I. Introduction

Corporate social responsibility (CSR) has received increasing attention from firms and researchers in the past few decades. Wood (1991) indicates that CSR originates from the expectations of the society for business adopting appropriate business behavior and outcomes. Mohr and Webb (2005) suggest that CSR can have stronger effects on consumers' purchase intensions than price. For example, American consumers care about firms' efforts in social responsibility and may use the information as a purchasing criterion. Therefore, in the long run, the benefits of being more socially responsible would reflect on firms' profits.

Porter and Kramer (2006) present a systematic analysis linking competitive advantage to CSR. In particular, they explain not only how a company can use competitive strategies to plumb the opportunity of CSR but also how CSR enhances its long-term competitiveness. They point out two key reasons why many companies, which have launched CSR efforts, find these efforts not as productive as they could be. One reason is that these companies simply consider CSR as a cost, a constraint, or a charitable deed. The other reason is that these companies do not incorporate CSR efforts as parts of their core business strategies.

The literature has provided numerous perspectives on CSR. One strand of the literature regards CSR as the private provision of public goods or the elimination of public bads (for example, Bagnoli and Watts, 2003; Kotchen, 2006; Besley and Ghatak, 2007). In general, the results obtained are parallel with the results obtained in the literature of private provision of public goods.

Another strand identifies the firm's incentives to invest in CSR (for example, Baron, 2001; Baron, 2009; Benabou and Tirole, 2010). Baron (2001; 2009) argues that to understand why some practices would be labeled as CSR, it

is necessary to examine the firms' motivation for adopting CSR. In particular, Baron argues that firms could adopt CSR for various reasons. Firms can be motivated by altruistic reasons to invest in pure CSR. Firms can also invest in strategic CSR, which can be motivated by self-interest, public politics, and private politics. When firms anticipate that performing CSR can improve their competitive status in the market, they should seize any opportunity as their strategic investment in CSR.

Early studies on environmental concerns under oligopolistic framework mainly focus on the mandatory regulations such as command-and-control, emission taxes, and cap-and-trade permits.[1] Some recent studies examine the impacts of non-profit maximizing firms on environmental regulations in polluting industries (for example, Bárcena-Ruiz and Garzón, 2002; Bárcena-Ruiz and Garzón, 2006; Wang and Wang, 2009; Ohori, 2014). These studies consider government regulations and firms' social concerns on environmental problems, but not on firms' strategic incentives for adopting environmental friendly actions to alleviate environmental damage.

Firms nowadays increasingly desire to appear "green" and participate in voluntary actions of internalizing environmental externalities. Addition to their pure CSR motivations, the firms anticipate that "green" consumers are willing to pay a higher price for their products can be another driving force for them taking environmental friendly actions. We can define these environmental friendly actions such as pollution abatement activities, eco-R&D, and green technology management to alleviate environmental damage as environmental corporate social responsibility (ECSR).

In a seminal paper on the differentiated private duopoly model, Singh and Vives (1984) compare the welfare ranking under price and quantity competition. They suggest that, relative to the equilibrium outcome under price competition, firms produce fewer outputs, charge higher prices, and earn higher profits under

quantity competition. However, social welfare under quantity competition is lower than that under price competition.

In this paper, we argue that the welfare ranking may change when the environmental damage caused by firms' production is considered. We use a stylized differentiated duopoly model originated by Singh and Vives (1984) to examine the impacts of competition structures on firms' incentives for undertaking the "doing-well-by-doing-good" strategy suggested by Baron (2001). Specifically, we extend the differentiated duopoly game into a two-stage game, in which firms commit to undertake environmental friendly actions in the form of pollution abatement in the first stage and make their quantity/price decisions in the second stage. As suggested by the literature that consumers care about firms' efforts in social responsibility and may use the information as a purchasing criterion, hence, we incorporate consumers' preferences for firms' ECSR investments into their utility function to examine how consumers' preferences for ECSR would influence firms' output/price and ECSR investment decisions. By regarding the substitutability between products as the intensity of market competition, we also examine the impacts of market competition on firms' output/price and ECSR investment decisions. Furthermore, the impacts of market competition structures on firms' output/price and ECSR investment decisions are also examined. Finally, the welfare measures regarding firms' profits, consumer surplus, and social welfare under quantity and price competition are also examined, respectively.

Alves and Santos-Pinto (2008) investigate firms' incentive of CSR activities for differentiated duopoly in quantity competition only. By characterizing firms' contribution to social causes as CSR, which is proportional to their sales, they examine the impacts of production cost and the degree of product differentiation on firms' CSR contributions. They find that a firm with a higher production cost will contribute more to social causes than that of a lower

production cost. Additionally, firms will always do CSR when products are complements but might not do CSR when products are substitutes. Firms will contribute positive CSR if the substitutability is large enough. Finally, they find that CSR increases outputs, prices, and profits.

