Environmental Corporate Social Responsibility and the Multi-product Firm

Chia-Chi Wang

Department of Business Management, Tatung University

40, *Sec.* 3, *Zhongshan N. Rd. Zhongshan District, Taipei City* 10452, *Taiwan*

Abstract

This paper considers a vertical related market to analyze the effect of implementing environmental corporate social responsibility (ECSR) for a multi-product firm. Assume that a downstream multi-product firm needs to buy key component from an upstream monopolist. There are some interesintg results. First, most previous studies mentioned that implementing ECSR is harmful for the firm's profit. However, we find that adopting ECSR may increase the multi-product firm's profit if the production causes the mild environmental damage. In other words, the multi-product firm may benefit from implementing ECSR. Secondly, the multi-product firm implementing ECSR may alleviate the problem of double marginalization. Lastly, if production causes the severe environmental damage, implementing ECSR can even obtain the triple-win (win-win-win) situation where the multi-product firm's total profit, the environmental quality and the social welfare are improved simultaneously.

Keyword: Multi-product firm, Environmental corporate social responsibility, Environmental quality

JEL: L11, L21, L22

1. Introduction

Firms producing diversified products are a markedly common phenomenon, particularly in high-tech industries. Bernard et al. (2010) collected data of more than 140,000 companies in the United States and analyzed them according to their five-digit industry codes. The results revealed that of the companies sampled, 39% produced diversified products, and the output of these companies accounted for 87% of the total output. Such results verify that firms producing diversified products are a common and current trend.

Apple Inc. is a famous multi-product manufacturer. Initially a manufacturer of personal computers, Apple Inc. shifted its business focus to consumer electronics in 2007, when it began producing hardware devices (e.g., iPhones, iPads, Apple TVs, and iWatches) and software systems (e.g., iOS and macOS) in addition to Mac computers. Furthermore, Apple has elevated its software and hardware development capabilities to meet the needs and positioning of its products. Other internationally renowned conglomerates that have engaged in product diversification include Samsung, LG Corporation, Asus, Sony, and Lenovo. Outside the electronics industry, Dyson, a British company nicknamed the "Apple Inc. of the home appliance industry," is a representative firm of product diversification. Dyson rose to fame because of its research and development and production of cyclonic vacuum cleaners. The company's small but powerful digital motors render its products light yet highly efficient. Dyson has subsequently developed other innovative products that use digital motors, including bladeless fans and hair dryers.

By observing these famous multi-product firms, there are some important features. First, the products manufactured by these firms generally need the same intermediate goods; for instance, smartphones and notebook computers use Samsung's dynamic random-access memory components and Dialog Semiconductor's

power management integrated circuits. Similarly, Dyson uses the aforementioned digital motors, which are smaller, lighter, and quieter than conventional motors, for its cleaners, hair dryers, and fans; such a practice has enabled the company to occupy a dominant position in the home appliance industry. [1]

The second feature is that these companies all pay attention to and exercise corporate social responsibility (CSR). According to a survey of the world's largest 250 firms conducted by KPMG in 2013, 59% of these firms adopted CSR. The Global Reporting Initiative divides CSR into three aspects, namely the environment, economy, and society. In recent years, countries worldwide have paid increasing attention to environmental-protection-related topics, particularly global climate change and energy resource depletion, both of which have a direct impact on environmental ecology and firms' sustainable development. Accordingly, international requirements and regulations on national environmental quality have become increasingly stringent.[2] Because of this emphasis on environmental protection, environmental CSR (ECSR) is now highly valued and commonly practiced by firms. [3]

This paper considers a theoretical model to answer the following questions. Implementation of CSR, especially environment-oriented CSR, by firms is generally regarded as firms engaging in charitable activities to benefit others at the expense of

[1] In the automotive industry, using the same intermediate goods is also common; for example, manufacturers of electric cars (e.g., Tesla and BMW), hybrid vehicles (e.g., Toyota and Lexus), and gasoline and diesel-powered vehicles (e.g., General Motors and Ford) all use components produced by Delphi and Bosch.

