]^2\} > 0]$

Numerically we find that $(1+\alpha)v_H^{IC} \geq v_H^{II} = 0.2533$.Substitution yields $8\theta^2(k-1)-\{(1+\alpha)(v_H^*)[4k-1]^2\}] \leq \theta^2[8(k-1)-(0.2533)[4k-1]^2] < \theta^2(2k-1)[4-(0.2533)[8k]] < 0 \Longrightarrow$ Nash equilibrium $\forall$ α

High to low: $\pi_1(v_H^*, v_L^*) \geq \pi_1(v_L, v_2 = v_L^*)$ for $v_L \leq v_L^*$ follows from the proof that $\pi_H > \pi_L$.

Bertrand – fix (CI): (NE $\forall\ \alpha < 0.59$)

Low to high: $\pi_2(v_L^*, v_H^*) \geq \pi_2(v_H, v_1 = v_H^*)$ for $v_H \geq v_H^*$

$\pi^{CI}_{LtoH}(v_H, v_1 = v_H^* \mid k \geq 1) = 4\theta^2 v_H^2(v_H - x) / [4v_H - x]^2 - v_H^2 / 2$ let $v_H = kx$, $k \geq 1 \Rightarrow$

$= 4\theta^2 k^2(v_H^*)(k-1) / [4k-1]^2 - k^2(v_H^*)^2 / 2$

$= k^2(v_H^*)\{8\theta^2(k-1)-(v_H^*)[4k-1]^2\}/\{2[4k-1]^2\}$

Necessary condition $[8\theta^2(k-1)/\{[4k-1]^2\} > (v_H^*)]$ fulfilled for $\alpha \geq 0.54$

Numerical test reveals that $\pi_2(v_L^*, v_H^*) < \pi_2(v_H, v_1 = v_H^*)$ if $\alpha \geq 0.59 \Longrightarrow$ Nash equilibrium $\forall\ \alpha < 0.59$

High to low: $\pi_1(v_H^*, v_L^*) \geq \pi_1(v_L, v_2 = v_L^*)$ for $v_L \leq v_L^*$ follows from the proof that $\pi_H > \pi_L$.

Appendix 3. Profits in the Case of a Fixed Cost of Quality

The firm producing the high quality product will earn a higher profit than the firm producing the low quality product in all Nash Equilibria in all scenarios. The proofs for the scenarios (CC) and (IC) are principally the same as for (II) and are omitted. In the case of the scenario (CI), it is only possible to solve numerically.

Proof for the case with 2 IOFs: i.e. that $\pi^{IOF}_H > \pi^{IOF}_L$

$\pi^{IOF}_H - \pi^{IOF}_L = (4p_H q_L - v_H^2) / 2 - (2p_L q_L - v_L^2) / 2$ [using (4.7)]

$= [2\{2p_H - p_L\}q_L - (v_H^2 - v_L^2)] / 2 = [2\{\theta(v_H - v_L)\}q_L - (v_H^2 - v_L^2)] / 2$ [using (4.5)]

$= (v_H - v_L)[2\theta q_L - (v_H + v_L)]/2 = (v_H - v_L)[2\theta^2 v_H - (v_H + v_L)(4v_H - v_L)]/2(4v_H - v_L)$ [using (4.8)]

$= v_L(z-1)[2\theta^2 z - v_L(z+1)(4z-1)] / 2(4z-1)$

Substitute $v_L^* = 0.0482\,\theta^2$ & $z = 5.2512 \Rightarrow [2\theta^2 z - v_L(z+1)(4z-1)] \geq 0 \Rightarrow \pi^{IOF}_H > \pi^{IOF}_L$

Proof for (CI): $\pi^{COOP}_H > (<) \pi^{IOF}_L$ IFF $\{z > (<) 1.9359\} \Leftrightarrow \{\alpha < (>) 15.1\}$

$\pi^{COOP}_H - \pi^{IOF}_L = \theta^2 v_H(v_H - v_L)(4v_H - v_L) / [4v_H - v_L]^2 - ((1+\alpha)v_H^2 - v_L^2)/ 2$

$= \theta^2 v_H[16v_H^3 - 32v_H^2 v_L + 3v_H v_L^2 - 2v_L^3] / 2[4v_H - v_L]^3$

$= \theta^2 z v_L[16z^3 - 32z^2 + 3z - 2] / 2[4z-1]^3$

$\Longrightarrow$ IFF $(z = 1.9359) \Leftrightarrow (\alpha = 15.1)$ THEN $(\pi^{COOP}_H = \pi^{IOF}_L)$ AS $\{16z^3 + 3z - 32z^2 - 2\} = 0$

IFF $\{z >(<) 1.9359\} \Leftrightarrow \{\alpha <(>) 15.1\}$ THEN $\{\pi^{COOP}_H >(<) \pi^{IOF}_L\}$ AS $\{16z^3 + 3z - 32z^2 - 2\} >(<) 0$

Hence, the high-quality firm will earn a higher profit for all α < 15.1. As previously noted, a Nash equilibrium only exist for α < 0.59 implying that any case were the low-quality firm earns higher profit than the high-quality firm is not a stable equilibrium.