Manasakis, Mitrokostas, and Petrakis (2013; 2014) emphasize the importance of a credible information disclosure mechanism for a sustainable CSR related good market due to the credence feature of firms' CSR investment. Liu, Wang, and Lee (2015) investigate the impacts of competition structures on firms' incentives for adopting ECSR, which is certified by a NGO. They show that the certifier will set a standard lower than the optimal one to induce firms to adopt certified ECSR, and the standard in Cournot competition is higher than that in Bertrand competition. They also show that firms and consumers both benefit from firms' certified ECSR. Here, rather than modeling firms' ECSR investments proportional to their sales, we consider firms' ECSR investments in some green technology management, which would reduce a given level of emission, as credible commitments. Therefore, instead of modeling CSR as variable costs of firms' production, we perceive firms' ECSR investments as fixed costs.

Similar to Alves and Santos-Pinto (2008), our results suggest that firms will invest in ECSR if and only if the product differentiation is sufficiently large both in quantity and in price competition, though the product differentiation may influence firms' ECSR investments differently in quantity and price competition. Our results also suggest that, compared to the equilibrium outcome under price competition, firms produce fewer outputs, charge higher prices, invest more in ECSR activities, and discharge less emission under quantity competition. Social welfare under quantity competition would be higher than that under price competition if the marginal environmental damage were too large. Therefore, we find a trade-off between consumer surplus and environmental damage in generating social welfare in the polluting industry.

The rest of the paper is organized as follows. Section 2 describes the model and characterizes the quantity and price equilibria. Section 3 provides comparisons between the quantity and the price competition. Section 4 concludes the paper.

II. The Model

Following Manasakis, Mitrokostas, and Petrakis (2013; 2014), we consider the stylized version of the Singh and Vives (1984) model. On the demand side of the market, the utility function of a representative consumer is specified as follows:

$$U = (A + \alpha s_1)q_1 + (A + \alpha s_2)q_2 - \frac{1}{2}(q_1^2 + q_2^2 + 2\gamma q_1 q_2), \quad (1)$$

where q_i is firm i's output and s_i is the level of ECSR activities firm i undertakes, $i = 1, 2$. The parameter $\gamma \in (0, 1)$ is a measure of substitutability. The products are regarded as independent if $\gamma = 0$, and the products are regarded as perfect substitute if $\gamma = 1$. In other words, γ measures the intensity of market competition, with a higher γ corresponding to a fiercer competition. The positive parameter $\alpha \in (0, 1)$ represents a consumer's preference for the ECSR each firm undertakes. The consumer would obtain αs_i units of warm-glow preference when he purchases one unit of product from firm i. Thus, we may consider each firm undertakes ECSR activities as a quality improvement to promote its product since consumers value its ECSR investment. Note that, when $\alpha = 0$, the model converts to the Singh and Vives (1984) model and the equilibrium conditions of the model are treated as the benchmark.

The utility function of a representative consumer generates the system of linear demand functions as below:

$$q_i = \frac{(1-\gamma)A+\alpha s_i-P_i-\gamma(\alpha s_j-P_j)}{1-\gamma^2}, i, j = 1,2; i \neq j, \quad (2)$$

which can be inverted to get

$$P_i = A + \alpha s_i - q_i - \gamma q_j, i, j = 1,2; i \neq j. \quad (3)$$

Under the linear specification of demand functions, consumer surplus is derived as $CS = (q_1^2 + 2\gamma q_1 q_2 + q_2^2)/2$.

Suppose that each unit of firm i's product leads to one unit of emission. The extent of environmental damage is assumed to be given by $ED = d(e_1 + e_2)^2$, where d represents marginal environmental damage. Each firm undertakes pollution abatement activities as its ECSR investment and reduces its emission by investing s_i. Thus, firm i's emission level is given by $e_i = q_i - s_i$. We assume that each firm's investment in ECSR activities exhibits decreasing returns to scale, as captured by the quadratic cost function of ECSR, s_i^2.

On the supply side of the market, both firms use identical constant returns to scale production technologies with the same constant marginal cost $c < A$. Thus, firm i's profit function is given as the following equation:

$$\pi_i = (P_i - c)q_i - s_i^2, \ i = 1,2. \quad (4)$$

We consider the decision-making process of the firms in a two-stage game. In the first stage, each firm makes its ECSR commitment independently and simultaneously. In the second stage, observing the firms' ECSR commitment made in the first stage, the firms compete in quantity or in price. Notice that the credence attribute of firms' CSR investment may provide firms incentives to cheat consumers and may create an adverse selection problem. To solve the adverse selection problem, Manasakis, Mitrokostas, and Petrakis (2013; 2014) suggest that a credible information disclosure mechanism is needed. Here, we assume away the potential adverse selection problem and only focus on the effects of market competition

structures on firms' incentive for undertaking ECSR as well as equilibrium outcomes.