[2] At COP 21 in December 2015, all 195 participating countries signed the Paris Agreement, thereby agreeing to the long-term goal of controlling the average global temperature increase to within 1.5℃ for the remainder of this century, and to developed countries providing US$100 billion each year to help developing countries promote climate action.

[3] For instance, Taiwan Semiconductor Manufacturing Company Limited subscribes to green power to reduce carbon emissions and participates in tree conservation and afforestation projects; Alibaba Group supports green value trends by building energy-saving data centers; Asus promotes various energy conservation, environmental protection, green innovation, and zero landfill projects; and Sony exemplified extended producer responsibility by introducing the Sony Green Partner Program in 2003, where the company's partners were asked to collaborate in producing environmentally friendly products. These examples demonstrate the attention that many firms pay to ECSR.

their own profits. To incentivize firms to implement ECSR, governments typically offer subsidies or formulate relevant regulations in the initial stage.[4] We are curious about whether firms implement ECSR only because of government requirement or social pressure, or is it possible that firms adopt ECSR voluntarily? In other words, can firms increase their profits by adopting ECSR? Is it possible that firms use ECSR as a key strategy to elevate their competitiveness, generate profit, protect environmental quality, and benefit society, thereby creating a win-win-win situation for the economy, environment, and society and realizing the goal of sustainable development?

Studies on CSR theory have indicated that because firms are concerned with a variety of CSR dimensions, the objective functions that they use also vary. CSR is most commonly divided into two categories, namely consumer friendly initiative CSR and environmental CSR (ECSR). The related studies on consumer friendly initiative CSR have assumed that the primary goals of firms are to maximize profits and ensure consumer well-being. Therefore, firms' objective functions include profits and consumer surplus (Wang et al., 2012; Goering, 2012, 2013; Chang et al., 2014).

ECSR-related studies have indicated that firms' objective functions include profit and environmental quality, and thus reducing environmental pollution is within the firms' consideration. Lambertini and Tampieri (2015) presented a scenario of a market where one firm that adopted CSR and several other firms that pursued profit maximization are engaged in quantity competition. They assume that the firm can

[4] In 2014, Taiwan's Financial Supervisory Commission demanded that listed and over-the-counter firms in the food industry, financial industry, and chemical industry or those with paid-up capital of NT$10 billion or more prepare CSR reports. By 2016, the paid-up capital requirement was lowered to NT$5 billion. Many organizations have subsequently organized Best CSR Practice events, where awards are offered to encourage firms to engage in CSR. For example, the National Development Council has hosted the annual National Sustainable Development Award since 2004; the Bureau of Foreign Trade has hosted the Taiwan Green Classics Award; the Industrial Development Bureau has hosted Green Factory Certification events, and the Environmental Protection Administration has issued ratings such as the Carbon Reduction Action Award.

adopt environmental CSR and consumer friendly initiative CSR simultaneously and observe that if the CSR-engaging firm engages only in ECSR, it generates a profit lower than those of the other firms. Nevertheless, if the market becomes sufficiently large and the CSR-engaging firm engages in ECSR and consumer friendly initiative CSR, that firm generates a profit higher than those of the other firms.

Liu et al. (2015) introduced a scenario where a nongovernmental certifier sets an ECSR standard and verifies the achievements of firms. They analyzed how the different types of competitions affect the incentive firms in adopting ECSR. The results showed that the environmental standards set by the certification organization under Cournot competition were higher than under Bertrand competition. Lambertini et al. (2016) constructed a Ramsey model and assumed that firms emit pollutant during production. The results indicated that if the market becomes sufficiently large, the production output, accumulated capital, and profits of firms that engage in both ECSR and CFI-based CSR are higher than those of firms seeking only profit maximization.

The above studies show that CSR has been widely discussed in recent years. However, most of these studies have focused on consumer friendly initiative CSR, whereas few have focused on ECSR. In addition, all of the aforementioned studies conducted analyses under horizontal market structures. Furthermore, the above studies have all conducted analyses and discussions under the assumption that each firm produces only one product.

