GCOE Discussion Paper Series

Global COE Program
Human Behavior and Socioeconomic Dynamics

Discussion Paper No. 276

Quality improvement to meet competitive fringe

Noriaki Matsushima and Ren-Jye Liu

August 2012

GCOE Secretariat
Graduate School of Economics
OSAKA UNIVERSITY
1-7 Machikaneyama, Toyonaka, Osaka, 560-0043, Japan

Quality improvement to meet competitive fringe*

Noriaki Matsushima†
Institute of Social and Economic Research, Osaka University

Ren-Jye Liu
Industrial Engineering and Enterprise Information, Tunghai University

August 7, 2012

Abstract

We investigate what kind of competitive pressure induces existing firms to engage in more intensive innovation activities. We examine two types of competitive pressure: a price decrease in competitive fringe firms and a quality improvement therein. We use an oligopoly model with vertical differentiation to investigate this question. We show that a decrease in the exogenous price of competitive firms induces the two existent leading firms (one high-quality firm and one mid-quality firm) to engage in quality investments more if the ex ante quality level of the high quality product is large enough; otherwise, only the mid-quality firm engages more in quality investment. We also show that an increase in the exogenous quality level of competitive firms diminishes the incentive of the mid-quality firm to engage in quality investments.

JEL classification: L13, O31, D43

Key words: fringe firms, competitive pressure, investments, vertical differentiation

---

*The first author gratefully acknowledges the financial support in the form of a Grant-in-Aid for Basic Research from the Japanese Ministry of Education, Science and Culture. Needless to say, we are responsible for any remaining errors.

†Corresponding author: Noriaki Matsushima, Institute of Social and Economic Research, Osaka University, Mihogaoka 6-1, Ibaraki, Osaka 567-0047, Japan. Phone: +81-6-6879-8571. E-mail: nmatsush@iser.osaka-u.ac.jp

1 Introduction

Almost all firms suffer from competitive pressures applied by domestic and foreign competitors. As a reaction to competitive pressure, many firms try to restructure their production environments. For instance, they try to improve their production efficiencies (engage in process innovation) and their product qualities (engage in product innovation). Because most firms in the real world face these problems, investigating this reaction is important.

In reality, companies in the People's Republic of China (China) pose severe competitive challenges to companies in many industries around the world. As a real world example in the bicycle industry, we refer to how non-Chinese incumbent firms react to competitive pressure by Chinese firms.[1] To meet the threat of low-cost, low-price competition posed by small-sized Chinese bicycle firms, the Republic of China (Taiwan)'s two leading bicycle assemblers, Giant and Merida (which are known around the world), have formed Taiwan's A-Team, an association of Taiwanese bicycle assemblers and suppliers, since 2002. These two companies are the prime movers of Taiwan's A-Team. The A-Team also includes 19 suppliers—11 original members and an additional 8 suppliers that joined a year after the organization was founded. Taiwan's bicycle industry A-Team has had a mandate for improving industry performance in three main areas: production efficiency, product development, and market intelligence. Antony Lo, who serves as the president of Giant and A-Team, told journalists that he hoped for the establishment of A-team to break the myth that it is not possible for competitors to cooperate in Taiwan. He also noted that A-Team's mandate was to use existing, high quality labor and technology to focus on product differentiation to increase value adds so that Taiwanese bicycle production might be seen as distinct from that in China and elsewhere. In total, three goals for the venture were put forward: (1) the implementation of lean production both within assembly plants and throughout the supply chain, (2) effective co-innovation with suppliers, and (3) co-marketing.

This case in the bicycle industry implies that the two leading assemblers, Giant and Merida, need to further improve their product quality. This also means that a higher intensive com-

[1] The assertions in this paragraph are based on Brookfield et al. (2008).

petitive pressure enhances the incentives of those firms to engage in quality investments. As summarized in Vives (2008) and Schmutzler (2009), however, the well-known theories in industrial organization do not clearly explain situations in which more intensive competitive pressure enhances the incentives of those firms to engage in quality investments. Although several papers consider the investment incentives of firms that produce vertically differentiated goods (Motta, 1992, 1993; Rosenkranz, 1995), these papers do not discuss the relation between competitive pressure and the incentives of such firms to engage in quality investments. Greenstein and Ramey (1998) is an exception in that it considers such a relation. The main purpose of their paper is to reassess Arrow's (1962) results concerning the effect of market structure on the returns from process innovation in the two cases: a vertically differentiated duopoly and a monopoly with competitive fringe. Previous papers do not discuss the change in competitive pressure caused by competitive fringe firms in the context of R&D investments. We need to know what kind of competitive pressure induces existing firms to engage in more intensive innovation activities. We therefore provide a simple model to explain it.