2.1 Quantity Competition

The game is solved by backward induction. In the second stage, each firm simultaneously and independently chooses its output to maximize its own profits. The second-stage Nash equilibrium is characterized as follows:

$$q_i = \frac{(A-c)}{2+\gamma} + \frac{2\alpha s_i - \gamma\alpha s_j}{4-\gamma^2}, i, j = 1,2; i \neq j, \tag{5}$$

$$P_i = \frac{A+(1+\gamma)c}{2+\gamma} + \frac{2\alpha s_i - \gamma\alpha s_j}{4-\gamma^2}, i, j = 1,2; i \neq j, \tag{6}$$

$$\pi_i = \left[\frac{(A-c)}{2+\gamma} + \frac{2\alpha s_i - \gamma\alpha s_j}{4-\gamma^2}\right]^2 - s_i^2, i, j = 1,2; i \neq j. \tag{7}$$

By differentiating q_i with respect to s_i and s_j, we have the following lemma.

Lemma 1:

Under quantity competition, the ECSR activities create the demand-expanding effect of the firms, i.e., $\partial q_i/\partial s_i = 2\alpha/(4-\gamma^2) > 0$, *and the demand-shifting effect between the firms, i.e.,* $\partial q_i/\partial s_j = -\gamma\alpha/(4-\gamma^2) < 0$.

Lemma 1 suggests that a firm would produce more outputs if it undertakes a greater level of ECSR. However, the firm would produce fewer outputs and set a lower price if its rival invests more in ECSR activities. Note that the demand-expanding effect is always greater than the demand-shifting effect since $\gamma \in (0,1)$. Note also that the demand-expanding effect and the demand-shifting effect are both stronger when the market competition becomes more intense, i.e., $\partial^2 q_i/\partial s_i \partial\gamma = \partial^2 P_i/\partial s_i \partial\gamma > 0$ and $\partial^2 q_i/\partial s_j \partial\gamma = \partial^2 P_i/\partial s_j \partial\gamma < 0$.

In the first stage, each firm simultaneously and independently determines its investment in ECSR activities. By differentiating firm i's profit with respect to s_i, we obtain the results as follows:

$$\frac{\partial \pi_i}{\partial s_i} = \left(A + \alpha s_i - 2q_i - \gamma q_j - c\right)\frac{\partial q_i}{\partial s_i} - \gamma q_i \frac{\partial q_j}{\partial s_i} - s_i. \tag{8}$$

From Eq. (8), firm i's ECSR investment, s_i, influences π_i from various aspects. The first term of Eq. (8) is the demand-expanding effect, the second term is the demand-shifting effect, and the third term is the marginal cost of ECSR investment. Firms would choose to increase their ECSR investments if the aggregate of demand-expanding effect and demand-shifting effect is greater than the marginal cost of ECSR. By solving $\partial \pi_i / \partial s_i = 0$, we obtain the following result:

$$s_i = \frac{2\alpha(2-\gamma)(A-c)-2\gamma\alpha^2 s_j}{(4-\gamma^2)^2-4\alpha^2}, i, j = 1,2; i \neq j. \tag{9}$$

It suggests that firms' ECSR investments are strategic substitutes under quantity competition since firm *i* would invest less in ECSR activities if its rival invests more in ECSR activities.

Let superscript *C* denote the subgame perfect Nash equilibrium (SPNE) under quantity competition. For the symmetry of consumers' preferences and firms' production technologies, we focus on the symmetric SPNE only. The SPNE is described as follows:[2]

$$s_i^C = \frac{2\alpha(A-c)}{\Delta^C}, \tag{10}$$

$$q_i^C = \frac{(4-\gamma^2)(A-c)}{\Delta^C}, \tag{11}$$

$$e_i^C = \frac{(4-\gamma^2-2\alpha)(A-c)}{\Delta^C}, \tag{12}$$

$$P_i^C = \frac{(4-\gamma^2)[A+(1+\gamma)c]-2\alpha^2 c}{\Delta^C}, \tag{13}$$

where $\Delta^C \equiv (2+\gamma)(4-\gamma^2) - 2\alpha^2 > 0$.

