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Quality Differentiation if Market Share matters

Alexander Ellert & Oliver Urmann*

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Abstract

Using a vertical differentiation model, we investigate the product quality strategies of two competing firms maximizing market shares. The firms are facing variable costs of quality improvement and choose their prices under the constraint of nonnegative profits. We show that in equilibrium there is no differentiation in quality if the market coverage is either increasing or decreasing and concave in quality. Otherwise the existence of an equilibrium depends on the structure of the game. If the firms choose their qualities simultaneously there is no equilibrium, while there is an equilibrium with a first mover advantage and quality differentiation in the sequential quality competition.

JEL-Classification: L10; L13; L21; I11

Keywords: Market share maximization; Vertical differentiation; Health care market

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1 Introduction

Economic research suggests that firms may follow a variety of objectives (Baumol, 1958; Simon, 1964; Freeman, 1984, among others). Empirical results support this suggestion (Peck, 1988; Borkowski, 1999). Profit, sales and market share turn out to be the most important goals. Therefore theoretical works mostly focus on one or more of these objectives. Fershtman & Judd (1987) consider a mixture of profits and sales, while Jansen et al. (2007) and Ritz (2008) focus on profits and market share in the context of strategic incentivisation. Often one objective is considered to be predominant and profit maximization is often chosen as the main goal (Tirole, 1988; Jensen, 2002, among others). In fact in the strategic delegation literature the additional goals of market share and sales are used strategically to supplement profit maximization which is the sole goal of the firm's owner. Besides strategic considerations also the type of its business model influences the firm's objective crucially. E.g. for non profit organizations profit maximization obviously is not a reasonable objective, while sales maximization and market share maximization remain valid.¹ While sales maximization has been studied widely for quite some time now (Lackman & Craycraft, 1974; Niskanen, 1968; Fershtman, 1985; Sklivas, 1987, among others), market share maximization has received relatively small attention (Gannon, 1973; Denzau et al., 1985, among others).

To demonstrate the relevance of market share maximization we take a closer look at the health care market and the market for arts. Museums and public theaters are classic examples for non profit organizations in the market for arts and to increase the attention of potential customers both have to advertise. Instead of an advertising campaign in the media they also can decide to exhibit a special show as an attraction. The extra costs of such a special show often have to be paid by the customers via an additional entrance fee and the art firms try to maximize attendance. Another example is the market for health insurance. In many countries there is a statutory health insurance which ensures primary health care. In most of these countries the primary health care is provided by regulated non profit organizations such as health insurance funds. Steinberg (1986) shows that health insurance firms generally aim for sales maximization.² Due to demographic change, epidemiological transition and the rapid technological progress the health care market is divided into primary and additional health care. Additional health insurance not only means additional health

¹Hansmann (1987) also analyzed several other goals non profit organizations might pursue as the managers' career expectations or their personal income. These goals can be achieved by the means of market share maximization or sales maximization.

²Steinberg (1986) calls it budget maximization.

care for consumers but also an additional market for health insurance companies which incorporates a high cross selling potential³ and allows the companies to differentiate.⁴ While compared to primary health care the business volume of the additional health care market is still relatively small, its quantity of sales is already high. Therefore the performance in the market for additional health insurance has an impact on the achievement of objectives in the primary health care market. So it is reasonable to assume the health insurance companies try to reach as many consumers as possible with their additional health care products to utilize this subsidiary effect in order to maximize their budget in the primary health care market. Here market share maximization in the additional health care market is used strategically to supplement the main goal of sales maximization. Based on this considerations there are markets in which market share maximization is the dominant objective of competing firms, where the competition takes place in prices and product design. The latter is only possible by differentiation which can be differentiation by taste or differentiation by quality.

Based on Hotelling (1929) differentiation by taste for market share maximization was analyzed first by Gannon (1973).⁵ In his work he shows that in a duopolistic market the companies always choose the geographical center independent of the consumers individual demand. So market share maximizing firms do not differentiate themselves in taste. For profit maximizing firms this only holds in a very special case (Hotelling, 1929).

Differentiation by quality was first analyzed by Gabszewicz & Thisse (1979), Shaked & Sutton (1982) and Tirole (1988) for profit maximizing firms. They showed that differentiation takes place even if quality improvement is costless to relax price competition. If quality improvement is costly, differentiation is still a valuable instrument for profit maximizing firms (Ronnen, 1991; Motta, 1993; Boom, 1995; Aoki & Prusa, 1997; Lehmann-Grube, 1997, among others). But if profit maximization is not the goal of a company, there is no reason to fear price competition. In this work we analyze whether quality differentiation is still a useful tool in a market share maximizing framework.

The rest of the article proceeds as follows. Section 2 introduces our model framework. Section 3 examines the strategies of our market participants. We focus on two different market settings. First, we derive market equilibria of our game in section 4. Then, section

³Consumers buying additional health insurance might tend to choose the same health insurance company for their primary health care.

⁴In contrast to the primary health care, health insurance companies can provide products of different quality as additional health care.

⁵First research in this field stems from Devletoglou & Demetriou (1967). Following Devletoglou (1965) they assumed that there exists a threshold for the consumers reaction.

5 looks at equilibria in a sequential setting. The concluding section, section 6, summarizes our main result and briefly discusses future research.