The model structure is as follows. There are two leading firms and a competitive fringe of firms. The leading firms produce vertically differentiated products. The quality level of the two products is higher than that of competitive firms. Given the exogenous price of competitive firms, the two leading firms compete in the final product market. In this market, therefore, each consumer has the following four options: he/she purchases (1) the highest quality product, (2) the mid-quality product, (3) the lowest quality product, and (4) nothing. We investigate how a decrease in the exogenous price of competitive firms changes the marginal gains of the two leading firms from quality improvements in the two products. We interpret the decrease in the exogenous price of competitive firms as intensified competitive pressure. We believe that this model setting captures the example of the Taiwanese bicycle industry mentioned earlier: the two leading firms are analogous to Giant and Merida, and the decrease in the exogenous price of competitive firms is akin to the threat of low-cost, low-price competition by small Chinese bicycle firms. Note that the situation discussed in our paper is related in the context of minimum quality standard (Scarpa, 1998; Valletti, 2000). A minimum quality standard compulsorily enhances the product quality of firms that would produce lower quality products if the standard did not exist. This standard is related to the exogenous competitive pressure discussed in our paper. The models in Scarpa (1998) and Valletti (2000) cannot distinguish between the effect of the changes in the price and quality of low quality firms (which enforce a minimum quality standard) on the firms that produce high quality products.

We show that a decrease in the exogenous price of competitive firms induces the existing leading firms to engage more in quality investments if the *ex ante* quality level of the highest quality product is large enough; otherwise, only the mid-quality firm engages more in quality investment. We also show that an increase in the exogenous quality level of competitive firms diminishes the incentive of the mid-quality firm to engage in quality investments. Because our paper distinguishes between the two effects of competition enhancement, a price decrease in competitive products and a quality improvement in competitive products, we can clarify the difference between the two effects. Our results add a new insight to the existing knowledge on R&D and on the quality standard. Moreover, in the bicycle industry, the result is consistent with the field experience of Brookfield et al (2008) when they visited Giant in September 2011. Brookfield et al observed site innovation and an innovation-driven atmosphere in Giant. For example, the logistics chain of the subcontractor parts right from subcontractors' facilities to the company's plant is not only smooth but also considers the quality requirements. Many operators have implemented measures to ensure quality in both the machining line and the assembly line to meet quality assurance standards. Furthermore, our result clearly indicates the condition that existing firms can collaborate with each other in their R&D activities, which provides a useful managerial implication for existing companies facing competitive threats from emerging firms.

Ishida et al. (2011) is closely related to our paper. They consider a Cournot competition model with heterogeneous firms engaging in cost-reducing activities. They show that the entry of weak firms, which can also engage in cost-reducing R&D, enhances the incentive of existing efficient firms to engage in cost-reducing investments. This implies that the leading firms in this market enhance their R&D incentives. In their model, because firms produce homogenous products, all firms directly compete with each other. In other words, only their cost conditions differ. On the other hand, in our paper, the products are vertically differentiated. This implies that the entry of low-quality competitive firms does not equally influence the incumbents. Moreover, our paper shows that an entry does not enhance the incentive of the leading firm, which produces the highest quality product, but does enhance the incentive of the mid-level firm, which produces the second-best quality product. This property of the relation between competitiveness and innovation incentives in Ishida et al. (2011) is quite different from ours.

2 Model

The utility of a consumer depends simply on the price and the quality of the product. Each consumer is supposed to buy a unit of product from the firm that ensures to him/her the highest utility, except if all the prices exceed his/her income. Consumers are supposed to have the same income y but are different in their intensity of preference for quality.

Before we discuss a duopoly model with competitive firms, we explain a simple monopoly model with competitive firms, which clarifies the effect of competitive firms on the incentives of dominant firms to engage in quality investments.