In this market, firms may use their decisions in output and in ECSR to maximize their own profits. By differentiating Eq. (11) with respect to γ, we find that firms would always produce fewer outputs in a market of fiercer competition, i.e., $\partial q_i^C / \partial \gamma < 0$. However, firms' decisions on ECSR investments are more complex. By differentiating Eq. (10) with respect to γ, we obtain the effect of market competition on firms' incentives for undertaking ECSR as follows:

$$\frac{\partial s_i^C}{\partial \gamma} = -\frac{2\alpha(A-c)(2+\gamma)(2-3\gamma)}{[\Delta^C]^2} \begin{matrix} > \\ = \\ < \end{matrix} 0 \; if \; \gamma \begin{matrix} > \\ = \\ < \end{matrix} \frac{2}{3}. \tag{14}$$

We summarize the result in Lemma 2.

Lemma 2:

Under quantity competition, the firm's investment in ECSR increases in γ *when the market competition is intense, i.e. i.e.,* $\gamma > 2/3$*; however, the firm's investment in ECSR activities decreases in* γ *when the market competition is soft, i.e.,* $\gamma < 2/3$.

Recall that consumers may regard firms' ECSR investments as quality improvement and the more intense the market competition is the stronger demand-expanding effect and demand-shifting effect of ECSR are. Lemma 2 suggests that, when firms' products are highly homogeneous and the market competition is fiercer, i.e., $\gamma > 2/3$, firms would tend to increase their investments in ECSR to strengthen the product differentiation in ECSR, which would soften the production competition. On the other hand, when the product differentiation is so large and the market competition is mild, i.e., $\gamma < 2/3$, the demand-expanding effect and demand-shifting effect of firms' ECSR investments may be not as beneficial as they are in a highly competitive market. Therefore, firms would choose to invest less in ECSR in a mildly competitive market.

Define the social welfare as the sum of equilibrium profits and consumer surplus minus environmental damage. The equilibrium profits, consumer surplus, environmental damage, and social welfare under quantity competition are obtained as follows:

$$\pi^C = \frac{(A-c)^2\left[\left(4-\gamma^2\right)^2-4\alpha^2\right]}{[\Delta^C]^2}, \tag{15}$$

$$CS^C = \frac{(A-c)^2\left(4-\gamma^2\right)^2(1+\gamma)}{[\Delta^C]^2}, \tag{16}$$

$$ED^C = \frac{4d(A-c)^2\left(X^C\right)^2}{[\Delta^C]^2}, \tag{17}$$

$$SW^C = \frac{(A-c)^2\left[Y^C-4d\left(X^C\right)^2\right]}{[\Delta^C]^2}, \tag{18}$$

where $X^C \equiv 4-\gamma^2-2\alpha > 0$ and $Y^C \equiv (3+\gamma)(4-\gamma^2)^2-8\alpha^2 > 0$.

Comparing the equilibrium profits with that in the benchmark model, i.e., $\alpha = 0$, we have the following lemma.

Lemma 3:

Under quantity competition, for any $\gamma \in (0,1)$*, the firm would undertake ECSR activities if and only if* $\alpha < \sqrt{(2+\gamma)^2(1-\gamma)}$.

Lemma 3 suggests that providing consumers' preferences for firms' ECSR, firms would benefit from undertaking ECSR if and only if the product differentiation is sufficiently large. In other words, firms would invest in ECSR if and only if the market competition is mild.

In summary, under quantity competition, firms will invest in ECSR if and only if the product differentiation perceived by consumers is sufficiently large. Given

firms invest in CSR activities, if the consumers perceive the products as being close substitutes, *i.e.*, $\gamma > 2/3$, the firms would increase their ECSR investments as the homogeneity of the goods increases. However, if the consumers perceive a large product differentiation between the products, *i.e.,* $\gamma < 2/3$, the firms would increase their ECSR investments as the product differentiation increases.

2.2 Price Competition

Turning to the market of price competition, in the second stage of the game, each firm simultaneously and independently sets its price to maximize its own profit. The second-stage Nash equilibrium is characterized as follows:

$$P_i = \frac{(2+\gamma)[(1-\gamma)A+c]+(2-\gamma^2)\alpha s_i-\gamma\alpha s_j}{4-\gamma^2}, i, j = 1,2; i \neq j, \tag{19}$$

$$q_i = \frac{(2+\gamma)(1-\gamma)(A-c)+(2-\gamma^2)\alpha s_i-\gamma\alpha s_j}{(1-\gamma^2)(4-\gamma^2)},\ i, j = 1,2; i \neq j, \tag{20}$$

$$\pi_i = \left[\frac{(2+\gamma)(1-\gamma)(A-c)+(2-\gamma^2)\alpha s_i-\gamma\alpha s_j}{(1-\gamma^2)(4-\gamma^2)}\right]^2 - s_i^2,\ i, j = 1,2; i \neq j. \tag{21}$$

