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Duopoly Price Competition: When Consumers are Uncertain about Quality

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Abstract

This paper attempts to explain the behaviors of both consumers and firms when they face quality uncertainty during competition. By using the method of simulation, it is found that quality uncertainty leads to market failure in that it produces behaviors that decrease consumer welfare and distort profits among firms. This is because in the presence of quality uncertainty, consumers have to use price as a signal of product quality. As a result, uninformed consumers who face difficulty in recognizing the quality of each product will be easily deceived by firms. Even in a situation where no one is deceived, there are still some losses in consumer welfare from the deceiving attempt. That is, the utility level is lower than it would be in cases where there is no quality uncertainty. Therefore, information about quality should be given to consumers before they make a decision in order to achieve the highest level of social welfare in the market.

Keywords: Quality Competition, Quality Uncertainty

1. Introduction

The quality of a product is an important non-price technique which is used by firms in order to compete with each other. Vertical differentiation is now the classical model used to analyze the firm's choices of quality. Researchers such as Motta (1993) and Symeonidis (2003) use quality choice in their models in order to explain the impact of quality to competition equilibrium. However, both papers only consider the firm's behavior and conclude that a low-quality firm receives less profit than a high-quality firm in price competition where consumers are fully informed. However, in reality a low-quality firm sometimes receives more profit than a high-quality firm does. To reflect this phenomenon, this study relaxes the assumption that consumers have full information on the quality of products in the quality-setting model used by previous studies. Some simulations are conducted and the changes in the agents' behaviors and the equilibrium outcomes due to uncertainty in product quality are observed.

2. Overview of the Game of Quality Competition

This model is based on Motta's (1993) quality-setting model in which firms compete in product quality. It is assumed that some consumers are not informed about the quality of products unlike in Motta's model. Consumers' utility function is specified as a function of the consumers' taste, the quality of the good consumed and the price of the good. Suppose that the utility of consumer i to product j is $u_{ij} = \theta_i v_j - p_j$ where u is the utility measured in currency unit, θ_i is the taste parameter reflecting the consumers' willingness-to-pay for quality, v_j is the product's quality and p_j is its price. It is assumed that θ_i is distributed on the interval $(0,\overline{\theta}_i)$ and θ is uniformly distributed with a unit density. Consumers make their purchasing decision based on their preferences and will buy a particular good if it satisfies their preferences. Each customer has a reservation price for a product. The reservation price is $\theta_i v_j$ in the utility function. If the actual price of the good is higher than the reservation price, the consumer will not buy the goods. On the other hand, if the actual price is lower than the reservation price, the consumer will buy the goods. There are some consumers with arbitrarily high θ that are willing to pay any price for the highest product quality possible.

The basic model operates in a partial-equilibrium framework where there is a single consumption good and two competitors in the market ($j = H$ or L). There are two stages to the game. In the first stage, both firms decide on the quality of the product they would produce with their capacity and $v_j > 0$. Firm H can produce a higher-

quality product than firm L ($v_H \geq v_L$) and hence the ratio of firm H and firm L's quality (r = $\frac{v_H}{v_L}$) is greater than 1. Since the market has two firms, the taste parameter is classified into three levels. The highest taste parameter level is $\bar{\theta}$, and only consumers in this group prefer firm H's product strictly more than firm L's product. θ_{HL} denotes the taste parameter of consumers who are indifferent between buying a high- or low-quality product. This means the consumers' utility from both products are the same, $\theta_{HL} v_H - p_H = \theta_{HL} v_L - p_L$, and $\theta_{HL} = \frac{p_H - p_L}{v_H - v_L}$. θ_{L0} . is the taste parameter of consumers who are indifferent between buying and not buying low quality product. Likewise, the consumers' utility from consuming a low-quality product or is equivalent to his utility of not consuming the product $\theta_{l0} v_L - p_L = 0$, and $\theta_{L0} = \frac{p_L}{v_L}$. The demand function is derived using different levels of the taste parameter. The demand function of consumers who prefer firm H's product refers to those consumers who have preferences between $\bar{\theta}$ and θ_{HL} and the demand function of consumers who prefer firm L's product refers to those who have preferences between θ_{HL} and θ_{L0}. Other consumers whose preferences are below θ_{L0} do not buy the product (Because there are some consumers cannot buy both products, this market called uncovered market). Then, uncovered market demand is a convex function that $\sum D_j(p_j, \theta_i, v_j) < 1$ and $D_j(p_j, \theta_i, v_j) > 0$ for $j = H, L$. The demand function can be written as

$$D_j = \begin{cases} q_H(p_H, p_L, \theta_i, v_H, v_L) = \left[\bar{\theta} - \theta_{HL}\right] = \left(\bar{\theta} - \frac{p_H - p_L}{v_H - v_L}\right) \\ q_L(p_H, p_L, \theta_i, v_H, v_L) = \left[\theta_{HL} - \theta_{L0}\right] = \left(\frac{p_H - p_L}{v_H - v_L} - \frac{p_H}{v_L}\right) \end{cases} \quad (1)$$

In addition, the quality of the product plays an important role in the cost function of the firms. If firms do not invest in new technology, they are forced to leave the market. On the other hand, if they adopt advanced technology quickly, they will yield a positive return. Some studies such as Janssen-Rasmusen (2002) and Carlton-Dana (2004) emphasized that an increase in the quality is associated with an increase in the marginal cost. The relationship between the market size and the distribution of quality depends on the quality being produced. In particular, if the fixed cost increases only slowly in the quality, the cost of the quality is borne largely by the variable cost. Then, the main component of quality cost is the variable cost. In this study, it is assumed that quality cost is solely comprised of only the variable cost. This variable cost, $C(q_j, v_j)$, depends on the marginal cost (c_j) and the quantity (q_j) can be written as $C(q_j, v_j) = q_j\, c_j(v_j)$ where the marginal cost is the function of quality that firms produced. In the short-term, since there cannot be any extreme changes in technology,