Suppose that there are a dominant firm and competitive fringe firms. We call this situation a "monopoly with fringe firms." The product quality of the dominant firm is q_d and that of competitive fringe firms is q_c. The former is larger than the latter, that is, $q_d > q_c$. The conditional indirect utility of a consumer of type θ buying one unit of product i $(i = d, c)$ is given by

$$V_i(\theta) = y - p_i + \theta q_i, \tag{1}$$

where p_i is the price of product i. Consumers are supposed to be distributed on $[0, 1]$. The parameter $\theta \in [0, 1]$ is interpreted to be the intensity of preference for quality. The distribution and the density functions are given by $F(\theta)$ and $f(\theta) = F'(\theta)$. We assume that the functions satisfy the standard second-order condition of the monopolist's optimization problem.

We assume that the price of competitive fringe firms, p_c, is exogenously given. This means that competitive fringe firms do not have any market power. Their available production technology determines the price of their products. For instance, when the factors for production (e.g., labor, material, facility) are cheap, the price p_c is low. The marginal cost of the dominant firm is constant and assumed to be zero for simplicity.

We consider a simple one-shot game. The dominant firm sets its price p_d. Under the model, we investigate the effects of the changes in p_c and q_c on the incentive of the dominant firm to engage in quality investments.

3 Result

3.1 Price reduction

First, we investigate the effects of a decrease in p_c on the incentive of the dominant firm to engage in quality investments.

Let p_d^* be the equilibrium price. The profit of the dominant firm is

$$\pi_d(p_d^*) = p_d^* \left(1 - F\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right).$$

The marginal gain from the quality improvement is given by

$$\frac{\partial \pi_d(p_d^*)}{\partial q_d} = \frac{p_d^*(p_d^* - p_c)}{(q_d - q_c)^2} f\left(\frac{p_d^* - p_c}{q_d - q_c}\right).$$

If a decrease in p_c increases the derivative, it enhances the incentive of the dominant firm to improve its product quality; that is, the latter statement holds if

$$\frac{\partial^2 \pi_d(p_d^*)}{\partial q_d \partial p_c} < 0.$$

We now show that this inequality holds. A simple calculation yields

$$\begin{aligned}\frac{\partial^2 \pi_d(p_d^*)}{\partial q_d \partial p_c} =& -\frac{p_d^*}{(q_d - q_c)^2}\left[f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^* - p_c}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right] \\ &+ \frac{1}{(q_d - q_c)^2}\left[(2p_d^* - p_c) f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^*(p_d^* - p_c)}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right]\frac{dp_d^*}{dp_c}.\end{aligned} \tag{2}$$

Using the first-order condition, we derive dp_d^*/dp_c:

$$\frac{dp_d^*}{dp_c} = \left(f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^*}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right) \Bigg/ \left(2f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^*}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right)$$

Note that the denominator of this fraction is equal to the product of the second-order condition and -1. This implies that this denominator is positive. Substituting dp_d^*/dp_c into $\partial^2\pi_d(p_d^*)/\partial q_d \partial p_c$, we have

$$\frac{\partial^2\pi_d(p_d^*)}{\partial q_d \partial p_c} = -\frac{p_c}{(q_d-q_c)^2} f\left(\frac{p_d^*-p_c}{q_d-q_c}\right) \Big/ \left(2f\left(\frac{p_d^*-p_c}{q_d-q_c}\right) + \frac{p_d^*}{q_d-q_c} f'\left(\frac{p_d^*-p_c}{q_d-q_c}\right)\right) < 0.$$

We have the following proposition.

Proposition 1 *A decrease in p_c enhances the incentive of the dominant firm to engage in quality improvement. That is,*

$$\frac{\partial^2\pi_d(p_d^*)}{\partial q_d \partial p_c} < 0.$$

A decrease in p_c has two effects. First, a decrease in p_c makes the indifferent consumer's θ larger. In other words, consumers around this indifferent consumer are highly sensitive to quality improvement (an effect that we call the "direct effect"). A slight improvement in the product quality significantly decreases the indifferent consumer's θ when p_c is small. The direct effect enhances the incentive to improve product quality. This is related to the first term of $\partial^2\pi_d(p_d^*)/\partial q_d \partial p_c$ in (2). Second, a decrease in p_c diminishes the demand for the dominant firm. The decrease induces the dominant firm to lower its price p_d (an effect that we call the "pricing effect"). The pricing effect diminishes the gain in quality improvement. This is related to the second term of $\partial^2\pi_d(p_d^*)/\partial q_d \partial p_c$ in (2). In this model setting, the direct effect dominates the pricing effect. Therefore, a decrease in p_c enhances the incentive of the dominant firm to engage in quality improvement.