From Eq. (19) and (20) we obtain the effect of s_i and s_j on q_i and P_i, given as below:

$$\frac{\partial q_i}{\partial s_i} = \frac{(2-\gamma^2)\alpha}{(1-\gamma^2)(4-\gamma^2)} > 0, \tag{22}$$

$$\frac{\partial q_i}{\partial s_j} = -\frac{\gamma\alpha}{(1-\gamma^2)(4-\gamma^2)} < 0, \tag{23}$$

$$\frac{\partial P_i}{\partial s_i} = \frac{(2-\gamma^2)\alpha}{(4-\gamma^2)} > 0, \tag{24}$$

$$\frac{\partial P_i}{\partial s_j} = -\frac{\gamma\alpha}{(4-\gamma^2)} < 0. \tag{25}$$

Thus, we have the following lemma.

Lemma 4:

Under price competition, firm would produce more and charge a higher price if it invest more in ECSR. However, the firm would produce less and charge a lower price if its rival invests more in ECSR.

Lemma 4 suggests that, similar to that in the market of quantity competition, firms' investments in ECSR create demand-expanding effect of the firm and the demand-shifting effect between the firms. The demand-expanding effect is always greater than the demand-shifting effect. Additionally, both the demand-expanding effect and the demand-shifting effect increase with the intensity of market competition.

In the first stage, each firm simultaneously and independently chooses its investment in ECSR. By differentiating firm i's profit with respect to s_i, we obtain its reaction function in choosing s_i against s_j, which is given by

$$s_i = \frac{\alpha(2-\gamma^2)(2+\gamma)(1-\gamma)(A-c)-\alpha^2\gamma(2-\gamma^2)s_j}{(1-\gamma^2)(4-\gamma^2)^2-\alpha^2(2-\gamma^2)}, i, j = 1,2;\ i \neq j. \tag{26}$$

Eq. (26) suggests that the ECSR investments are also strategic substitutes under price competition since firm *i* would invest less in ECSR if its rival invests more in ECSR.

Let superscript *B* denote the SPNE under price competition. The symmetric SPNE is given as follows:[3]

$$s_i^B = \frac{\alpha(2-\gamma^2)(A-c)}{\Delta^B}, \tag{27}$$

$$q_i^B = \frac{(4-\gamma^2)(A-c)}{\Delta^B}, \tag{28}$$

$$e_i^B = \frac{(4-\gamma^2-\alpha(2-\gamma^2))(A-c)}{\Delta^B}, \tag{29}$$

$$P_i^B = \frac{(4-\gamma^2)(1+\gamma)[(1-\gamma)A+c]-\alpha^2(2-\gamma^2)c}{\Delta^B}, \tag{30}$$

where $\Delta^B \equiv (1+\gamma)(2-\gamma)(4-\gamma^2)-\alpha^2(2-\gamma^2) > 0$.

By differentiating Eq. (27) with respect to γ, we obtain the following result:

$$\frac{\partial s_i^B}{\partial \gamma} = -\frac{\alpha(2-\gamma)(2\gamma^4+3\gamma^3-2\gamma^2-2\gamma+4)(A-c)}{[(1+\gamma)(2-\gamma)(4-\gamma^2)-\alpha^2(2-\gamma^2)]^2} < 0, \ \forall \gamma \epsilon\ (0, 1). \tag{31}$$

Thus, we have the following lemma.

Lemma 5:

Under price competition, firms' investments in ECSR decrease in γ *for all* $\gamma \in (0, 1)$.

Lemma 5 suggests that firms would invest less in ECSR if consumers perceive higher homogeneity of the products and the price competition is more intense. Singh and Vives (1984) suggest that firms are less able to raise prices above marginal cost in price competition than in quantity competition. Therefore, if the price competition becomes more intense, firms would always tend to compete in price rather than in ECSR investment, even though ECSR investment may increase product differentiation and soften the price competition.

The equilibrium profits, consumer surplus, environmental damage, and social welfare under price competition are obtained as below:

$$\pi_i^B = \frac{(A-c)^2\left[(4-\gamma^2)^2(1-\gamma^2)-\alpha^2(2-\gamma^2)^2\right]}{[\Delta^B]^2}, \tag{32}$$

$$\mathrm{CS}^B = \frac{(A-c)^2(4-\gamma^2)^2(1+\gamma)}{[\Delta^B]^2}, \tag{33}$$

$$ED^B = \frac{4d(X^B)^2(A-c)^2}{[\Delta^B]^2}, \tag{34}$$

$$SW^B = \frac{(A-c)^2\left[Y^B - 4d\left(X^B\right)^2\right]}{[\Delta^B]^2}, \tag{35}$$

where $X^B \equiv 4-\gamma^2-\alpha(2-\gamma^2) > 0$ and $Y^B \equiv (4-\gamma^2)^2(1+\gamma)(3-2\gamma) - 2\alpha^2(2-\gamma^2)^2 > 0$.