the production process remains the same among firms. The difference in the quality arises from capital and workers' skill that high-quality firms have that are higher than a low-quality firm. In order to simplify the analysis, it is assumed that firm H's marginal cost is $c_H(v_H) = cv_H$, $(c < 1)$. Furthermore, firm L can imitate firm H's existing technology by reverse engineering. Thus, its marginal cost can be written as $c_L(v_L) = cv_L$. Firms never choose the quality beyond the domain of the linear function, so the marginal cost of the firm is not greater than its quality: $c_j \leq v_j$. This is an important assumption because if the firms choose a quality that is larger than the marginal cost and aims to make a non-negative value, consumers' utilities are less than zero for all taste parameters. This implies that firms cannot sell any product in the market. From the demand function and the cost function, the profit function is

$$\prod_j (v_j, q_j, p_j) = q_j (p_j - cv_j) \tag{2}$$

When both firms compete in the market with different levels of quality, the competition equilibrium is Nash equilibrium.

To analyze the behavior of consumers, this study assumes two types of consumers, the informed and the uninformed. An informed buyer always knows the true quality of the product. On the other hand, an uninformed buyer can only tell a high quality and a low quality firm apart if they are charging different prices; otherwise, uninformed buyers face "quality uncertainty". If the two firms charge the same price, the dilettantes are unable to distinguish the high quality firm from the low quality one until after the purchase. Motta (1993) assumed that all consumers are informed. If both firms set their prices depending on the quality of their product (named as separating-price strategy), firm L has a lower profit than firm H. This is because firm L's price is different from that of firm H and consumers can detect the difference in the quality from the prices. Therefore, firm L is at a disadvantage. When there are uninformed buyers in the market however, firm L can "deceive" an uninformed consumer by setting the same price as firm H while continuing to produce low quality products (named as pooling-price strategy). Let the superscripts P and S indicate a pooling-price strategy and a separating-price strategy, respectively. When firm L uses a pooling-price strategy, there exists some quality uncertainty in the market since uninformed buyers face the difficulty of distinguishing the quality of product from different firms. Such uncertainty in quality affects firm H's outcomes in that it loses some customers to firm L. To capture this, two variables are constructed — the fraction of uninformed consumer (λ) and the proportion of uninformed consumers who mistake firm L's product to be high quality (α). Both variables lie between 0 and 1. The proportion of informed consumer is ($1-\lambda$).

3. The Quality-price Competition Model with Quality Uncertainty

This model has a solution of a sub-game competition equilibrium which can be obtained by employing the price-setting rule. This is obtained by maximizing the profit function (equation 2) with respect to both products' price. Since only firm L has the incentive to deceive uniformed consumers, it will decide on its price only after firm H has already set its price. Hence, firm H is the price leader in the market and adopts a separating price strategy. In the next stage, firm L adopts firm H's price strategy. However, firm H can anticipate firm L's strategy. Firm H realizes that firm L can bring about either a pooling or a separating equilibrium, depending on its choice of p_H. If firm H expects firm L to use a separating price strategy, it can set an optimal separating price: p^*_H for firm L. If firm H cannot set the optimal price that forces firm L to use a separating price strategy, firm H will set a price which gives it the highest profit when firm L uses a pooling price strategy.

If both firms use a separating-price strategy, all consumers can distinguish the producers based on their different product price. The price and profit outcomes are given by the equation 3 to 6. When consumers are able to tell the producers apart, firm L's profit is in accordance with equation 6. On the other hand, if both firms adopt a pooling-price strategy, both λ and α have to be taken into consideration. In this case, firm H's demand equation (equation 7) is comprised of two parts (Proof of this equation is in chapter 4 of Chaiwat (2007)). The first part is for informed consumers who only purchase the product when its price truly reflects its quality and do not purchase otherwise. The second part is for uninformed consumers who face quality uncertainty and have to choose a producer randomly with the probability α of being cheated by firm L. The price of both firms is p_H and the profit outcomes are equation 7-8.

Separating price of firm H $$p_H^S = p_H = \frac{rv_L(r-1)(\bar{\theta}+c)}{2r-1} \tag{3}$$

Separating price of firm L: $$p_L^S = p_L = \frac{(p_H - cv_H)v_L}{2v_H} \tag{4}$$

Separating profit of firm H: $$\pi_H^S = \frac{rv_L(\bar{\theta}+cr-r\bar{\theta})^2}{4r^2-6r+2} \tag{5}$$

Separating profit of firm L: $$\pi_L^S = \frac{(p_H - cv_H)^2 v_L}{4v_H(v_H - v_L)} \tag{6}$$

Pooling profit of firm H:

$$\pi_H^S = (1-\lambda)(\bar{\theta} - \frac{p_H}{v_H})(p_H - cv_H) + (1+\alpha)\lambda(\bar{\theta} - \frac{2p_H}{v_H + v_L})(p_H - cv_H) \tag{7}$$

Pooling profit of firm L: $$\pi_L^P = \alpha\lambda(\bar{\theta} - \frac{p_H}{v_E})(p_H - cv_L) \quad ; v_E = \frac{v_H + v_L}{2} \qquad (8)$$

The optimal separating price: p^*_H is the price that firm L chooses which gives it the separating profit as given in equation 6 or the pooling profit as given in equation 8. Using the ratio of high and low quality (r) and defining $v_H = r\, v_L$, firm L will choose the separating profit when $\pi_L^S \geq \pi_L^P$ or when