3.2 Quality improvement

We consider another scenario wherein the competitive condition of the dominant firm worsens. An increase in q_c also enhances the competitiveness of the market. If the marginal gain of the dominant firm from the quality improvement is monotonically increasing in q_c, an increase in q_c enhances the incentive of the dominant firm to improve its product quality; that is, the latter statement holds if

$$\frac{\partial^2\pi_d(p_d^*)}{\partial q_d \partial q_c} > 0.$$

We now show that the inequality *does not hold*; that is, an increase in q_c diminishes the incentive of the dominant firm to improve its product quality. A simple calculation yields

$$\begin{aligned}\frac{\partial^2 \pi_d(p_d^*)}{\partial q_d \partial q_c} =& \frac{p_d^*(p_d^* - p_c)}{(q_d - q_c)^3}\left[2f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^* - p_c}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right] \\ &+ \frac{1}{(q_d - q_c)^2}\left[(2p_d^* - p_c) f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^*(p_d^* - p_c)}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right]\frac{dp_d^*}{dq_c}.\end{aligned} \tag{3}$$

Using the first-order condition, we have

$$\frac{dp_d^*}{dq_c} = -\frac{\frac{1}{q_d - q_c}\left((2p_d^* - p_c) f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^*}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right)}{\left(2f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^*}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right)}.$$

Substituting it into $\partial^2 \pi_d(p_d^*)/\partial q_d \partial p_c$, we have

$$\frac{\partial^2 \pi_d(p_d^*)}{\partial q_d \partial q_c} = -\frac{p_c^2}{(q_d - q_c)^3} f^2\left(\frac{p_d^* - p_c}{q_d - q_c}\right) \Big/ \left(2f\left(\frac{p_d^* - p_c}{q_d - q_c}\right) + \frac{p_d^*}{q_d - q_c} f'\left(\frac{p_d^* - p_c}{q_d - q_c}\right)\right) < 0.$$

We have the following proposition.

Proposition 2 *An increase in q_c diminishes the incentive of the dominant firm to engage in quality improvement. That is,*

$$\frac{\partial^2 \pi_d(p_d^*)}{\partial q_d \partial q_c} < 0.$$

An increase in q_c also has two effects. First, an increase in q_c makes the indifferent consumer's θ larger. This is similar to the direct effect in the previous subsection. This is related to the first term of $\partial^2 \pi_d(p_d^*)/\partial q_d \partial q_c$ in (3). Second, an increase in q_c diminishes the demand for the dominant firm. This has two negative effects: the "pricing effect" and the "elasticity effect." The former is similar to that in the previous section. The latter is that an increase in q_c enhances the price elasticity of demand. This is an additional negative effect on the incentive to engage in quality improvement although a decrease in p_c merely diminishes demand for the dominant firm. The two negative effects are related to the second term of $\partial^2 \pi_d(p_d^*)/\partial q_d \partial q_c$ in (3). In this model setting, the direct effect is dominated by the two negative effects. Therefore, an increase in q_c diminishes the incentive of the dominant firm to engage in quality improvement.

4 Duopoly with competitive fringe firms

We extend the basic model by incorporating another dominant firm. We call this situation a "duopoly with fringe firms." Firms 1 and 2 produce products with quality q_1 and q_2, respectively ($q_1 > q_2$). Competitive fringe firms produce products with quality q_c. Firms 1 and 2 compete in quantity (Bonnano (1986) and Motta (1993)). To simplify the analysis, we assume that $F(\theta) = \theta$.