Comparing the equilibrium profits with that in the benchmark model, i.e., $\alpha = 0$, we have the following lemma.

Lemma 6:

Under price competition, the firms would engage in ECSR activities if and only if $\gamma \in (0, \sqrt{3}-1)$.

That is, under price competition, the firms would benefit from undertaking ECSR if and only if the product differentiation is sufficiently large, i.e., $\gamma < \sqrt{3}-1$.

In summary, under price competition, the firms would invest in ECSR if and only if the product differentiation is sufficiently large. Furthermore, the firms would tend to compete in lowering price rather than in ECSR investment if the market competition becomes fiercer.

III. Comparison of Price and Quantity Competition Equilibria

In this section, we first examine the impacts of firms' ECSR investments on their output and price decisions under quantity and price competition. Then we examine the impacts of competition modes on market and societal outcomes by comparing the equilibrium outputs, prices, ECSR investments, and consumer welfare between price and quantity competition.

Proposition 1:

The demand-expanding effect and demand-shifting effect of firm's ECSR investment under price competition are greater than those under quantity competition are.

Proposition 1 suggests that a firm's ECSR investment has a greater positive effect on its own output decision under price than that under quantity competition. Furthermore, its rival's investment in ECSR activities has a greater negative effect on its output decision under price than under quantity competition. In duality, Proposition 1 also suggests that a firm's ECSR investment has a greater positive effect on its price decision under quantity than that under price competition. However, the effects of its rival's investment in ECSR activities on its price decision are the same under quantity and price competition.

We now examine the impacts of competition modes on firms' decisions of output, price, and ECSR investment by comparing the equilibrium conditions under quantity and price competition. For the purpose of comparison, we assume that $\alpha^2 < (2+\gamma)^2(2-3\gamma+\gamma^2)/(2-\gamma^2)$. Note that this assumption satisfies the second-order stability conditions at both quantity and price competition equilibria.

By taking the differences of the equilibrium output, price, and ECSR investment between quantity and price competition, we obtain the following conditions: [4]

$$s_i^C - s_i^B > 0, \tag{36}$$

$$q_i^C - q_i^B < 0, \tag{37}$$

$$e_i^C - e_i^B < 0, \tag{38}$$

$$P_i^C - P_i^B > 0. \tag{39}$$

We summarize Eqs. (36)-(39) in Proposition 2.

Proposition 2:

Relative to the equilibrium conditions under price competition, the firms invest more in ECSR, produce fewer outputs, discharge less emission, and charge a higher price under quantity competition.

This result is similar to the result suggested by Singh and Vives (1984). In particular, firms have lower market power to raise price above marginal cost under price competition since the perceived elasticity of demand of a firm is greater than that under quantity competition. Therefore, Proposition 2 suggests that relative to the firms under quantity competition, the firms under price competition tend to compete with a lower price rather than a higher ECSR investment, even though the firms understand that their ECSR investments may increase product differentiation and soften the market competition. Consequently, it leads to the result that, relative to the equilibrium under quantity competition, firms tend to charge a lower price, invest less in ECSR, produce more outputs, and discharge more emission under price competition.

It can also be shown that, the more differentiated the products are, i.e., a lower γ, the smaller is the difference between the equilibrium outputs under quantity and price competition both increase. For example, with a large product differentiation between the products, each firm has a greater market power and acts as a monopolist of its product in the market. In this case, the equilibrium outputs and prices are similar under quantity and price competition. However, if the consumers perceive their products as being close substitutes, rather than investing more in ECSR, the firms under price competition tend to compete with a lower price, which may enlarge the output and price gaps between the equilibrium under quantity and price competition.

Finally, by taking the difference of the consumer surplus and environmental damage between quantity and price competition, we obtain the following relations:

$$CS^C - CS^B < 0, \tag{40}$$

$$ED^C - ED^B < 0. \tag{41}$$

Thus, we have the following proposition.

Proposition 3:

Relative to the equilibrium under price competition, while the consumer surplus is lower under quantity competition, the environmental damage is less serious under quantity competition as well.