2 Model

Our model framework builds on the following basic assumptions. There are two market share maximizing firms, firm 1 and firm 2, which compete in a duopolistic market. At the first stage of the game the firms choose their respective quality S_1 and S_2 either simultaneously or in sequential order. At the second stage of the game the firms choose their prices P_1 and P_2 simultaneously under the constraint of nonnegative profits. This constraint means that the firms run a self-financing business in this market. The interval $[\underline{S}, \bar{S}] \subset \mathbb{R}_0^+$, with $\underline{S} = 0$, gives the possible qualities the firms can choose for their products.⁶ The consumers are described via their valuation of quality $\theta \in [\underline{\theta}, \bar{\theta}] \subset \mathbb{R}_0^+$, with $\underline{\theta} = 0$. If the two firms provide the same quality at the same price, the total demand is split between the two firms in equal parts.

Motta (1993) analyzed quality differentiation in the presence of fixed costs of quality improvement and also in presence of variable costs of quality improvement for profit maximizing firms. Also for market share maximizing firms both types of costs are possible. We focus on variable costs of quality improvement, since especially the health care market, where market share maximization is a reasonable goal for many firms, becomes more and more important. The main part of the product costs in such a market accrues at the moment of purchase by consumers.⁷ The costs are therefore described by

$$TC : [\underline{S}, \bar{S}] \times [0, \bar{\theta} - \underline{\theta}] \rightarrow \mathbb{R}_0^+, \quad (S, \omega) \mapsto \omega \cdot C(S),$$

with ω being the output. The unit costs are independent of output and described by the twice continuously differentiable function

$$C : [\underline{S}, \bar{S}] \rightarrow \mathbb{R}_0^+, \quad S \mapsto C(S),$$

with $C'(S) > 0$ for all $S > \underline{S}$. The cost function is exogenous and identical for both firms.

The net utility of a consumer with preference parameter θ from buying a product with quality S at a price $P \geq C(S)$ is given by the Mussa-Rosen utility function (Mussa & Rosen,

⁶The term product is to be seen in a broad sense. It especially includes all kinds of services.

⁷In the health market there are obviously high fixed costs due to R & D, but the health insurance fund only has to pay for each application.

1978)

$$u_\theta : [\underline{S}, \bar{S}] \times \mathbb{R}_0^+ \rightarrow \mathbb{R}, \quad (S, P) \mapsto u_\theta(S, P) = \theta \cdot S - P. \quad (1)$$

Consumers maximize their individual utility and buy at most one unit. Only if the utility is nonnegative the consumer buys the product, meaning we might face an uncovered market. If he is indifferent between two products he buys the one with the higher quality. The marginal consumer who has utility zero from buying a product is given by

$$\theta_0(S, P) = \frac{P}{S}. \quad (2)$$

The consumer with preference θ_{ind} , who is indifferent between the two products, is determined by $u_{\theta_{ind}}(S_1, P_1) = u_{\theta_{ind}}(S_2, P_2)$. This leads to

$$\theta_{ind}(S_1, S_2, P_1, P_2) = \frac{P_2 - P_1}{S_2 - S_1} \quad (3)$$

The resulting market shares for the two firms are described by

$$D : [\underline{S}, \bar{S}]^2 \times \mathbb{R}^+ \times \mathbb{R}^+ \rightarrow [0, \bar{\theta} - \underline{\theta}]^2, \\ (S_1, S_2, P_1, P_2) \mapsto (D_1(S_1, S_2, P_1, P_2), D_2(S_1, S_2, P_1, P_2)),$$

where D_1 is the demand for the product of firm 1 und D_2 for firm 2 respectively. So the maximization problem is given by

$$\begin{aligned} D_1(S_1, S_2, P_1, P_2) \xrightarrow{S_1, P_1} \max & & s.t. & & P_1 \geq C(S_1), \\ D_2(S_1, S_2, P_1, P_2) \xrightarrow{S_2, P_2} \max & & & & P_2 \geq C(S_2). \end{aligned} \quad (4)$$

For $S_2 < S_1$ the resulting total demand TD is

$$TD(S_2, P_2) := \bar{\theta} - \theta_0(S_2, P_2) \quad (5)$$

and the market coverage is therefore given by $\frac{TD(S_2, P_2)}{\bar{\theta}}$.

3 The firms' strategies

We solve the game via backward induction. On the second stage the firms simultaneously choose their prices for given and known qualities to maximize their respective market share. If the firms choose the same quality $S = S_1 = S_2$, the only stable price equilibrium will be at $P = C(S)$, otherwise the companies have the incentives to underbid each other. So we only

have to focus on the situation $S_1 \neq S_2$ and without loss of generality we assume $S_1 > S_2$ from which follows $P_1 > P_2$. We then have

$$D_1(S_1, S_2, P_1, P_2) = \bar{\theta} - \frac{P_1 - P_2}{S_1 - S_2} \quad (6)$$

$$D_2(S_1, S_2, P_1, P_2) = \frac{P_1 - P_2}{S_1 - S_2} - \frac{P_2}{S_2}. \quad (7)$$

As one can easily see, the demand is decreasing, if the firm increases its price. So in this case we also have $P_i = C(S_i)$ for $i = 1, 2$. Hence, as the solution of the second stage game we always have price equal to the unit costs. In order to simplify notation we suppress prices as arguments from now on.

On the first stage the firms choose their qualities. To choose their qualities optimally the firms need to know how the consumers react on changes in quality. Note that total demand is now $TD(S_2) = TD(S_2, C(S_2)) = \bar{\theta} - \frac{C(S)}{S}$. So total demand only depends on quality and the slope of the unit cost function.