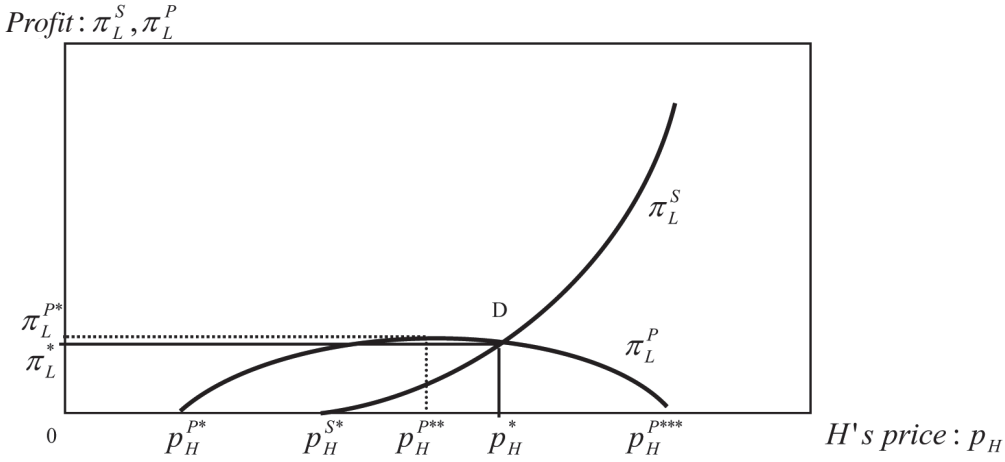
$$p_H \geq \frac{\left[\begin{array}{l} crv_L^2(r+1) + 4\alpha c\lambda r v_L^2(r-1) + 2\alpha\lambda r v_L^2\bar{\theta}(r^2-1) + \\ \sqrt{\{rv_L^4\{-c(r+1)[1+r+8\alpha\lambda r(r-1)][cr+4\alpha\lambda\bar{\theta}(r-1)] + \\ r[c(1+4\alpha\lambda(r-1)+r) + 2\alpha\lambda\bar{\theta}(r^2-1)]^2\}\}} \end{array}\right]}{v_L(1+r+8\alpha\lambda r(r-1))}$$

The results show that if the conditions contained, $r \geq 2$, $\bar{\theta} \geq$ and $\alpha \geq \frac{0.25}{\lambda}$ are approved, the value in parentheses will be positive. There is a critical point for p_H, above that point, firm L always prefers the separate price strategy. Furthermore, below that point, firm L prefers a pooling-price strategy. When the price is equal to the critical point, firm L is indifferent between both strategies. The intuition for this is straightforward: firm L's optimal separating price is always a proportion of p_H, so that when p_H low, firm L's separating profit is is low as well.

Figure 1 shows the optimal separating profit and the pooling profit as a function of p_H as a special case. As p_H rises, the separating profit starts at $p_H = p_H^{S^*} = c$ and then it rises monotonically. Although the pooling profit graph is like the downward parabola in that it rises first and then there is a downturn when it has monopoly power in the market. In Figure 1, the pooling profit starts up at $p_H = p_H^{P^*} = 0.5c$ and when the price of the high quality product increases until $p_H = p_H^{P^{***}} = 0.75\bar{\theta}$ (both results are obtained by finding p_H when $\pi_L^P = 0$), the separating profit is a large amount and firm L does not choose a pooling-price strategy. From the diagram, the pooling profit reaches the maximum level when $p_H = p_H^{P^{**}} = \frac{(c+1.5\bar{\theta})}{4}$ and the highest of pooling profit is $\pi_L^{P^*} = 0.02(1.5\bar{\theta} - c)^2$. Theses two curves intersect at point D where $p_H = p^*_H$. At this point, the profit of firm L when there is quality uncertainty is equal to its profit when there is no quality uncertainty and is equal to

$$\pi_L^* = 0.25\left(0.43c - 0.21\bar{\theta} - 0.14\sqrt{2.25\bar{\theta}^2 + 1.5c\bar{\theta} - 5c^2}\right)^2 .$$

Figure 1 Profit function for firm L



π_L^S is the profit of firm L when there is no quality uncertainty in the market. For the low levels of p_H, firm L is better off using a pooling-price strategy because the low price set by firm H leaves little room for firm L to earn profit. At high levels of p_H, firm L earns higher profit by adopting the separating price strategy.

The social welfare of consumers is derived by integrating the utility function in the taste parameter. If firm L uses a separating price, the consumer surplus is shown by equation 9. However, if firm L wants to cheat uninformed consumers by using a pooling price strategy, consumers' surplus is shown by equation 10 where θ_{0E} is the taste parameter for uninformed consumers. Informed consumers who prefer a high-quality product will buy from a high-quality firm but others who prefer a low-quality product will leave the market because the product's price is too high when the quality is low. Consumer surplus is comprised of three parts. The first part is consumer surplus for informed consumers which is (1 - λ) of the total consumers. The second and third parts denote consumer surplus for uninformed consumers which is affected by firm L's probability to successfully pass off as a high quality producer. More precisely, the second part captures a case where uninformed consumers are not cheated by firm L, that is, they get the product that has the quality that they expected: $v_H > v_E$. On the other hand, the third part refers to a case where uninformed consumers are cheated and get a product that has a lower quality than expected.

Consumer surplus when firm L uses a separating-price strategy:

$$CS = \{\int_{\theta_{HL}}^{\bar{\theta}} [\theta v_H - p_H]d\theta)\} + \{\int_{\theta_{L0}}^{\theta_{HL}} [\theta v_L - p_H]d\theta\} \tag{9}$$

$$= \frac{1}{2(4v_H - v_L)^2}\left\{ v_H \left\{ \begin{array}{l} c^2 v_H(4v_H + 5v_L) - 2\bar{\theta}cv_H(4v_H + 5v_L) \\ + \bar{\theta}[v_L^2(1-\bar{\theta}) + 4v_H^2(4-3\bar{\theta}) + v_H v_L(13\bar{\theta} - 8)\end{array}\right\}\right\}$$