Consumer θ_1 is indifferent between firms 1 and 2, and is represented as

$$-p_1 + \theta_1 q_1 = -p_2 + \theta_1 q_2 \quad \rightarrow \quad \theta_1 = \frac{p_1 - p_2}{q_1 - q_2}.$$

Consumer θ_2 is indifferent between firm 2 and competitive fringe firms, and is represented as

$$-p_2 + \theta_2 q_2 = -p_c + \theta_2 q_c \quad \rightarrow \quad \theta_2 = \frac{p_2 - p_c}{q_2 - q_c}.$$

The demands for firms 1 and 2, d_1 and d_2, are given by

$$d_1 = 1 - \theta_1 = 1 - \frac{p_1 - p_2}{q_1 - q_2}, \quad d_2 = \theta_1 - \theta_2 = \frac{p_1 - p_2}{q_1 - q_2} - \frac{p_2 - p_c}{q_2 - q_c}.$$

We have to invert the system of demand functions. This gives the following inverse demand functions:

$$p_1(d_1, d_2) = q_1 + p_c - q_c - (q_1 - q_c)d_1 - (q_2 - q_c)d_2, \tag{4}$$

$$p_2(d_1, d_2) = q_2 + p_c - q_c - (q_2 - q_c)d_2 - (q_2 - q_c)d_1. \tag{5}$$

The profits of firms 1 and 2 are

$$\pi_1 = p_1(d_1, d_2)d_1, \quad \pi_2 = p_2(d_1, d_2)d_2.$$

The first-order conditions lead to

$$d_1^* = \frac{p_c + 2q_1 - q_2 - q_c}{4q_1 - q_2 - 3q_c},$$
$$d_2^* = \frac{(2q_1 - q_2 - q_c)p_c + (q_1 - q_c)(q_2 - q_c)}{(q_2 - q_c)(4q_1 - q_2 - 3q_c)},$$
$$d_c^* = \frac{q_c(q_1 - q_c)(q_2 - q_c) - ((q_1 - q_c)^2 + 2(q_1(q_2 - q_c) + q_2(q_1 - q_2)))p_c}{q_c(q_2 - q_c)(4q_1 - q_2 - 3q_c)}.$$

Note that d_c^* is the demand for fringe firms and is derived by $d_c = (p_2 - p_c)/(q_2 - q_c) - p_c/q_c$. For any $i \in \{1, 2, c\}$, d_i^* must be larger than 0. We therefore impose the following assumption:

$$p_c < \frac{q_c(q_1 - q_c)(q_2 - q_c)}{(q_1 - q_c)^2 + 2(q_1(q_2 - q_c) + q_2(q_1 - q_2))}.$$

The profits of the firms are

$$\pi_1^* = (q_1 - q_c)(d_1^*)^2,$$
$$\pi_2^* = (q_2 - q_c)(d_2^*)^2.$$

4.1 Price reduction

As in the previous section, we derive the cross partial derivatives of the profits to evaluate the effect of a decrease in p_c on the incentives of firm 1 and 2 to engage in quality investments. The partial derivatives and the cross partial derivatives of the profits are given as

$$\begin{aligned}
\frac{\partial \pi_1^*}{\partial q_1} &= \frac{(p_c + 2q_1 - q_2 - q_c)(7(q_1 - q_c)^2 + (q_1 - q_2)^2 - (4p_1 + p_2 - 5p_c)p_c)}{(4q_1 - q_2 - 3q_c)^3}, \\
\frac{\partial \pi_2^*}{\partial q_2} &= ((q_1 - q_c)(q_2 - q_c) + (2q_1 - q_2 - q_c)p_c) \\
&\quad \times \frac{(q_1 - q_c)(q_2 - q_c)(4q_1 + q_2 - 5q_c) - (7(q_1 - q_c)^2 + (q_1 - q_2)^2)p_c}{(q_2 - q_c)^2(4q_1 - q_2 - 3q_c)^3}, \\
\frac{\partial^2 \pi_1^*}{\partial q_1 \partial p_c} &= -\frac{2((4q_1 + q_2 - 5q_c)p_c - (q_2 - q_c)^2)}{(4q_1 - q_2 - 3q_c)^3}, \\
\frac{\partial^2 \pi_2^*}{\partial q_2 \partial p_c} &= -\frac{2\{(q_1 - q_c)(q_2 - q_c)^3 + (2q_1 - q_2 - q_c)(7(q_1 - q_c)^2 + (q_1 - q_2)^2)p_c\}}{(q_2 - q_c)^2(4q_1 - q_2 - 3q_c)^3}.
\end{aligned}$$

From the equations, we have the following proposition.