Proposition 1. *If the total demand is increasing in quality, there exists a unique subgame perfect Nash Equilibrium in pure strategies with no quality differentiation.*

Proof. Since the total demand $TD = \bar{\theta} - \theta_0$ is increasing in quality, we have $\frac{d\theta_0(S)}{dS} \leq 0$. Thus an increase in quality leads to more consumers buying the product as long as $\theta_0(S) \leq \bar{\theta}$. So no consumers buy the low quality product, which is why both firms provide a product with the maximal possible quality \bar{S} . (\bar{S}, \bar{S}) indicates the unique Nash Equilibrium in pure strategies. \square

As we can see in Proposition 1 both firms have an incentive to provide the maximal quality, if total demand is increasing in quality. Let us now consider a decreasing total demand. We assume $TD(\underline{S}) = \bar{\theta}$ and $TD(\bar{S}) = 0$.⁸

Analogously to the proof of Proposition 1 we now have $\frac{d\theta_0(S)}{dS} > 0$, such that a quality improvement leads to less consumers buying the product. This is a necessary condition for differentiation in quality. To analyze the possible strategies of the firms we show how firm 2 can react to the quality S_1 of firm 1. Basically firm 2 has three options to react. It can either choose a higher quality ($S_2 > S_1$) which we will call “overbidding”, choose the same

⁸The latter equality is intuitive, since even if a higher quality was possible, there would be no consumers willing to buy the product. The former equality is for ease of calculation. According to (5) the total demand is $TD(\underline{S}) = \bar{\theta} - \frac{C(\underline{S})}{\underline{S}}$. Although we have $\underline{S} = 0$, according to l’Hospitals rule the equality holds, as long as we also have $C(\underline{S}) = 0$ and $C'(S) \rightarrow 0$ for $S \rightarrow \underline{S}$.

quality ($S_2 = S_1$) which we will call “equalizing” or choose a lower quality ($S_2 < S_1$) which we will call “underbidding”.

The resulting demand of firm 2 is given by

$$D_2(S_1, S_2) = \begin{cases} \bar{\theta} - \min(\bar{\theta}, \theta_{ind}(S_1, S_2)), & S_1 < S_2 \\ \frac{\bar{\theta} - \theta_0(S_2)}{2}, & S_1 = S_2 \\ \min(\bar{\theta}, \theta_{ind}(S_1, S_2)) - \theta_0(S_2), & S_1 > S_2. \end{cases} \quad (8)$$

Obviously if firm 2 equalizes the two firms share the market equally, according to the assumption on the consumer’s behavior. So now we need to take a closer look at the strategies “overbidding” and “underbidding”.

Overbidding

If firm 1 chooses the quality S_1 , firm 2 can overbid with every quality S_2 from the set $(S_1, \bar{S}]$. In this case it is not possible to derive an optimal overbidding strategy. For every $S_2 > S_1$ we can find $\tilde{S}_2 \in (S_1, S_2)$ with $D_2(S_1, \tilde{S}_2) > D_2(S_1, S_2)$.⁹ Thus, the closer the overbidding quality is to S_1 the higher is the market share for firm 2. The limiting overbidding strategy leads to $\lim_{S_2 \searrow S_1} \theta_{ind}(S_1, S_2) = C'(S_1)$. We will denote this limiting strategy by S_1+ and call it “marginal overbidding”.¹⁰ The marginal overbidding strategy is only reasonable, as long as $C'(S_1) < \bar{\theta}$, otherwise there will be no demand for the product of the overbidding firm.

Underbidding

If firm 1 chooses the quality S_1 , firm 2 can underbid with every quality S_2 from the set $[\underline{S}, S_1)$. The first order condition $\frac{\partial D_2(S_1, S_2)}{\partial S_2} = 0$ again does not need to have an interior solution on (\underline{S}, S_1) . Then either underbidding with $S_2 = \underline{S}$ is optimal, which we call minimal underbidding, or underbidding with a slightly lower quality than S_1 is the best underbidding

⁹In the case of increasing total demand for $\tilde{S}_2 \in (S_1, S_2)$ we have $\theta_{ind}(S_1, \tilde{S}_2) < \theta_{ind}(S_1, S_2)$.

¹⁰Technically no $S_2 \in (S_1, \bar{S}]$ satisfies the first order condition $\frac{\partial D_2(S_1, S_2)}{\partial S_2} = 0$. If the overbidding quality had to be chosen from $[S_1 + \delta, \bar{S}]$ for $\delta > 0$, $S_2 = S_1 + \delta$ would be the optimal overbidding strategy. δ can be interpreted as a threshold required for quality differentiation being recognized by the consumers. For sufficiently small δ the results remain valid while the formulas would become more complicated and less intuitive. In the further analysis we therefore assume that the overbidding firm will choose marginal overbidding.

strategy. Analogously to the case of overbidding this will be called “marginal underbidding”, denoted by S_1- .¹¹ In general we define the optimal underbidding quality by

$$r_u(S_1) := \arg \max_{S_2 < S_1} D_2(S_1, S_2).$$

We always have $\theta_{ind}(S_1, r_u(S_1)) \leq \bar{\theta}$, because for S_2 with $\theta_{ind}(S_1, S_2) > \bar{\theta}$ it is

$$D_2(S_1, S_2) = \bar{\theta} - \frac{\theta_0(S_2)}{2},$$

which is decreasing in S_2 . It is also intuitively clear, that once $\theta_{ind}(S_1, S_2) = \bar{\theta}$ a further increase in the underbidding quality S_2 will lead to a smaller market share for firm 2, since the demand for the product of firm 1 is already zero. As long as the following inequality