Appendix 4. Nash Equilibrium with a Variable Cost of Quality

Bertrand – variable (II): (NE $\forall$ α)

Low to high: $\pi_2(v_L^*, v_H^*) \geq \pi_2(v_H, v_1 = v_H^*)$ for $v_H \geq v_H^*$

$\pi^{II}_{LtoH}(v_H, v_1 = v_H^* \mid k \geq 1) = 4\theta^2k^2v_H[k(1+2\alpha)-1]^3/ [4(1+2\alpha)^2k^2 - (5+8\alpha)k+ 1]^2 - k^2v_H^2/2$

==>

$\partial\pi^{II}_{LtoH}/\partial k = kv_H\{\{4\theta^2[k(1+2\alpha)-1]^2[[4(1+2\alpha)^3k^3+(1+2\alpha)k^2[8(1+2\alpha)-3(5+8\alpha)]$
$+5k(1+2\alpha)-2]] - v_H[4(1+2\alpha)^2k^2-(5+8\alpha)k+1]^3\}\}= 0$

Numerically, we find that for each α there is only one root satisfying the assumption that $k \geq 1$. Substituting a specific numerical value of α and the corresponding equilibrium quality, v_H^*, into the FOC ($\partial\pi^{IC}_{LtoH}/\partial k$) we extract the k's satisfying the assumption $k \geq 1$. By substituting these k's into π^{II}_{LtoH} we can conclude that the low-quality firm has no incentive to deviate from the original equilibrium, i.e. $\pi^{II}_L > \pi^{II}_{LtoH}$ $\forall$ α.

Following the same procedure, for both producers in all scenarios, it can be concluded that there exists a Nash equilibrium in scenarios (II) and (CC) $\forall$ α, in scenario (IC) there exists a Nash equilibrium $\forall$ $\alpha \leq 0.3448$ and in scenario (CI) $\forall$ $\alpha \leq 0.6564$.

Appendix 5. Homogenous Products with a Variable Cost of Quality

Summary:	q_T	CC	>	IC = CI	>	II
	p	II	>	IC = CI	>	CC
	PS $\forall$ $\alpha \leq 0.86$	II	>	IC = CI	>	CC
	$\forall$ $\alpha > 2.87$	CC	>	IC=CI	>	II

In Bertrand duopoly, both firms will set their price equal to marginal cost, and $p_i = p_j$. Hence, $p_i^{IOF} = mc^{IOF} = 4\alpha vq_i$ and $p_i^{COOP} = mc^{COOP} = 2\alpha vq_i$. The profit function for IOFs and COOPs will be respectively, $\pi_i^{IOF} = [p_i - [\partial c^F_{ki}/\partial q_{ki}]]q_i - v^2/2 = p_iq_i - 2\alpha vq_i^2 - v^2/2$.

Scenario (II): $p_i^{IOF} = p_j^{IOF} = 4\alpha vq_i = 4\alpha vq_j$ ==> $q_i = q_j$
$q_i+q_j = q_T \equiv (\theta v\text{-}p)/v = (\theta v-4\alpha vq_i)/v = 2q_i^{IOF}$

==> $q_i = \theta/2(1+2\alpha)$ $q_T = \theta/(1+2\alpha)$ $p = 2\theta\alpha v/(1+2\alpha)$

$\pi_i^{IOF} = p_iq_i - 2\alpha vq_i^2 - v^2/2 = \theta^2\alpha v/2(1+2\alpha)^2 - v^2/2$; $\pi_i^{IOF}{}_{Farm} = [\partial c^F_{ki}/\partial q_{ki}]\, q_i - C_i = \alpha vq_i^2 = \theta^2\alpha v/4(1+2\alpha)^2$

$PS = 2\,[\pi_i^{IOF} + \pi_i^{IOF}{}_{Farm}] = \theta^2\alpha v/(1+2\alpha)^2 - v^2 + \theta^2\alpha v/2(1+2\alpha)^2 = 3\theta^2\alpha v/2(1+2\alpha)^2 - v^2$

Scenario (CC): $p_i^{COOP} = p_j^{COOP} = 2\alpha vq_i = 2\alpha vq_j$ ==> $q_i = q_j$
$q_T = 2q_i = q_T \equiv (\theta v\text{-}p)/v = (\theta v-2\alpha vq_i)/v = 2q_i$

==> $q_i = \theta/2(1+\alpha)$ $q_T = \theta/(1+\alpha)$ $p = \theta\alpha v/(1+\alpha)$

$\pi_i^{COOP} = p_iq_i - \alpha vq_i^2 - v^2/2 = \theta^2\alpha v/4(1+\alpha)^2 - v^2/2$

$PS = 2\pi_i^{COOP} = \theta^2\alpha v/2(1+\alpha)^2 - v^2$

Scenario (IC) and (CI): $p_i^{IOF} = p_j^{COOP} = 4\alpha vq_i^{IOF} = 2\alpha vq_j^{COOP}$ ==> $2q_i^{IOF} = q_j^{COOP}$
$q_i^{IOF} + q_j^{COOP} = 3q_i^{IOF} = 1.5q_j^{COOP} = q_T = (\theta v-4\alpha vq_i^{IOF})/v = 3q_i^{IOF}$

==> $q_i^{IOF} = \theta/(3+4\alpha)$ $q_j^{COOP} = 2\theta/(3+4\alpha)$ $q_T = 3\theta/(3+4\alpha)$ $p = 4\theta\alpha v/(3+4\alpha)$

$\pi_i^{COOP} = p_iq_i - \alpha vq_i^2 - v^2/2 = 4\theta^2\alpha v/(3+4\alpha)^2 - v^2/2$; $\pi_i^{IOF} = p_iq_i - 2\alpha vq_i^2 - v^2/2 = 2\theta^2\alpha v/(3+4\alpha)^2 - v^2/2$

$\pi_i^{IOF}{}_{Farm} = [\partial c^F_{ki}/\partial q_{ki}]\, q_i - C_i = \alpha vq_i^2 = \theta^2\alpha v/(3+4\alpha)^2$

$PS = \pi_i^{COOP} + \pi_i^{IOF} + \pi_i^{IOF}{}_{Farm} = 6\theta^2\alpha v/(3+4\alpha)^2 - v^2 + \theta^2\alpha v/(3+4\alpha)^2 = 7\theta^2\alpha v/(3+4\alpha)^2 - v^2$

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