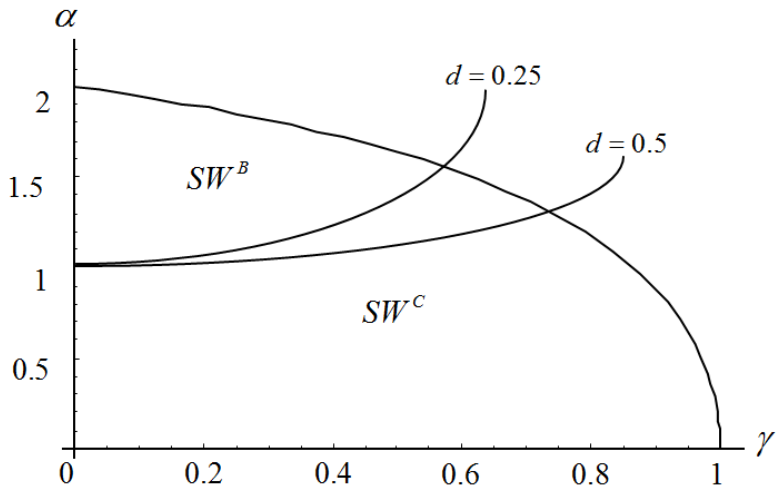
Proposition 3 suggests that there is a trade-off between environmental externalities (pollution) on the one hand and consumer surplus on the other. The trade-off between consumer surplus and environmental damage may explain the difference in social welfare under quantity and price competition. In particular, by comparing the social welfare under quantity and price competition, the following relations are held:

$$SW^C - SW^B \gtreqless 0 \quad if \quad d \gtreqless \frac{Y^B(\Delta^C)^2 - Y^C(\Delta^B)^2}{4[(X^B\Delta^C)^2 - (X^C\Delta^B)^2]}. \tag{42}$$

Note that $\Delta^C > \Delta^B > 0$, $X^B > X^C > 0$, and $Y^C > Y^B > 0$. Then, it can be shown that $SW^C - SW^B > 0$ if the marginal environmental damage is so large that the increment in consumer surplus due to additional output is smaller than the increment in environmental damage.

We use the following example to demonstrate the impact of consumers' preferences for the firms' investments in ECSR activities, the product differentiation between the goods, and the marginal environmental damage on social welfare ranking between quantity and price competition. Figure 1 illustrates the social welfare ranking between price and quantity competition when $d = 0.25$ and 0.5, respectively. Given the feasible regions satisfying the second-order stability

conditions, Figure 1 suggests that the closer substitutes the consumers perceive the two products, i.e., a higher γ, and/or the lower consumers' preference for the firms' investment in ECSR activities, i.e., a lower α, quantity competition will provide higher social welfare than price competition. Furthermore, as marginal environmental damage decreases, i.e., a lower d, the region of higher social welfare for price competition increases.



Data source: This study.

Figure 1. Welfare Ranking

IV. Conclusions

The well-known result in the literature of differentiated oligopoly competition that price rather than quantity competition delivers a greater amount of total output and higher social welfare may not hold when firms' production involves environmental damage. This paper examines firms' incentives in undertaking environmental friendly actions on pollution abatement as their ECSR investments. We find that, relative to the equilibrium outcome under price competition, (i) the

firms invest more in ECSR activities under quantity competition; (ii) the firms produce fewer outputs under quantity competition; (iii) the firms discharge less emission under quantity competition; and (iv) the firms charge a higher price under quantity competition.

Regarding the welfare measures, we find that, while consumer surplus is higher under price competition, environmental damage is more serious under price competition as well. That is, there is a trade-off between consumer surplus and environmental damage in generating social welfare in the industry. If the marginal environmental damage were too large, then social welfare under quantity competition would be higher than that under price competition.

In the analysis, we assume consumers' full information on firms' investments in environmental friendly actions, which provokes complete demand-shifting effect of consumers. However, it is important to investigate the issues related to the credible information disclosure mechanism regarding firms' ECSR investment. Manasakis, Mitrokostas, and Petrakis (2013; 2014) emphasize the importance of a credible information disclosure mechanism for a sustainable CSR related good market. In general, they find that CSR activities with a credible information disclosure system are welfare enhancing for consumers and firms and should be encouraged. Thus, the certification system of firms' ECSR activities, which is either certified by market force, public politics, and private politics, will play a significant role in understanding the dynamic process between firms' strategic ECSR incentives and consumers' preferences for firms' ECSR activities endogenously.

Furthermore, Manasakis, Mitrokostas, and Petrakis (2014) consider consumers' heterogeneous preferences for firms' CSR in a Hotelling world and suggest that the demand function each firm faces positively depends on consumers' expectation of firm i's CSR efforts as well as on the average type of consumer preferences for CSR. In this paper, we consider a representative consumer's preference for firms' ECSR only, and the type of consumer's preferences for firms' ECSR, i.e., α, can be

viewed as the average type of consumers' preferences for firms' ECSR in a Hotelling world. It would be interesting to investigate firms' incentives for ECSR investment when various distributions of consumer types are considered. These challenging topics should be future research.