$$\frac{\partial D_2(S_1, S_2)}{\partial S_2} < 0 \quad \Leftrightarrow \quad \frac{\theta_0(S_1) - \theta_0(S_2)}{S_1 - S_2} < \theta'_0(S_2) \quad (9)$$

holds, firm 2 has the incentive to decrease the quality of its product. Due to $TD = \bar{\theta} - \theta_0$ this especially is the case for all combinations of $S_2 < S_1$ if the total demand is strictly convex (see figure 1).¹² Then for all S_1 the optimal underbidding strategy is $S_2 = \underline{S}$. If total demand is strictly concave, choosing a higher underbidding quality S_2 always leads to an increase in demand for firm 2. Thus marginal underbidding is the optimal underbidding strategy. If total demand is decreasing at a linear rate, the resulting demand for firm 2 is independent of the chosen underbidding quality. We then assume that firm 2 chooses the marginal underbidding quality.

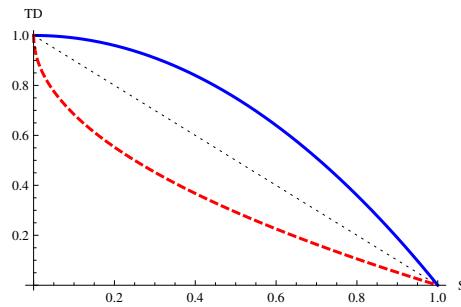


Figure 1: Concave (blue) and convex (red, dashed) total demand with $\bar{\theta} = 1$.

¹¹Again an optimal underbidding strategy technically does not exist in this case, but we adopt our concept of the limiting strategy to keep the calculations simple.

¹²The firms choose their prices equal to their unit costs. Hence, θ_0 and therefore the total demand only depends on S . A strictly convex total demand implies a strictly convex θ_0 .

Optimal reaction

To decide which reaction is optimal, we have to compare the resulting market shares. Special attention has to be paid on those qualities which leave the competitor indifferent between two or more strategies.

First we will compare overbidding and equalizing. Let the quality at which the competitor is indifferent between those strategies be called S_{OE} .¹³ Comparing the resulting market shares for firm 2 and solving $D_2(S_{OE}, S_{OE+}) = D_2(S_{OE}, S_{OE})$ yields

$$\frac{\bar{\theta} + \theta_0(S_{OE})}{2} = C'(S_{OE}). \quad (10)$$

If the left hand side of (10) is greater, overbidding dominates equalizing and vice versa. Now we examine at which quality firm 2 is indifferent between underbidding and equalizing, which we will call S_{UE} . Comparing the resulting market shares leads to

$$\theta_{ind}(S_{UE}, r_u(S_{UE})) - \theta_0(r_u(S_{UE})) = \frac{\bar{\theta} - \theta_0(S_{UE})}{2}. \quad (11)$$

Underbidding dominates, if in (11) the left hand side is greater. It remains the quality that leaves firm 2 indifferent between overbidding and underbidding, which we will call S_{OU} . The comparison of the market shares leads to

$$\bar{\theta} - C'(S_{OU}) = \theta_{ind}(S_{OU}, r_u(S_{OU})) - \theta_0(r_u(S_{OU})). \quad (12)$$

Here overbidding dominates underbidding, if the left hand side of (12) is greater.

Having analyzed the possible reactions of the two firms and identified the qualities that leave the competitor indifferent, we are now able to derive the reaction functions of the firms. Based on those reaction functions we can examine the interaction between the quality choices of the two firms. Here we have to distinguish between simultaneous and sequential competition at the first stage.

4 Simultaneous first stage quality competition

In this section we consider a simultaneous first stage quality competition. The structure of the game is shown in figure 2. While marginal overbidding is the only relevant overbidding

¹³ S_{OE} is without loss of generality the chosen quality of firm 1, leaving firm 2 indifferent between overbidding and equalizing. Furthermore we assume that in the case of indifference the firms choose the same quality for their products.

strategy, the optimal underbidding strategy r_u depends on the slope of the total demand. From (9) we know that in the case of concave total demand it is $r_u(S) = S-$ for all S with $\theta_{ind}(S, S-) \leq \bar{\theta}$, while in the case of strictly convex total demand we have $r_u(S) = \underline{S}$ for all S .

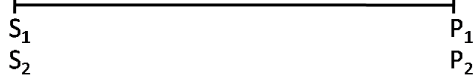


Figure 2: Game structure with simultaneous quality choice.

Concave total demand

From (12) for the marginal underbidding strategy we get

$$C'(S_{OU}) = \frac{\bar{\theta} + \theta_0(S_{OU})}{2}.$$

According to (10) we then have $S_{OU} = S_{OE}$. Obviously this leads to $S_{OU} = S_{OE} = S_{UE}$. To analyze the firms' behavior, we need to derive the reaction functions.