Consumer surplus when firm L uses a pooling-price strategy:

$$CS = \{(1-\lambda)(\int_{\theta_{0H}}^{\bar{\theta}} [\theta v_H - p_H]d\theta)\} + \{(1-\alpha)\lambda(\int_{\theta_{0E}}^{\bar{\theta}} [\theta v_H - p_H]d\theta)\} + \{\alpha\lambda(\int_{\theta_{0E}}^{\bar{\theta}} [\theta v_L - p_H]d\theta)\}$$

$$= (1-\lambda)\left[v_H \frac{\bar{\theta}^2}{2} - p_H\bar{\theta} - v_H \frac{\theta_{0H}^2}{2} + p_H\theta_{0H}\right] + (1-\alpha)\lambda\left[v_H \frac{\bar{\theta}^2}{2} - p_H\bar{\theta} - v_H \frac{\theta_{0E}^2}{2} + p_H\theta_{0E}\right] \tag{10}$$

$$+ \alpha\lambda\left[v_L \frac{\bar{\theta}^2}{2} - p_H\bar{\theta} - v_L \frac{\theta_{0E}^2}{2} + p_H\theta_{0E}\right] \quad ; \theta_{0H} = \frac{p_H}{v_H} \text{ and } \theta_{0E} = \frac{p_E}{v_E}$$

4. Simulation of Competition Game with Quality Uncertainty

The profits and social welfare depend on value of $\bar{\theta}$, c, v_L, r, λ, and α. Therefore, this study simulates the unobserved factors at different levels of optimal price, with the aim of finding the competition equilibrium with quality uncertainty. In some studies, $\bar{\theta}$, c and v_L are assumed to be exogenous unobserved variables that both agents do not have the power to manipulate. In contrast, this study allows the values of these variables to vary within a specified range. The upper bound of consumers' taste parameter is denoted by $\bar{\theta}$ and it represents the highest preference of consumers in the market. It can be set to equal 1 ($\bar{\theta}$ = 1) in order to simplify the analysis. The marginal cost, of c is assumed to be fixed in the short- term and is set at 0.1. In order to explain the equilibrium results, the effect of a firm's quality through the ratio of high to low quality, r is examined instead of the direct value of v_L. The variables, r, λ, and α are of interest because they have direct effects on the pooling profits of both firms.

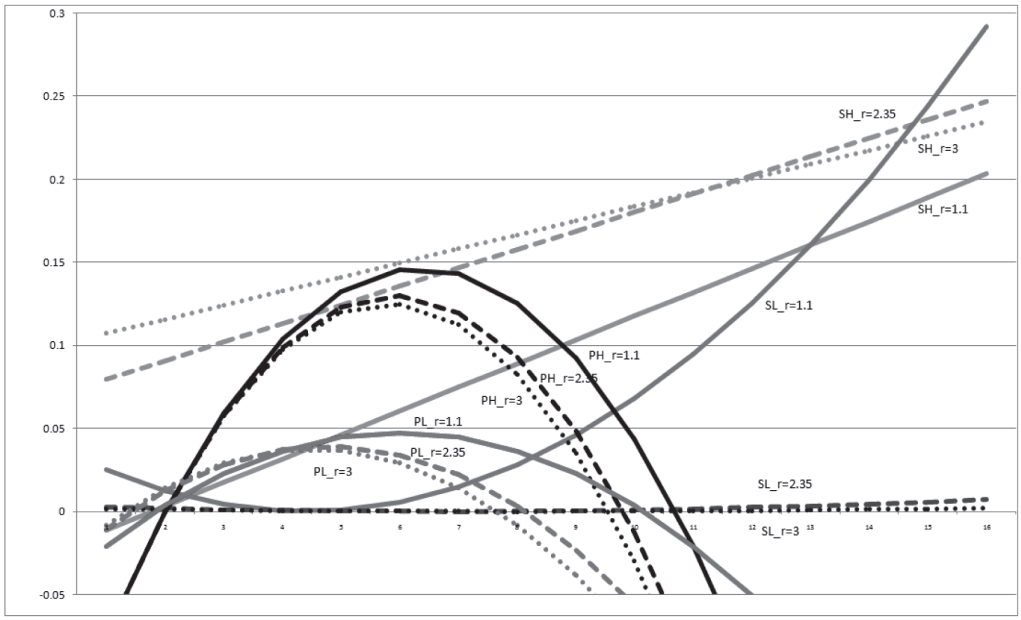
There are four simulation cases. In case 1, the value of λ is fixed at 0.5. This means that there are an equal number of informed and uninformed consumers in the market. Furthermore, it is assumed that the probability that uninformed consumers are deceived by firm L is also 0.5. In case 2, λ is simulated by fixing the value of r as a value which coincides with the case where the separating and the pooling profit are the same (r = 2.35) and α is equal to 0.5. In order to emphasize the effect of α on the

competition results, case 3 simulates α with a fixed value of r and λ _equals to 2.35 and 0.5 respectively. Later on, this study considers Case 4 as a special case where λ=1 and then varies the value of α to analyze the competition solutions.

Case 1: Simulating the Value of r with λ = 0.5 and α = 0.5

Case 1 varies the value of r from 1.1 to 3 and finds the changes in all profits and consumer surplus[1]. The results of the simulation are shown in Figure 2 where r equals to 1.1, 2.35 and 3. The Y-axis represents all profits and consumer surplus while the X-axis represents the value of p_H. The pooling profits are the inverted-U curves and the separating profits are the upward curves. The profit curves are similar to Figure 1 in that they both have the intersections of profits for separating and pooling prices for each level of r.

Figure 2 Simulation of Firms' Profits in Case 1



[1] SH denotes the separating profit of firm H, SL denotes the separating profit of firm L, PH denotes the pooling profit of firm H and PL denotes the pooling profit of firm L. CS_separating denotes consumer surplus with a separating-price strategy and CS_pooling denotes consumer surplus with a pooling-price strategy. The corresponding number indicates the value of r.