Studies on the topic of multi-product can primarily be divided into two categories The first category involves strategy analysis of multi-product firms in horizontal markets (Bailey and Friedlaender, 1982; Bulow et al., 1985; Witteloostuijn and Wegberg, 1992; Johnson and Myatt, 2003; Eckel and Nearly, 2010; Bernard et al., 2011; Kawasaki et al., 2014), whereas the second category involves strategy analysis in vertical markets (Arya and Mittendorf, 2010; Kopel et al., 2016).

Studies in the first category outnumber those in the second category and explore optimal output decisions of multi-product firms (to be made by firms with diversified products) from various perspectives, including the demand perspective (Eckel and Nearly, 2010) and supply perspective. Firms with diversified products have a cost advantage over those with only one product (Bailey and Friedlaender, 1982). In the first category, aspects such as competition type (Bulow et al., 1985), strategic effects between firms (Bernard et al., 2011), and the entry of potential firms (Witteloostuijn and Wegberg, 1992; Johnson and Myatt, 2003; Kawasaki et al., 2014) are used to examine firms' optimal decisions.

Although studies in the second category that consider vertical markets are critical, they are relatively few in number. Arya and Mittendorf (2010) created a vertical market structure where a supplier monopolizes the upstream market and a multi-product firm that produces products A and B in downstream market. The multi-product firm engages in a Cournot competition with another firm in market A and monopolizes the market B. They revealed that for a firm with diversified products, the discrimination pricing of a supplier may create social welfare of a higher level than that created using uniform pricing. Kopel et al. (2016) constructed a successive monopoly model that enables the downstream market exist a multi-input-multi-output firm to examine the outsourcing decisions made by a firm. The results indicated that firms may have their intermediate goods manufactured by outside firms even if the outsourcing cost is higher than the cost of manufacturing the intermediate goods on their own. In addition, the results revealed that a higher degree of competition in the intermediate goods market diminishes the profits of the downstream firm.

The above discussion shows that despite many studies having investigated the multi-product firms' strategies and decisions, most of the discussions concerned the horizontal market structures. Because vertical related model (where professional

division of labor is practiced) are a common market structure observed in various industries and implementation of CSR is common among multi-product firms, the effects of ECSR implementation on multi-product firms' decisions warrant further exploration. We assume that there is a multi-product firm who may adopt ECSR and produce product A in polluting industry and produce product B in non-polluting industry. Both of products A and B need a key component which buys from a monopoly upstream firm. We find some interesting results which are very different with that of the setting of single-product firm.

The remainder of this paper proceeds as follows. The following section presents the model. Section3 provides analyses of the output decisions of multi-product firm and input price decision of intermediate firm. Section 4 investigates the impact of implementing ECSR on the equilibrium outcomes by compare the equilibrium results with and without implementing ECSR. Section 5 provides some concluding remarks.

2. The model

This paper considers a vertical related structure. The downstream market exists a multi-product firm (firm h) who produces two independent products, A and B.[5] Note that product A is the polluting industry and product B is non-polluting industry. The inverse demand function is $p_i(q_i)$, $i = A, B$, where p_i and q_i is the price and output of market i, respectively. Assume that $p_{i'}(q_i) < 0$, and that the following condition holds for all $q_i > 0$.

The marginal cost of product i is z_i, $i = A, B$. Producing one unit of final goods needs one unit of intermediate goods. The intermediate firm (firm 1) sets the input price as w_1 and suffers a constant marginal cost of c_1 for producing intermediate goods.

[5] We assume that the firm sell each of the two final products, A and B, as a monopolist on two independent market to rule out strategic effect on the downstream market and focus on the effect of adopting ECSR.

According to the setting above, the downstream multi-product firm's profit function in market *i* can be represented as:

$$\pi_i(q_i,w_1) = [p_i(q_i) - z_i - w_1]q_i, \ i = A, \ B. \tag{1}$$

The upstream firm's profit function can be shown as:

$$\pi_1(w_1) = (w_1 - c_1)[q_A + q_B]. \tag{2}$$

Because product A is the polluting industry and product B is non-polluting industry, the process of producing product A generates pollutant. One unit of product emits one unit of pollutant. Let $D(E)$ be the environmental damage function, where E is the total pollution emission of industry A. The marginal environmental damage is represented as $D'(E) = \phi, \ \phi > 0$.