Lemma 2. *If the total demand is concave, the reaction function is given by*

$$r(S) = \begin{cases} S+, & S < S_{OE} \\ S, & S = S_{OE} \\ r_u(S), & S > S_{OE}. \end{cases} \quad (13)$$

Proof. According to (9), since we have a concave total demand, the only relevant underbidding strategy is marginal underbidding $r_u(S_1) = S_1-$ on $\{S_1 \mid \theta_{ind}(S_1, S_1-) \leq \bar{\theta}\}$ and choosing $r_u(S_1) = \inf\{S_2 \mid S_2 < S_1, \theta_{ind}(S_1, S_2) \geq \bar{\theta}\}$ on $\{S_1 \mid \theta_{ind}(S_1, S_1-) > \bar{\theta}\}$. We further have $S_{OE} \in \{S_1 \mid \theta_{ind}(S_1, S_1-) \leq \bar{\theta}\}$, since otherwise there would be no demand in case of overbidding. So on $\{S_1 \mid \theta_{ind}(S_1, S_1-) > \bar{\theta}\}$ firm 2 will never be indifferent between overbidding and equalizing. Hence, on $[\underline{S}, S_{OE})$ overbidding dominates underbidding and equalizing. On $(S_{OE}, \bar{S}]$ underbidding dominates overbidding and equalizing. In S_{OE} all three strategies yield the same market share and according to our assumptions the firms equalize. Thus we yield the reaction function (13). \square

To improve readability, we denote the reaction function of firm 1 and firm 2 by r_1 and r_2 respectively, with $r_1 = r_2 = r$. Now that we have derived the reaction function, we are able to examine whether equilibrium strategies exist.

Proposition 3. *If the total demand is concave, there exists a unique subgame perfect Nash Equilibrium in pure strategies with no quality differentiation.*

Proof. The two firms have the same reaction function given by (13). Therefore we have $r_1(r_2(S)) = r_2(r_1(S)) = S$ if and only if $S = S_{OE}$. Thus (S_{OE}, S_{OE}) is the unique Nash Equilibrium in pure strategies. \square

As an example let the unit cost function be given by $C(S) = \kappa S^\alpha$, with $\kappa > 0$, $\alpha > 1$, so the total demand is decreasing. Let further $\bar{\theta} = 1$ and $\bar{S} = \left(\frac{\bar{\theta}}{\kappa}\right)^{\frac{1}{\alpha-1}}$, so that we have $\theta_0(\bar{S}) = \bar{\theta}$. While κ is the scale parameter, α determines the shape.¹⁴

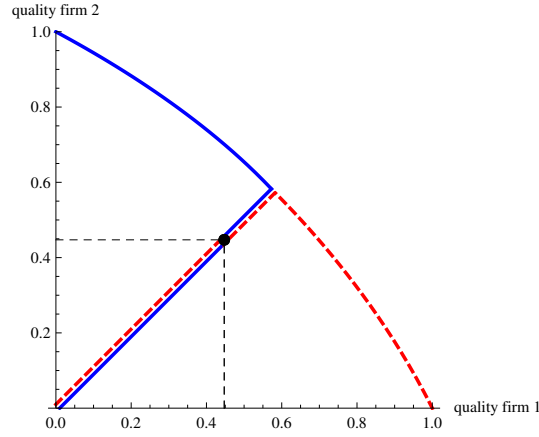


Figure 3: Reaction functions of firm 1 (blue) and firm 2 (red, dashed) with $\kappa = 1$ and $\alpha = 3$.

Let us take a look at the reaction function of firm 2 in figure 3: As we have seen before, if firm 1 chooses a quality $S_1 \in [\underline{S}, S_{OE}) = [0, \frac{1}{\sqrt{5}})$, marginal overbidding is the optimal reaction. If $S_1 = S_{OE} = \frac{1}{\sqrt{5}}$, firm 2 is indifferent between overbidding, underbidding and equalizing and according to (13) reacts with equalizing. In the case of $S_1 \in (S_{OE}, \bar{S}] = (\frac{1}{\sqrt{5}}, 1]$, firm 2 reacts with underbidding. On $(\frac{1}{\sqrt{5}}, \frac{1}{\sqrt{3}}]$ marginal underbidding is the optimal strategy. If we have $S_1 \in (\frac{1}{\sqrt{3}}, 1]$, marginal underbidding is not optimal anymore, since it is $C'(S_1) > C'(\frac{1}{\sqrt{3}}) = 1 = \bar{\theta}$. Here we have $r_2(S_1) = \frac{1}{2} \left(\sqrt{4 - 3S_1^2} - S_1 \right)$, which leads to $\theta_{ind}(S_1, r_2(S_1)) = \bar{\theta}$ for all $S_1 \in (\frac{1}{\sqrt{3}}, 1]$. Since firm 1 has the same reaction function as firm 2, the two reaction functions intersect only in $(S_{OE}, S_{OE}) = (\frac{1}{\sqrt{5}}, \frac{1}{\sqrt{5}})$, which is the unique Nash Equilibrium in pure strategies for the special cost function.

¹⁴ $\alpha > 2$ leads to a strictly concave total demand, $\alpha < 2$ leads to strictly convex total demand and $\alpha = 2$ is the case of a linear total demand.

Strictly convex total demand

According to (9), in the case of strictly convex total demand we have $r_u(S) = \underline{S}$ for all $S \in (\underline{S}, \bar{S}]$. From (12) we get

$$\bar{\theta} - \theta_0(S_{OU}) = C'(S_{OU}). \quad (14)$$

Lemma 4. *If the total demand is strictly convex, we have $S_{UE} < S_{OU} < S_{OE}$. The reaction function is therefore given by*

$$r(S) : [\underline{S}, \bar{S}] \rightarrow [\underline{S}, \bar{S}], \quad S \mapsto r(S) := \begin{cases} S+, & S \leq S_{OU}, \\ \underline{S}, & S > S_{OU}. \end{cases} \quad (15)$$