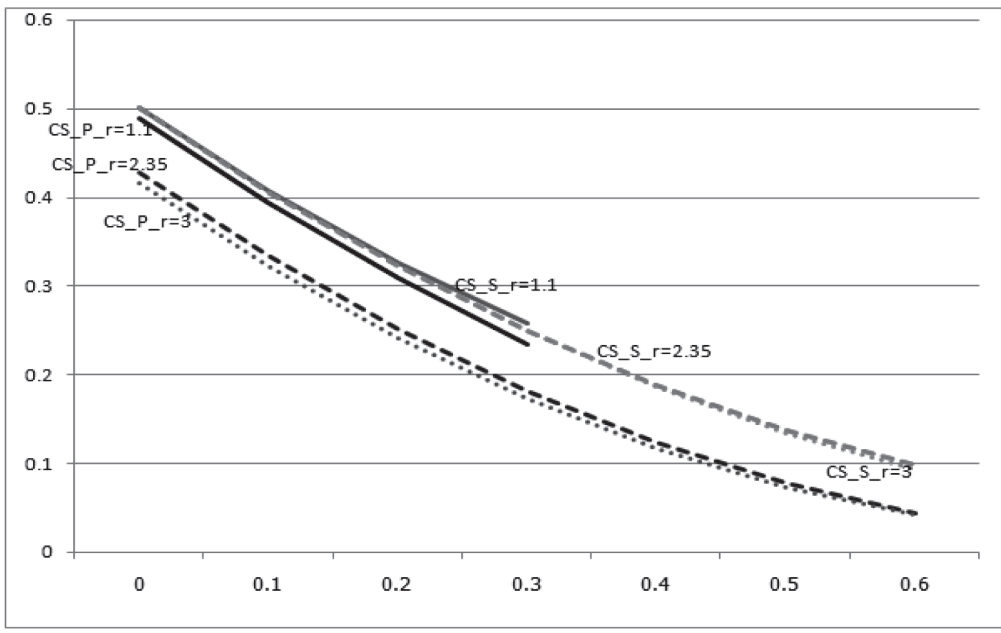
All of the separating profit curves have a positive slope, that is, the profit increases with the price of high-quality products. If r rises, the separating profit of firm H increases. This implies that when consumers clearly realize the difference between high and low quality products, they begin to buy products from both firms. However, the separating profit of firm L decreases, because firm L loses their consumers to firm H when buyers know that the quality gap is widening. When $r = 1.1$, the high quality to low quality ratio is too small, and the separating profit of firm H (SH_r = 1.1) is at its lowest value (SH_r = 1.1 curve is below compares with other SH curves). It means that when r increases, the separating profit of firm H increases but with a declining rate. SH_r = 1.1 and SL_r = 1.1 curves intersect at the high price of firm H, implying that when consumers realize that there is a small quality differentiation, consumers choose to buy a low-quality product instead of a higher-quality product.

When considering the pooling profit, the profit curves are similarly downward U-shaped. However, the pooling profit of firm H is greater than that of firm L at every level of r due to the effects of λ and α. To be more precise, since half of the consumers cannot differentiate the product's quality, both firms' pooling profits are the same initially. However, the gap between both firms' profits starts to widen as the pooling profit of firm H increase since some consumers are informed and some uninformed consumers are not taken in by firm L. In other words, an increase in the profit gap reflects the behavior of informed consumers which deter firm L from cheating. If r increases, informed consumers can distinguish between the two types of quality and thus firm L's sales volume decrease, especially when the price of firm H is high. On the other hand, uninformed consumers perceive that the expected quality of both firms has decreased. Therefore, the pooling profit is higher for firm L at the lower price of firm H. But at the higher price level, uninformed consumers think the price is greater than the expected quality. This led the sales volume and the pooling profit of firm L to decrease.

Since firm L's strategy to compete is the key determinant of both firms' profits, it deserves further analysis. Consider firm L's separating profit and its pooling profit. It can be seen that when quality is less differentiated, firm L can choose both strategies according to the price of firm H and other factors such as λ and α. But when quality is more differentiated, firm L is motivated to choose a pooling-price strategy that gives it more profit than the separating price strategy. It should be noted that firm L can gain positive profit when it uses a pooling-price strategy within a certain range of prices set by firm H.

In turning to consumer surplus, the results show that the welfare of consumers of both firms has a negative slope. When firm H's prices increase, consumers use more money to buy goods and this reduces their wealth and welfare levels. As can be seen from the diagram, consumer surplus, when both firms used separating price strategy (CS_S) changed only slightly when r increases because firms set different prices to reflect the true product's quality and consumers are able to distinguish them (three consumer surpluses: CS_S_r = 1.1, CS_S_r = 2.35 and CS_S_r = 3 are nearly the same lines). Therefore, a low-quality product fetches a low price when the welfare is highest. When both firms used pooling price strategies (CS_P) the consumer's surpluses are different. When r increases, the welfare of consumers decrease. This cause from the deceived consumers more suffers from consuming a poor-quality product at a high price. The consumer surplus steadily decreases as buyers realize that the quality of the product they buy has less value than they expected. The increase of the difference between true and expected qualities is due to a decrease in consumer surplus.