The downstream multi-product firm may implement Environmental Corporate Social Responsibility (ECSR). If the multi-product firm implements ECSR, then it cares about not only its profits in markets A and B, but also the environmental quality. Therefore, the objective function of this multi-product firm is the sum of the two markets' profits and minus the environmental damage. This paper follows the setting of ECSR in Lambertini and Tampieri (2015) and Lambertini et al. (2016). They assume that the type of ECSR is altruistic form of CSR, which means that the firm would decrease the output to obtain the goal of reducing emissions.[6]

According to the setting above, the objective function of the downstream

[6] Geoffrey P. Lantos indicates that there are three forms of corporate social responsibility, altruistic form, strategic form and ethical form. The enterprises can use different way to decrease the pollutant emission. If the enterprises decrease the pollutant emission by decreasing the output, then we called it as altruistic form of CSR. If the enterprises reduce the pollutant emission by adopting green technology, then we called it as strategic form of CSR.

multi-product firm can be shown as

$$\Omega_h(q_A, q_B, w_1) = \pi_A(q_A, w_1) - \alpha D(E(q_A, w_1)) + \pi_B(q_B, w_1), \quad (3)$$

where α is the degree of ECSR for the multi-product firm, $\alpha \in [0,1]$. A value of α shows the importance of ECSR. The multi-product firm cares more about the environmental quality if the value of α is higher. If $\alpha = 0$, then the multi-product firm is a pure profit-maximizing firm who does not adopt ECSR.

This paper establishes a two stages game to analyze the effect of implementing ECSR for the downstream multi-product firm on equilibrium outcomes. In stage 1, the upstream firm maximizes profit to determine its optimal input price. In stage 2, given the input price, the downstream multi-product firm decides its optimal outputs in markets A and B respectively. We use backward induction to obtain the subgame perfect equilibrium.

3. Outputs of multi-market and optimal input price

In stage 2, we analyze the multi-product firm's output equilibrium. The multi-product firm maximizes its objective function by choosing q_A and q_B, respectively. The first-order conditions (FOCs) are:

$$\frac{d\Omega(q_A,q_B;w_1)}{dq_A} = p_A + p_A' q_A - z_A - \alpha D'(E) - w_1 = 0,$$
$$\frac{d\Omega(q_A,q_B;w_1)}{dq_B} = p_B + p_B' q_B - z_B - w_1 = 0.$$

Rearranging the above equations, the optimal outputs are determined by the

conditions that marginal benefit is equal to marginal cost.

$$p_A + p'_A q_A = z_A + \alpha D'(E) + w_1, \tag{4}$$

$$p_B + p'_B q_B = z_B + w_1. \tag{5}$$

From (4), we can find that the output of market A is not only affected by the costs of production and input factor but also by the degree of ECSR (α). A higher degree of ECSR (or a higher degree of marginal environmental damage) leads to a greater incentive for the multi-product firm to reduce the output of market A. By observing (5), the output of market B is only affected by its production cost and input price. According to (4) and (5), we can obtain the equilibrium outputs of two market as $q_A(w_1)$ and $q_B(w_1)$. The impacts of input price on the equilibrium outputs of two markets are $dq_A/dw_1 < 0$ and $dq_B/dw_1 < 0$, respectively. In addition, both of the degree of ECSR (α) and the marginal environmental damage (ϕ) have negative effects on q_A i.e., $dq_A/d\alpha = -D'(E) < 0$ and $dq_A/d\phi = -\alpha < 0$. However, the output of market B is not affected by the degree of ECSR and the marginal environmental damage, i.e., $dq_B/d\alpha = 0$ and $dq_B/d\phi = 0$.