Endnotes

1. Previous research on governmental regulation on environmental tax and permit systems provided the rationale for the second-best solution, depending upon the relative effects of distortions such as market power, excessive entry, vertical structure, and externality.
2. The second-order conditions for stability in the first stage is given by $\alpha^2 < (4-\gamma^2)^2/4$. This provides the interior solutions at quantity equilibrium.
3. The second-order stability conditions in the first stage is given by $\alpha^2 < (2+\gamma)^2(2-3\gamma+\gamma^2)/(2-\gamma^2)$. This provides the interior solutions in the price equilibrium.
4. Note that $\Delta^C \equiv (2+\gamma)(4-\gamma^2) - 2\alpha^2 > \Delta^B \equiv (1+\gamma)(2-\gamma)(4-\gamma^2) - \alpha^2(2-\gamma^2) > 0$.

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Appendix

Proof of Lemma 3

Let $\Delta^{C} \equiv (2+\gamma)(4-\gamma^2)-2\alpha^2$. It can be shown that $sign(\pi^{C}-\pi^{*}) = sign[(2+\gamma)^2(1-\gamma)-\alpha^2]$. In the quantity competition, if and only if $(2+\gamma)^2(1-\gamma)>\alpha^2$, the firms which engages in CSR activities would obtain greater profits. Note that this condition meets the second-order conditions for stability.

Proof of Lemma 6

Let $\Delta^{B} \equiv (1+\gamma)(2-\gamma)(4-\gamma^2)-\alpha^2(2-\gamma^2)$. It can be shown that $sign(\pi^{B}-\pi^{*}) = sign[(1+\gamma)(2-\gamma)^2(2-2\gamma-\gamma^2)-\alpha^2(2-\gamma^2)(1-\gamma)]$.

In the price competition, the firms which engages in CSR activities would obtain greater profits if and only if $2-2\gamma-\gamma^2>0$, i.e., $\gamma \in \left(0,\sqrt{3}-1\right)$, and $(1+\gamma)(2-\gamma)^2(2-2\gamma-\gamma^2)>\alpha^2(2-\gamma^2)(1-\gamma)$. However, from the second-order conditions for stability, we can rule out the latter condition.

Proof of Proposition 1

From Eq. (8) and (23) we compare the effect of CSR on the firm's choice of production in the quantity and price competition:

$$\frac{\partial q_i}{\partial s_i}|_{Cournot} - \frac{\partial q_i}{\partial s_i}|_{Bertrand} = \frac{-\alpha\gamma^2}{(1-\gamma^2)(4-\gamma^2)} < 0.$$

From Eq. (9) and (24) we compare the effect of CSR inputted by it's rival on the firm's choice of production in the quantity and price competition:

$$\frac{\partial q_i}{\partial s_j}|_{Cournot} - \frac{\partial q_i}{\partial s_j}|_{Bertrand} = \frac{\alpha\gamma^3}{(1-\gamma^2)(4-\gamma^2)} > 0.$$

From Eq. (8) and (25) we compare the effect of CSR on the firm's choice of price in the quantity and price competition:

$$\frac{\partial P_i}{\partial s_i}|_{Cournot} - \frac{\partial P_i}{\partial s_i}|_{Bertrand} = \frac{\alpha\gamma^2}{(4-\gamma^2)} > 0.$$

From Eq. (9) and (26) we compare the effect of CSR inputted by it's rival on the firm's choice of price in the quantity and price competition:

$$\frac{\partial P_i}{\partial s_j}|_{Cournot} - \frac{\partial P_i}{\partial s_j}|_{Bertrand} = 0.$$

環境企業社會責任於異質雙佔市場的經濟福利分析

劉志成*、Sang-Ho Lee**、王鳳生***

在污染產業中，相對於數量競爭而言，文獻上價格競爭導致較高的市場總產出與社會福利的結論將不必然成立。本文檢視污染產業中，數量與價格競爭環境對於廠商策略性履行環境企業社會責任的誘因與經濟福利的影響。研究結果指出，相對於價格競爭模式下的市場均衡，廠商在數量競爭模式下產量較低，價格較高，減污投入較多，污染排放較少。換言之，在價格競爭模式下，較高的產量雖然提升了消費者剩餘，較少的減污投入卻增加了環境污染損害。因此，權衡消費者剩餘與環境污染損害對於社會福利消長的影響，我們發現當污染造成的邊際損害過大的情況下，數量競爭模式下的社會福利將會高於價格競爭模式下的社會福利。

關鍵詞：環境企業社會責任、異質雙佔、消費者剩餘、社會福利

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