Proof. Since the total demand is strictly convex, for all $S_2 < S_1$

$$\theta'_0(S_1) < \frac{\theta_0(S_1) - \theta_0(S_2)}{S_1 - S_2}$$

holds. Especially for $S_1 = S_{OU}$ and $S_2 = \underline{S}$ we have

$$\theta'_0(S_{OU}) < \frac{\theta_0(S_{OU})}{S_{OU}} \iff C'(S_{OU}) - \theta_0(S_{OU}) < \theta_0(S_{OU}) \iff C'(S_{OU}) < 2\theta_0(S_{OU}).$$

If we now had $S_{OU} < S_{OE}$, we would get

$$S_{OU} < S_{UE} \stackrel{(11)}{\iff} \theta(S_{OU}) < \frac{\bar{\theta}}{3} \stackrel{(12)}{\iff} C'(S_{OU}) > \frac{2\bar{\theta}}{3} > 2\theta_0(S_{OU}),$$

which is contradictory to the total demand being strictly convex. Therefore we have $S_{UE} < S_{OU}$ and

$$\begin{aligned} S_{UE} < S_{OU} &\implies \theta_0(S_{UE}) < \theta_0(S_{OU}) \\ &\stackrel{(11),(12)}{\implies} \frac{\bar{\theta} - \theta_0(S_{UE})}{2} < \bar{\theta} - C'(S_{OU}) \\ &\implies \frac{\bar{\theta} - \theta_0(S_{OU})}{2} < \bar{\theta} - C'(S_{OU}) \\ &\implies C'(S_{OU}) < \frac{\bar{\theta} + \theta_0(S_{OU})}{2} \\ &\stackrel{(10)}{\implies} S_{OU} < S_{OE}. \end{aligned}$$

For the optimal reactions we now have the following rules for behavior: On $[\underline{S}, S_{UE}]$ overbidding dominates equalizing and equalizing dominates underbidding. On $(S_{UE}, S_{OU}]$ overbidding dominates underbidding and underbidding dominates equalizing. On $(S_{OU}, S_{OE}]$ underbidding dominates overbidding and overbidding dominates equalizing. On $(S_{OE}, \bar{S}]$ underbidding dominates equalizing and equalizing dominates overbidding. Thus we yield the reaction function (15). \square

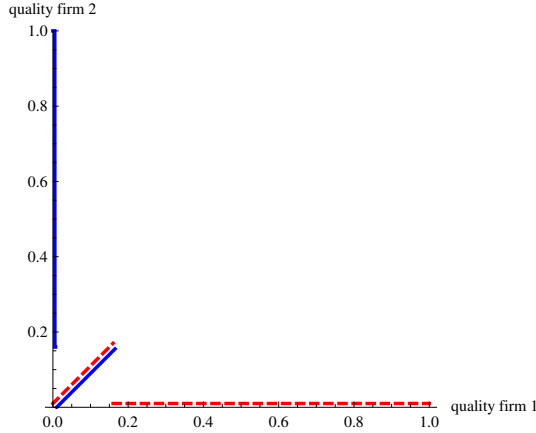


Figure 4: Reaction functions of firm 1 (blue) and firm 2 (red, dashed) with $\alpha = \frac{3}{2}$ and $\kappa = 1$.

The shape of the reaction functions is shown in figure 4. One can see that in this special case of $C(S) = S^{3/2}$ no equilibrium exists, since the reaction functions do not intersect. In general the following result holds.

Proposition 5. *If the total demand is strictly convex, there is no Nash Equilibrium in pure strategies.*

Proof. If firm 1 chooses its quality $S_1 \in [\underline{S}, S_{OU}]$, overbidding is the dominant strategy. Thus, if (S_1^*, S_2^*) was an equilibrium, it has to be $(S_1^*, S_2^*) \in (S_{OU}, \bar{S}]^2$. For $S_1^* \in (S_{OU}, \bar{S}]$, according to (15) we have $r_2(S_1^*) = \underline{S} \notin (S_{OU}, \bar{S}]$. Then again we have $r_1(r_2(S_1^*)) = r_1(\underline{S}) = \underline{S} \notin (S_{OU}, \bar{S}]$. Hence, S_1^* is no equilibrium strategy for firm 1. Since this also holds for firm 2, there exists no Nash Equilibrium in pure strategies. \square

In this section we have derived sufficient conditions for the existence of a unique Nash Equilibrium in pure strategies in the case of simultaneous first stage quality competition.

5 Sequential first stage quality competition

In this section we consider a sequential first stage quality competition. The structure of the game is shown in figure 5. While in this section we consider a sequential first stage quality competition, we still assume a simultaneous second stage price competition, meaning the firms enter the market simultaneously. We further assume that the firms commit themselves to the chosen quality. This means the quality leader cannot adjust its quality after observing the quality chosen by the follower. We will again solve the problem via backward induction. The price competition on the second stage remains the same, while on the first stage we

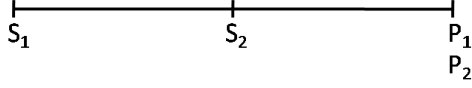


Figure 5: Game structure with simultaneous quality choice.

now have a subgame of sequential quality choices. The leader will anticipate the follower's reaction and therefore choose the quality that maximizes his market share given the optimal reaction by the follower. Therefore the leader's market share might differ from the follower's. Without loss of generality let firm 1 be the leader and firm 2 be the follower. Let the reaction function of firm 2 be denoted by r_2 as before, then for every given quality choice S_1 of firm 1 the optimal answer of firm 2 is choosing the quality $S_2 = r_2(S_1)$. Knowing this, firm 1 faces the maximization problem

$$D_1(S_1, r_2(S_1)) \xrightarrow{S_1} \max. \quad (16)$$

In this section we will focus on a decreasing total demand.¹⁵

Concave total demand

The reaction function of the follower corresponds to the reaction function derived in Lemma 2 in the preceding section.