Figure 3 Simulation of Consumer Surpluses in Case 1

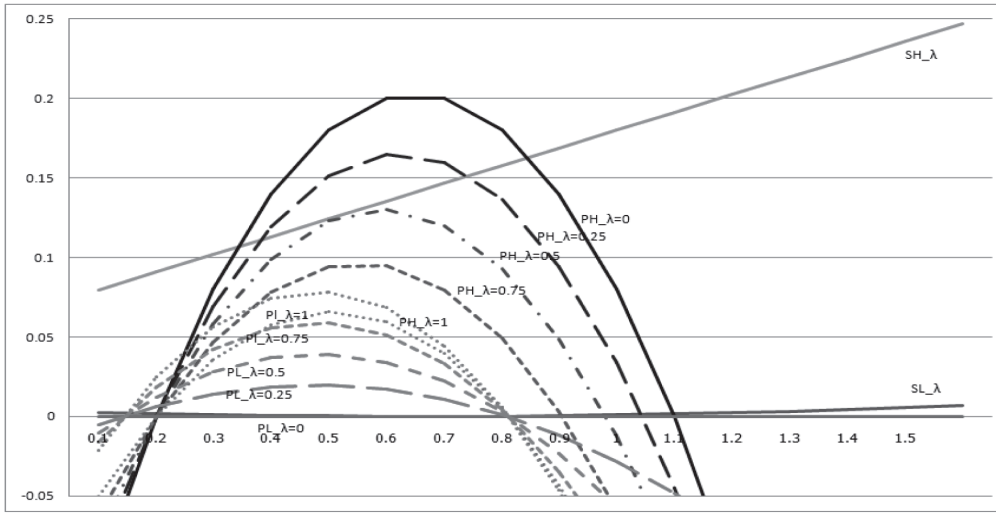


Case 2: Simulating the Value of λ with r = 2.35 and α = 0.5

In case 2, the value of λ is simulated. In order to examine the behavior of λ, r is fixed at a value which coincides with the case where the separating and the pooling profit are the same (r = 2.35) and α is equal to 0.5. When λ is varied, only the pooling profits of both firms and consumer surplus when both firms used pooling price strategy (CS_P) are affected. The value of λ does not affect the separating profit and consumer surplus when both firms used a separating price strategy (CS_S) because when both firms set their price according to the quality of their products, no one can be deceived by firms. Then, when λ is varied, both SH and SL are the same.

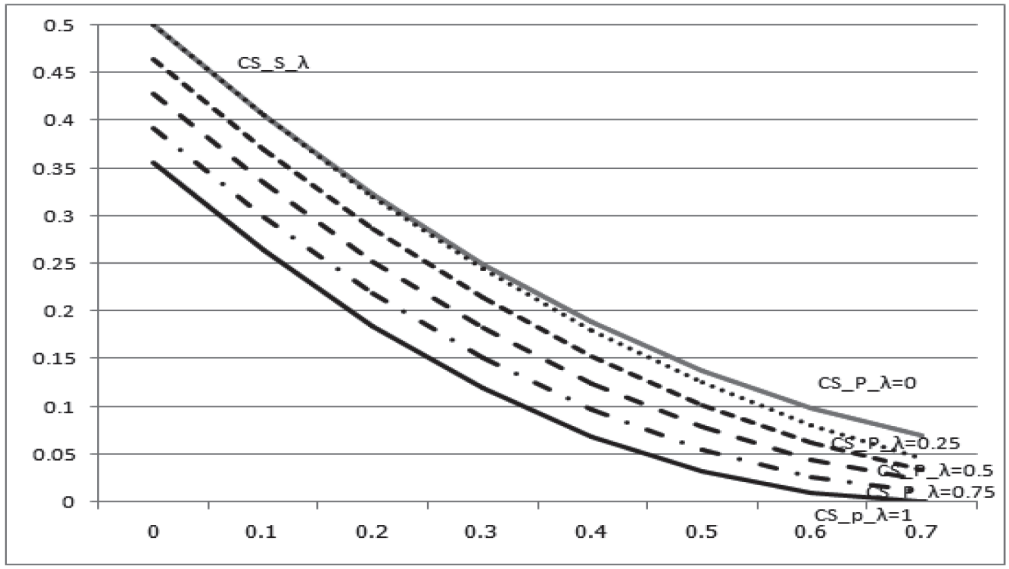
When λ = 0, all consumers are informed, thus firm L cannot use a pooling-price strategy and cheat consumers. If firm L insists on using a pooling-price strategy, it receives no profit (PL_λ = 0 is equal to zero), whereas firm H receives the highest profit (PH_λ = 0). When, all consumers are uninformed, firm L's profit depends on the probability that it can successfully deceive the consumers. To simplify λ behavior, α is assumed equal to 0.5, that is, half of uninformed consumers are successfully deceived by firm L and buy a low-quality product. Thus, both firms receive the same market share. The pooling profit of firm H (PH_ λ = 1) and that of firm L (PL_ λ = 1) are similar. The only difference stems from the difference in the cost of production. Firm H has higher costs than firm L does, so it has fewer profits. Furthermore, firm L's pooling profit increases while firm H's profits decrease when λ increases (PH decreases and PL increase). This is because when more consumers receive incomplete information about quality (more uninformed consumers); more buyers are deceived by the firms. Thus, the pooling profit of non-cheating firms reduces while the pooling profit of firm L more increases.

Figure 4 Simulation of Firms' Profits in Case 2



As concerns welfare, λ only affects CS_P such that when λ increases, CS_P decreases. From Figure 5, CS_S_λ and CS_P_$\lambda = 0$ are almost the same. The difference of both curves comes from the decimal-calculation. This situation is caused when $\lambda = 0$, which means that there are not uninformed consumers in the market; they have complete information by which to choose a suitable quality-product through its price. The strategies of both firms do not have an effect on selection. The, welfare of these situations are maximum when compared with others. In contrast, when $\lambda = 1$, consumer surplus from a pooling-price strategy (CS_P_$\lambda = 1$) is minimum. Because al l consumers are uninformed but firm L can deceived half of them, buyers suffer from the consumption of a poor quality-product and this leads to a decrease in welfare. The line of CS_P_$\lambda = 1$ is about half of that of a separating-price strategy (CS_S_λ). This means the social lose about half of welfare if they allow the deceived firm (firm L) exists in the market.

Figure 5 Simulation of Consumer Surpluses in Case 2



Case 3: Simulating the Value of α with r = 2.35 and λ = 0.5

In case 3, the study simulates the value of α. Like λ, α only affects the pooling profits (both PH and PL) and consumer surplus (CS_P). By giving misleading information to consumers and thus increasing the value of α, firm L's profits increase while firm H's profits decrease. When $\alpha = 0$, no uninformed consumers are deceived by firm L, thus, only firm H receives the pooling profit (PH_ $\alpha = 0$). This is because when prices are the same, everyone buys the higher quality product from firm H since they are able to distinguish the quality of the products. However, it is worthy to note that firm H's pooling profit in case 3 is less than in case 2. In an extreme situation, where $\alpha = 1$, all uninformed consumers are deceived by firm L but the pooling profit of firm H (PH_$\alpha = 1$) is still higher than the pooling profit of firm L (PL_$\alpha = 1$) since firm H's products are also bought by informed consumers.