Now, we go back to stage 1 to analyze the optimal input price of the upstream firm. Regarding the upstream firm that provides intermediate goods to the multi-product firm, the optimal input price is no longer determined solely based on a single product market. This is because when the derived demand for a product decreases, the upstream firm has an incentive to lower the price of said product to increase sales; however, this signifies that the upstream firm must also lower the product price in another market, thereby creating an unfavorable situation for the upstream firm. Therefore, for suppliers, optimal intermediate goods prices must be

determined when dealing with firms with diversified products that engage in ECSR.

The FOC on deciding the input price for the upstream firm when it faces the multi-product downstream firm is:

$$\frac{d\pi_1(w_1;\alpha)}{dw_1} = \overbrace{q_A(w_1,\alpha)+q_B(w_1)+w_1\left(\frac{dq_A(w_1,\alpha)}{dw_1}+\frac{dq_B(w_1)}{dw_1}\right)}^{\text{MR}} - \overbrace{c_1\left(\frac{dq_A(w_1,\alpha)}{dw_1}+\frac{dq_B(w_1)}{dw_1}\right)}^{\text{MC}} = 0 . \quad (6)$$

The first curly brace is marginal revenue and the second one is marginal cost. From (4) and (5), we know that a higher input price leads to a lower level of final goods, i.e. $dq_A/dw_1 < 0$, $dq_B/dw_1 < 0$. In addition, the input price is affected by the derived demands of both market A and B. Therefore, if one of the downstream market sizes is greater, then the input price is higher.

We are curious about that how the optimal input price affected by the implementing ECSR for the downstream firm. According to (6), we find that a higher degree of ECSR leads to a lower input price, i.e., $dw_1/d\alpha = -D'(E) < 0$. This is because a higher degree of ECSR results in a lower output level of product A, and thus reduces the derived demand of intermediate goods. This effect gives an incentive for the upstream firm to decrease the input price. In addition, the impact of implementing ECSR on the upstream firm's profit is

$$\frac{d\pi_1}{d\alpha} = \frac{\partial\pi_1}{\partial\alpha}+\frac{\partial\pi_1}{\partial w_1}\frac{\partial w_1}{\partial\alpha} = (w_1-c_1)\left(\frac{dq_A}{d\alpha}+\frac{dq_B}{d\alpha}\right)+\frac{dw_1}{d\alpha}\left(q_A+q_B\right) < 0 .$$

Therefore, implementing ECSR by the downstream firm harms the upstream firm's profit.

Lastly, to understand the concern of the multi-product firm when it implements ECSR, we use (7) below to shows the effect of the degree of ECSR on the multi-product firm's objective function, i.e.

$$\frac{d\Omega}{d\alpha} = \underbrace{\frac{\partial \Omega}{\partial \alpha}}_{\text{Direct effect}} + \underbrace{\frac{\partial \Omega}{\partial w_1}\frac{\partial w_1}{\partial \alpha}}_{\text{Indirect effect}} = \underbrace{-D'(E)q_A(w_1;\alpha,\phi) - q_A(w_1;\alpha,\phi)\frac{\partial w_1}{\partial \alpha}}_{\text{Net effect for market A}} \underbrace{- q_B(w_1)\frac{\partial w_1}{\partial \alpha}}_{\text{Net effect for market B}}. \quad (7)$$

(7)

The effect of α on the objective function of firm *h* can be divided by direct effect and indirect effect. An increase in α means that firm *h* more cares about the environmental quality and thus has an incentive to decrease the output of market A, which can be shown in direct effect, i.e., $-D'(E)q_A(w_1;\alpha) < 0$. However, implementing ECSR also affects firm *h*'s profit by the channel of the input price. A rise in α leads to a lower level of w_1, it benefits the profits both in market A and market B. On the contrary, if an increase in α leads to a higher level of w_1, then it is harmful for the multi-product firm's profit.

4. Comparison

In order to realize the effect of implementing ECSR on the input price and the final markets' profits, we provide an explicit function to explain more clearly. Assume that the inverse demand of market A and B are $p_A = a - q_A$ and $p_B = b - q_B$, respectively. The marginal cost for the multi-product firm to produce product *i* is constant z_i, $i = A, B$. Let the market efficient scale is $A \equiv a - z_A$ and $B \equiv b - z_B$. Note that environmental damage function is $D(E) = \phi q_A$, where ϕ is marginal environmental damage.