Proposition 6. *If the total demand is concave, there exists a unique subgame perfect Nash Equilibrium in pure strategies with no quality differentiation. There is neither a first nor a second mover advantage.*

Proof. If firm 1 decides to be the high quality provider, it has to choose a quality $S_1 > S_{OE}$. Of course the range of possible qualities in this case is limited by the condition $\theta_{ind}(S_1, r_2(S_1)) < \bar{\theta}$. For those qualities we have $r_2(S_1) = S_1 -$ such that the resulting market share is given by

$$D_1(S_1, r_2(S_1)) = \bar{\theta} - \theta_{ind}(S_1, S_1 -) = \bar{\theta} - C'(S_1),$$

which is obviously decreasing in S_1 . If on the other hand firm 1 decides to provide the low quality product, it has to choose $S_1 < S_{OE}$. Then of course it is $r_2(S_1) = S_1 +$ and we have

$$D_1(S_1, r_2(S_1)) = \theta_{ind}(S_1, S_1 +) - \theta_0(S_1) = C'(S_1) - \frac{C(S_1)}{S_1} = S_1 \theta'_0(S_1).$$

Since the total demand is concave, derivation of this term shows that the market share is increasing in S_1 . Hence, firm 1 will provide a product with the quality $S_1 = S_{OE}$. According

¹⁵If the total demand is increasing, the result from Proposition 1 remains valid.

to (13) firm 2 also chooses the quality $S_2 = S_{OE}$. Thus there is no quality differentiation and therefore both firms gain the same market share. \square

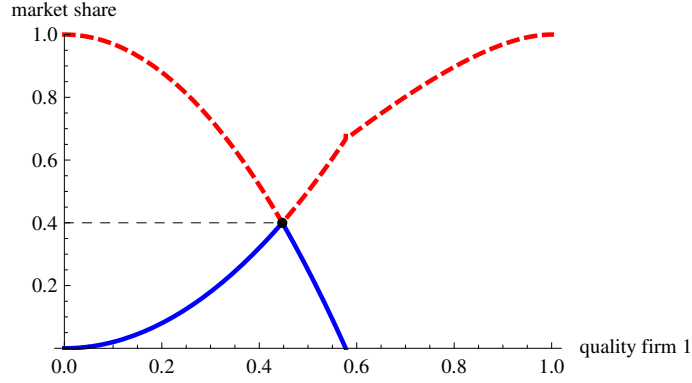


Figure 6: Market share of firm 1 (blue) and firm 2 (red,dashed) with optimal reaction of firm 2 with $\kappa = 1$ and $\alpha = 3$.

In figure 6 we see the resulting market shares for the two firms against the quality choice of firm 1. As we can see, firm 1 maximizes its market share by choosing its quality $S_1 = S_{OE} = \frac{1}{\sqrt{5}}$, resulting in a market share of $\frac{2}{5}$. If firm 1 chooses a different quality, the resulting market share would be less than $\frac{2}{5}$. A quality $S_1 > \frac{1}{\sqrt{3}}$ would leave firm 1 with zero market share, because firm 2 will provide the quality S_2 such that $\theta_{ind}(S_1, S_2) = \bar{\theta}$. Since firm 2 provides the same quality as firm 1 the resulting market share is also $\frac{2}{5}$, leaving the market uncovered. Thus there are incentives to collusion.

Strictly convex total demand

Proposition 5 states that there is no equilibrium in pure strategies, if the firms choose their qualities simultaneously. In the sequential quality competition the leader will choose his quality and commit himself. The follower reacts with his best response, so there will be an equilibrium. Now the reaction function of the follower corresponds to the reaction function given in Lemma 4.

Proposition 7. *If the total demand is strictly convex, there exists a unique subgame perfect Nash Equilibrium in pure strategies with quality differentiation and a first mover advantage.*

Proof. First we will show, that firm 1 chooses $S_1 = S_{OU}$. If firm 1 decides to provide the high quality product, the market share is obviously decreasing in S_1 , since we have for $S_1 \geq S_{OU}$

$$D_1(S_1, r_2(S_1)) = D_1(S_1, \underline{S}) = \bar{\theta} - \theta_0(S_1).$$

So firm 1 will at most provide the quality S_{OU} . It will also at least provide S_{OU} , since for $S_1 < S_{OU}$ and strictly convex C we have

$$\begin{aligned} D_1(S_1, r_2(S_1)) &= C'(S_1) - \theta_0(S_1) < C'(S_1) \\ &< C'(S_{OU}) \stackrel{(14)}{=} \bar{\theta} - \theta_0(S_{OU}) = D_1(S_{OU}, r_2(S_{OU})). \end{aligned}$$

Thus firm 1 chooses $S_1 = S_{OU}$ and according to Lemma 4 firm 2 responds with $S_2 = \underline{S}$. The resulting market shares in the equilibrium (S_{OU}, \underline{S}) are $D_2(S_{OU}, \underline{S}) = \theta_0(S_{OU})$ for firm 2 and $D_1(S_{OU}, \underline{S}) = \bar{\theta} - \theta_0(S_{OU})$ for firm 1. We have

$$\begin{aligned} D_1(S_{OU}, \underline{S}) > D_2(S_{OU}, \underline{S}) &\Leftrightarrow \bar{\theta} - \theta_0(S_{OU}) > \theta_0(S_{OU}) \\ &\stackrel{(14)}{\Leftrightarrow} \bar{\theta} - \theta_0(S_{OU}) > \bar{\theta} - C'(S_{OU}) \\ &\Leftrightarrow C'(S_{OU}) - \theta_0(S_{OU}) > 0. \end{aligned}$$