Proposition 3 *A decrease in p_c enhances the marginal gain from the marginal increase in q_i ($i = 1, 2$) given the other values; that is, $\partial^2 \pi_i^* / \partial q_i \partial p_c < 0$ if and only if*

$$\frac{(q_2 - q_c)^2}{4q_1 + q_2 - 5q_c} < p_c < \frac{q_c(q_1 - q_c)(q_2 - q_c)}{(q_1 - q_c)^2 + 2(q_1(q_2 - q_c) + q_2(q_1 - q_2))}$$

. Otherwise, a decrease in p_c enhances the marginal gain from the marginal increase in q_2, but diminishes that from the marginal increase in q_1.

As in the standard vertical differentiation model, the product of firm 2 is more similar to that of fringe firms than that of firm 1. Because of this similarity, a change in p_c affects firm 2 more. The inequality, $\partial d_2^*/\partial p_c > \partial d_1^*/\partial p_c$, reflects this property.

As in the previous section, a decrease in p_c enhances the incentive of firm 2 to engage in quality investment. The decrease in p_c, however, diminishes the amount of quantity supplied by firm 2, d_2^*, due to the shrinking of the inverse demand for firm 2, $p_2(d_1, d_2)$. Because of the strategic substitution between the productions of firms 1 and 2, the decrease in d_2 enhances the amount of quantity supplied by firm 1, d_1 (an effect we call the "strategic effect"). The decrease in p_c, however, shrinks the inverse demand for firm 1, $p_1(d_1, d_2)$ (an effect we call the "direct effect"). The latter two effects are trade-offs in the incentive of firm 1 to engage in quality investment. On the one hand, the direct effect does not depend on the exogenous parameters (see (4) and (5)), which means that $\partial p_i(d_1, d_2)/\partial p_c = 1$ is constant. On the other hand, the strategic effect depends on the exogenous parameters. We can easily find this by deriving the reaction functions of the firms:

$$d_1(d_2) = \frac{q_1 + p_c - q_c - (q_2 - q_c)d_2}{2(q_1 - q_c)}, \tag{6}$$

$$d_2(d_1) = \frac{q_2 + p_c - q_c - (q_2 - q_c)d_1}{2(q_2 - q_c)}. \tag{7}$$

Because $q_1 - q_c > q_2 - q_c$, a decrease in p_c diminishes $d_2(d_1)$ more than it reduces $d_1(d_2)$. This tendency becomes stronger as the value of q_1 increases. Because of this tendency, the strategic effect is stronger than the direct effect if the value of q_1 is large enough.

Numerical example We consider a two-stage game. First, firms 1 and 2 engage in quality investments given their *ex ante* quality levels. Second, given the investment levels, the two firms simultaneously determine their quantities supplied. We set the following numerical example: $q_c = 1/10$, $q_1 = 1/2 + e_1$, $q_2 = 1/5 + e_2$, and $I(e_i) = e_i^2/2$, where e_i is the quality improvement level of firm i and $I(e_i)$ is the investment cost of firm i. This kind of *ex ante* firm heterogeneity is often used in the context of R&D. See, for instance, Barros and Nilssen (1999) and Ishida et al. (2011).

We choose two values of p_c to check how a decrease in p_c changes the incentives of the two firms to engage in quality investments: (i) $p_c = 1/80$ and (ii) $p_c = 1/100$. Under the two cases, the equilibrium investment levels of the firms are given as follows:

$$(i)\ e_1 = 0.251222,\ e_2 = 0.081652;\quad (ii)\ e_1 = 0.251228,\ e_2 = 0.082198.$$

We find that the decrease in p_c from 1/80 to 1/100 enhances the R&D incentives of the firms.

4.2 Quality improvement

We briefly discuss the effect of an increase in q_c on the cross partial derivatives of the profits. Although the result of the calculus is highly complex, we find the following properties of the cross partial derivatives. First, the sign of $\partial^2\pi_1^*/\partial q_1\partial q_c$ is indeterminate. Second, the sign of $\partial^2\pi_2^*/\partial q_2\partial q_c$ is minus. The negative effect of an increase in q_c on the incentive of firm 2 is similar to that in the previous section. Because of the negative effect, the quantity supplied by firm 1 can increase. This enhances the incentive of firm 1 to engage in quality investment.