According to (4) and (5), the optimal outputs of the two final markets can be shown as $q_A = (A - \alpha\phi - w_1)/2$ and $q_B = (B - w_1)/2$, respectively. By substituting q_A and q_B into the upstream firm's profit and taking a derivative with respective to w_1, we obtain the optima input price from FOCs as:

$$w_1 = \frac{A + B - \alpha\phi + 2c_1}{4}. \tag{8}$$

The impact of the degree of ECSR on the input price is negative, i.e. $\partial w_1 / \partial \alpha < 0$. In addition, the input price increases with the market size no matter market A or B. By substituting w_1 into the outputs and profits of the multi-product firm, the equilibrium outputs and profits in the two final markets are

$$q_A = \frac{1}{8}(3A - B - 3\alpha\phi - 2c_1), \quad q_B = \frac{1}{8}(3B - A + \alpha\phi - 2c_1), \tag{9}$$

$$\pi_A = \frac{1}{64}(3A - B + 5\alpha\phi - 2c_1)(3A - B - 3\alpha\phi - 2c_1), \tag{10}$$

$$\pi_B = \frac{1}{64}(3B - A + \alpha\phi - 2c_1)^2, \tag{11}$$

where the non-negative output condition is $\alpha\phi < (3A - B - 2c_1)/3 \equiv \bar{\phi}$.

Now, we discuss the impact of adopting ECSR on the price of intermediate goods. We consider two extreme cases: the multi-product firm does not adopt ECSR ($\alpha = 0$), the multi-product firm adopts ECSR and gives the same weight on its profit and environmental damage ($\alpha = 1$). To simplify, we assume that the marginal cost of the multi-product firm is zero.[7] The difference of the input price between with and without implementing ECSR is

$$w_1^C - w_1^N = -\frac{\phi}{4} < 0. \tag{12}$$

The superscript of C represents the equilibrium under implementing ECSR ($\alpha = 1$); N

[7] This assumption only has quantitative changes but does not have qualitative changes.

represents the equilibrium under no adopting ECSR (α = 0).The negative sign of above equation means that the multi-product firm adopting ECSR reduces the input price. Moreover, if the production of the polluting industry causes a severer of environmental damage, then the input price with adopting ECSR reduces more. The differences of the two markets prices between with and without implementing ECSR are respectively

$$p_A^C - p_A^N = \frac{3\phi}{8} > 0, \qquad p_B^C - p_B^N = -\frac{\phi}{8} < 0. \tag{13}$$

Eq. (13) shows that adopting ECSR results in a higher price of product A which in the polluting industry and a lower price of product B which in the non-polluting industry. In other words, the double marginalization problem of non-polluting industry can be alleviated if the multi-product firm adopts ECSR. The above result is summarized in Proposition 1.

Proposition 1 *Implementing ECSR by the downstream multi-product firm can lead to a lower input price. In addition, the double marginalization problem of non-polluting industry can be alleviated by implementing ECSR.*

Next, we discuss the impact of implementing ECSR on the multi-product firm's profit. From (8), we know that an increase in the degree of ECSR reduces the input price which benefits the profits of the two final markets. Nevertheless, eq. (9) shows that a rise in the degree of concerning ECSR also reduce the output of product A (because of caring about the environmental damage), which has a negative effect on the profit of market A. Hence, the impact of implementing ECSR on the total profit of the

multi-product firm is ambiguous. Is it possible that implementing ECSR obtains the win-win situation where both of the multi-product firm's total profit and the environmental quality improve?