Figure 6 Simulation of Firms' Profits in Case 3

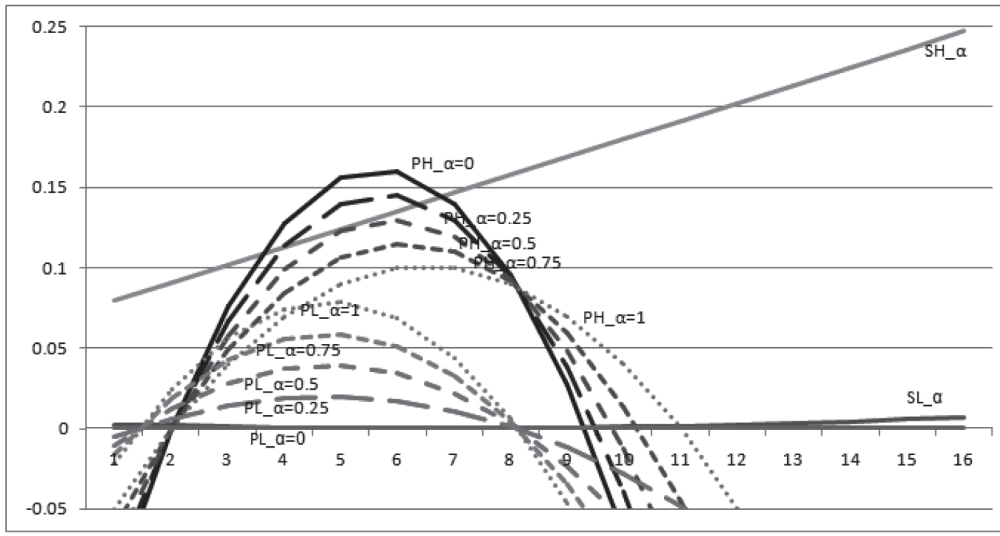
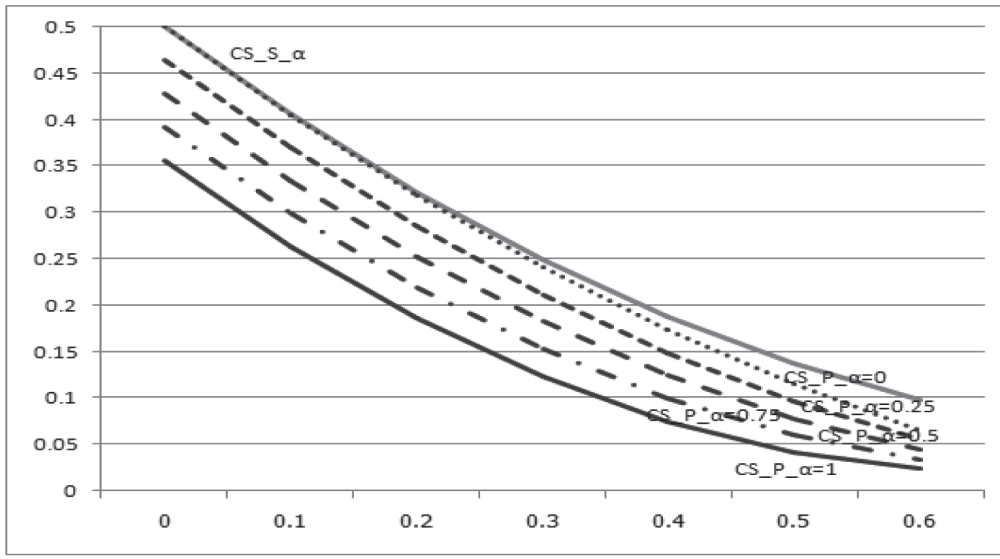


Figure 7 Simulation of Consumer Surpluses in Case 3



When half of the buyers are uninformed, the welfare of consumers depends upon the deceiving ability of firm L. The consumer surplus, when both firms used a separate profit, is not dependent on the value of α, thus, there is only one line (CS_S_α) that represents all of the consumer surplus. It is not surprising that CS_S_α and CS_P_α = 0 are almost the same. When $\alpha = 0$, firm L cannot deceive

uninformed consumers. Further, buyers can then purchase products with the desired quality at prices which prevail when all buyers are informed.

Case 4: Simulating the Value of α with r = 2.35 and $\lambda = 1$

This case considers profit and welfare by simulating the value of α when all consumers are uninformed ($\lambda = 1$). When firm L cannot cheat anyone, $\alpha = 0$ and the prices of both firms are the same, only firm H receive the pooling profit but at a lower level than in Case 3. As α increases, firm L's pooling profits increase. If α is less than 0.5, the pooling profit of firm L is less than that of firm H. Conversely, if α is greater than 0.5, the pooling profit of firm L is larger than that of firm H. At $\alpha = 0.5$, and both firms enjoy the same pooling profits. The slight difference between their profits is due to differences in cost. In the extreme situation where firm L has full cheating power ($\alpha = 1$), firm L earns all the pooling profits. The pooling profit of firm H is zero because there is no informed consumer who can distinguish between the qualities of the products sold by different sellers and firm H has no way of signaling its quality to uninformed buyers. Furthermore, firm L's pooling profit when $\alpha = 1$ is higher than firm H's pooling profit when $\alpha = 0$ because firm H faces high production costs.

As the number of deceived consumers increase, the consumer surplus falls. However, when all consumers are uninformed ($\lambda = 1$) and α is greater than 0.5, it is possible that consumer surplus falls into the negative region. This occurs when firm H charges a high price for its product which firm L imitates. As a result, for those consumers that are deceived by firm L, there is a huge gap between the price of the product and the quality of the product produced by firm L, thus consumer surplus declines sharply.