5 Conclusion

We investigate what kind of competitive pressure induces existing firms to engage in more intensive innovation activities. We examine two types of competitive pressure: a price decrease in competitive fringe firms and a quality improvement therein. We use an oligopoly model with vertical differentiation to investigate this question. This model setting enables us to investigate the effect of competitive pressure on firms producing different kinds of product qualities. We believe that this model setting captures the example of the Taiwanese bicycle industry mentioned earlier in the Introduction: the two leading firms are analogous to Giant and Merida, and the decrease in the exogenous price of competitive firms is akin to the threat of low-cost, low-price competition by small Chinese bicycle firms.

We show that a decrease in the exogenous price of competitive firms induces the existing leading firms to engage more in quality investments if the *ex ante* quality level of the highest quality product is large enough; otherwise, only the mid-quality firm engages more in quality investment. We also show that an increase in the exogenous quality level of competitive firms diminishes the incentive of the mid-quality firm to engage in quality investments. Because our paper distinguishes between the two effects of competition enhancement, a price decrease in competitive products and a quality improvement in competitive products, we can clarify the difference between the two effects. Our results add a new insight to the existing knowledge on R&D and on the quality standard. Moreover, our result clearly indicates the condition that existing firms can collaborate with each other in their R&D activities, which provides a useful managerial implication for existing companies facing competitive threats from emerging firms.

We do not consider cooperative actions concerning R&D between existing firms. In particular, in the example discussed in our paper, the manner in which the firms collaborate is an important topic. In our paper, we believe that we *partially* answer why firms form an R&D collaboration network. One of the possible reasons is that *both* firms need product quality improvements. If this does not hold, it is difficult to form such an R&D collaboration network. We need to further investigate why firms form an R&D collaboration network and how they coordinate within the network. This is left for future research.

References

[1] Arrow, Kenneth J. 1962. Economic Welfare and the Allocation of Resources for Invention. in NBER book *The Rate and Direction of Inventive Activity: Economic and Social Factors*, 609-626.

[2] Barros, Pedro P. and Nilssen, Tore. 1999. Industrial Policy and Firm Heterogeneity. *Scandinavian Journal of Economics* 101(4), 597-616.

[3] Bonnano, Giacomo. 1986. Vertical Differentiation with Cournot Competition. *Economic Notes* 15(2), 68-91.

[4] Brookfield, Jonathan., Liu, Ren-Jye., and MacDuffie, John Paul. 2008. Taiwan's Bicycle Industry A-Team Battles Chinese Competition with Innovation and Cooperation. *Strategy & Leadership* 36(1), 14-19.

[5] Greenstein, Shane. and Ramey, Garey. 1998. Market Structure, Innovation and Vertical Product Differentiation. *International Journal of Industrial Organization* 16(3), 285-311.

[6] Ishida, Junichiro., Matsumura, Toshihiro., and Matsushima, Noriaki. 2011. Market Competition, R&D and Firm Profits in Asymmetric Oligopoly. *Journal of Industrial Economics* 59(3), 484-505. 2011

[7] Motta, Massimo. 1992. Cooperative R&D and Vertical Product Differentiation. *International Journal of Industrial Organization* 10(4), 643-661.

[8] Motta, Massimo. 1993. Endogenous Quality Choice: Price vs. Quantity Competition. *Journal of Industrial Economics* 41(2), 113-131.

[9] Rosenkranz, Stephanie. 1995. Innovation and Cooperation under Vertical Product Differentiation. *International Journal of Industrial Organization* 13(1), 1-22.

[10] Scarpa, Carlo. 1998. Minimum Quality Standards with More Than Two Firms. *International Journal of Industrial Organization* 16(5), 665-676.

[11] Schmutzler, Armin. 2009. Is Competition Good for Innovation? A Simple Approach to an Unresolved Question. *Foundations and Trends in Microeconomics* 5(6), 355-428.

[12] Valletti, Tommaso M. 2000. Minimum Quality Standards Under Cournot Competition. *Journal of Regulatory Economics* 18(3), 235-245.

[13] Vives, Xavier. 2008. Innovation and Competitive Pressure. *Journal of Industrial Economics* 56(3), 419-469.