Since C is strictly convex, this shows the first mover advantage. □

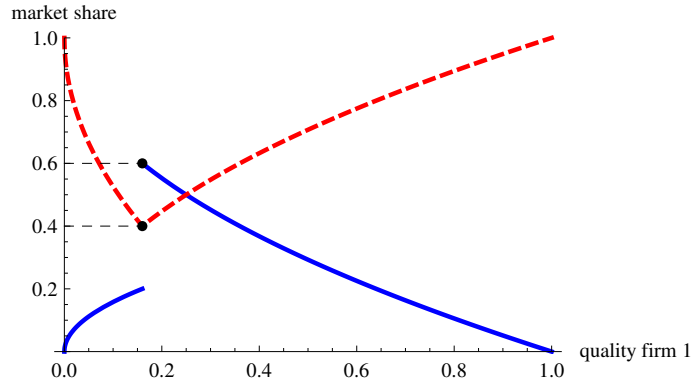


Figure 7: Market share of firm 1 (blue) and firm 2 (red, dashed) with optimal reaction of firm 2 with $\kappa = 1$ and $\alpha = \frac{3}{2}$.

Figure 7 shows the resulting market shares of the two firms against the quality choice of firm 1. As we can see, firm 1 maximizes its market share by choosing the quality $S_1 = S_{OU} = \frac{4}{25}$, resulting in a market share of $D_1(S_{OU}, \underline{S}) = \frac{3}{5}$. At $S_1 = S_{OU}$ the market share of firm 1 is noncontinuous, because at this quality the optimal reaction of firm 2 changes from marginal overbidding to underbidding with $S_2 = \underline{S}$. If firm 1 chose a quality different than S_{OU} , the resulting market share would be smaller but still positive. In equilibrium we can clearly see the first mover advantage of firm 1. Furthermore the market is fully covered and there is no incentive for collusion.

6 Conclusion and Outlook

In this paper we have analyzed a duopolistic quality competition of market share maximizing firms. We have shown that the equilibrium in the first stage quality competition highly depends on the slope of the cost function. The equilibrium quality is the maximum quality, if and only if the firms face concave unit costs, which leads to an increasing total demand. This holds for the simultaneous as well as for the sequential first stage competition.

If the unit cost function is convex, the firms will never choose the highest quality. This is because an increase in quality leads to a decrease in market coverage. We have taken a look at the firms' strategies overbidding, underbidding and equalizing, since the firms objective functions are not differentiable. The solution of the second stage price competition has shown, that the firms choose their prices according to their unit costs. So, in the case of market share maximization, quality differentiation is not used to relax price competition as it is in the case of profit maximization. Therefore for market share maximizing firms equalizing might be optimal. Special attention has been paid to those qualities which leave the firms indifferent in their reactions.

The analysis has shown, that if the firms face a concave total demand, there exists a unique Nash equilibrium in pure strategies, independent whether the first stage quality competition is simultaneous or sequential. Here a unique quality exists that leaves the firms indifferent between all three reactions and this is the equilibrium quality. There is no quality differentiation and no firm has the possibility to achieve quality leadership. Hence, there is neither a first nor a second mover advantage and both firms gain the same market share independent of the game's structure. So in our framework the firms' only possibility to increase their market shares is therefore given by collusion.

If the firms face a strictly convex total demand, there exists no Nash Equilibrium in pure strategies in the simultaneous first stage quality competition. One possible way to cope with this fact is collusion. Another possible way is to act first and avoid the simultaneous competition, since there exists a first mover advantage, if the first stage competition is sequential. The quicker moving firm then receives a higher market share than the competitor. Therefore the first stage competition might tend to be sequential in the case of strictly convex total demand, if collusion is prohibited. This leads to a fully covered market with no incentives for collusion.

The analysis has shown that the existence of an equilibrium highly depends on the slope of the unit cost function and therefore the total demand. In the case of increasing total demand the existence of an equilibrium is quite intuitive. However, it is rather surprising that in

the case of decreasing total demand there is a unique equilibrium if the total demand is concave, while there is no equilibrium if the total demand is strictly convex. An explanation for this is market coverage. The higher the market coverage for any given quality, the higher the possibility of existence of an equilibrium. If a substantial part of the market was left uncovered, the firms have the incentive to provide the product with the lowest possible quality. This again will cause an adjustment of the quality choice by the competitor.

In our paper the firms choose the lowest possible price for any given quality, since the only objective is market share maximization. If we relax this assumption, further research needs to be taken on the case of a mixed objective function. Firms that aim for profit and market share at the same time face a trade off between those two objectives, since a change in the price for a given quality influences the two objectives in different directions. As a special case the competition of a purely market share maximizing firm and a purely profit maximizing firm is of interest. This kind of competition might be appropriate in case of the health market where statutory and private health insurance firms compete (e.g. Germany).

To help to decide how competition in markets with firms that focus on various objectives should be organized, further research on the welfare implications of those objectives needs to be taken. Furthermore it needs to be analyzed whether the government can improve the market outcome by regulation.

Of course all mentioned aspects can also be analyzed for the case of fixed costs of quality improvement. Changes in the distribution of the consumers' preferences and the utility function might also be of interest for further investigations.

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