Figure 8 Simulation of Firms' Profits in Case 4

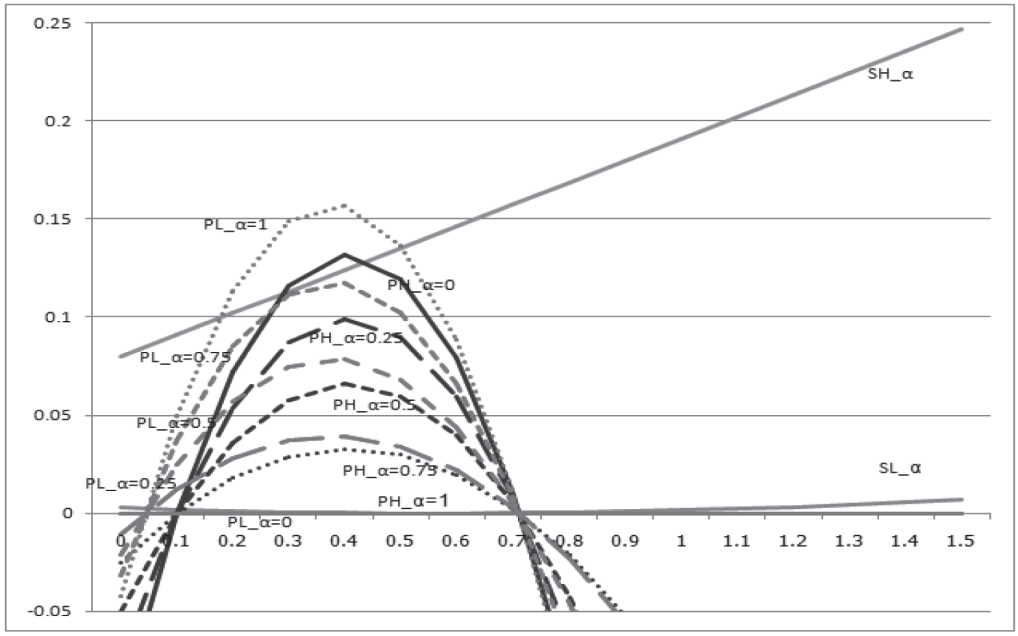
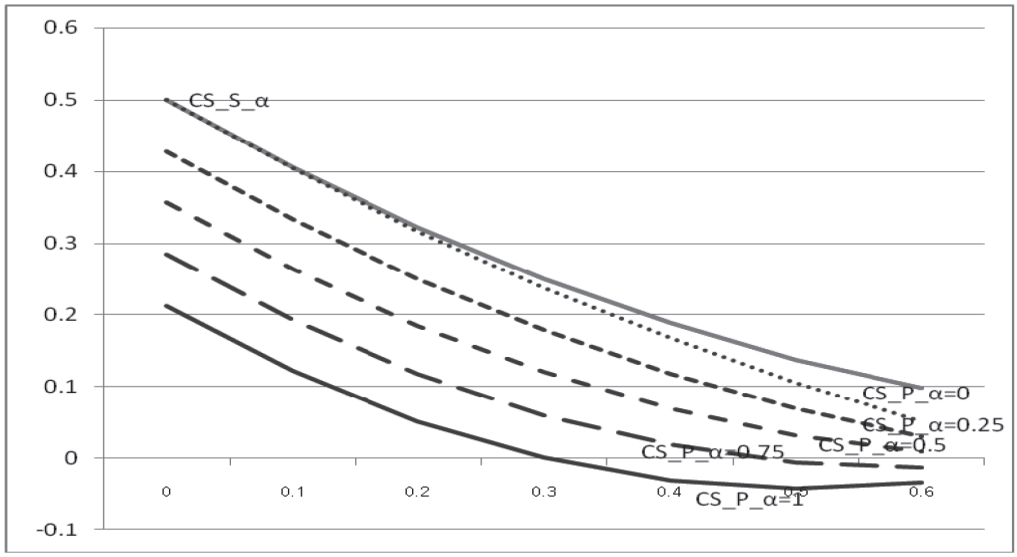


Figure 9 Simulation of Consumer Surpluses in Case 4



The results from all these cases show that consumer surplus is greater when both firms use a separating-price strategy than when firm L uses a pooling-price strategy. In addition, only an increase in p_H will decrease welfare while improvement in the quality of products produced by firm L has little effect on welfare.

5. Conclusion

In sum, the ratio of the quality of goods produced by a high and low-quality firm, the fraction of uninformed consumers and the ability of low-quality firms to successfully deceive an uninformed consumer are key factors which influence the low quality firm's choice of strategy. When a low-quality firm uses a pooling-price strategy, it is possible that it makes higher profits than a high-quality firm. In particular, if there is a large difference in the quality of products between the low- and high- quality firms, a low-quality firm has an incentive to adopt a pooling-price strategy. However, the level of profit it can make depends on the price set by a high-quality firm. If there are a large number of uninformed consumers in the market (λ is high), a low quality firm can also increase its profit by choosing the pooling-price strategy. Moreover, if the probability is high that uninformed consumers are deceived by a low-quality firm, then the low-quality firm has a high incentive to adopt pool-price strategies. However, when a low-quality firm uses a pooling-price strategy, some uninformed consumers are deceived and the total cost of social welfare decreases.

The uncertainty in product quality provides an opportunity for a low-quality firm to earn more profits than a high-quality firm. This uncertainty effect distorts the level of profits among firms and decreases the welfare of consumers. To avoid this effect, policy makers should set policies which reduce the incentives for low-quality firms to use pooling-price strategies. This can be achieved through monitoring and regulating the ratio of high-low quality in each product, the fraction of uninformed consumers and the deceiving ability of low quality firms. For example, consumer welfare will be improved if more information about the quality of products produced by different firms is made available and punishment is meted out to dishonest sellers who sell low-quality products at exorbitant prices.

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