Comparing the multi-product firm's profit under α = 0 with that under α =1, the difference of profits between the implementing and not implementing ECSR can be summarized as follows:

$$\pi_A^C - \pi_A^N = \frac{\phi}{32}\left(3A - B - 15\phi - 2c_1\right) > (<)0, \quad if \ \ \phi < (>)\phi_A, \qquad (14)$$

$$\pi_B^C - \pi_B^N = \frac{\phi}{64}\left(6B - 2A + \phi - 4c_1\right) > 0. \qquad (15)$$

From (14) and (15), we find an interesting result. In the previous studies on the issue of CSR, implementing ECSR will reduce the firm's profit. Hence the profit-maximizing firm has no incentive to adopt ECSR.[9] However, we find that implementing ECSR of the multi-product firm may not reduce its profit and may even increase its profit. Specifically, if the marginal environmental damage is not high, i.e. $\phi < \phi_A \equiv (6A - 2B - 4c_1)/15$, implementing ECSR increases the profit of market A for the multi-product firm. In addition, implementing ECSR always benefits the profit of market B no matter the degree of marginal environmental damage.

To investigate the impact of implementing ECSR on the total profit of the multi-product firm, we summarize (14) and (15). The difference of the total profit for the multi-product firm between implementing and not implementing ECSR is

$$\left(\pi_A^C + \pi_B^C\right) - \left(\pi_A^N + \pi_B^N\right) = \frac{\phi}{32}\left(2A + 2B - 7\phi - 4c_1\right) > (<)0, \quad if \ \ \phi < (>)\ \hat{\phi}. \ (16)$$

[9] See Lambertini and Tampieri (2015).

Eq. (16) shows that if the marginal environmental damage is not sufficiently high ($\phi < \hat{\phi} \equiv (2A + 2B - 4c_1)/7$), adopting ECSR will increase the total profit of the multi-product firm.

We use Figure 1 (a)-(c) to show the impact of adopting ECSR on the profits of market A, B and total market. From Figure 1, we find that adopting ECSR always benefits the profit of market B but has ambiguous impact on the profit of market A. If the degree of marginal environmental damage is not sufficiently high ($\phi < \hat{\phi}$), then the multi-product firm can benefit from adopting ECSR.

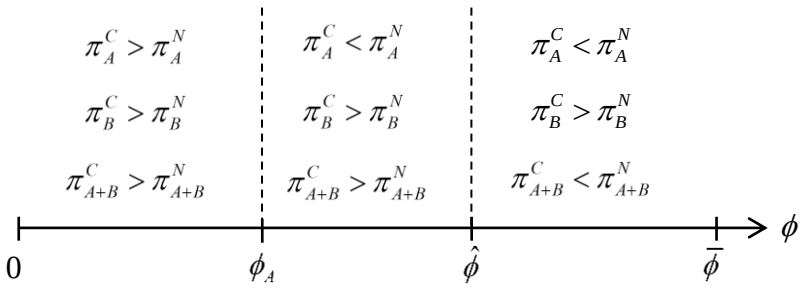

Figure 1. The impact of adopting ECSR on the profits of the multi-product firm in closed economy

The above result is summarized in Proposition 2.

Proposition 2 *If production causes mild environmental damage ($\phi < \hat{\phi}$), then total profits of the multi-product firm increases by implementing ECSR.*

The intuition of Proposition 2 is as follows. There are two effects of implementing ECSR on the multi-product firm's total profit: ECSR effect and vertical market effect. The multi-product firm who adopting ECSR cares about the environmental damage, so

it reduces the output of market A (polluting industry).This is called ECSR effect which has a negative effect on the multi-product firm's total profit. On the other hand, implementing ECSR also reduces the derived demand of intermediate goods, so the upstream firm decreases the input price which benefits the multi-product firm's profit of both market A and B. This is called vertical market effect which has a positive effect on the multi-product firm's total profit.

If the degree of marginal environmental damage is not sufficiently high ($0 < \phi < \phi_A$), the vertical market effect is greater than the ECSR effect. Therefore, both the profits of market A and B can increase by implementing ECSR. However, a magnitude of negative ECSR effect increases with the degree of marginal environmental damage. When $\phi > \phi_A$, the ECSR effect dominates the vertical market effect, and thus the profit of market A reduces by adopting ECSR. Because the profit of market B always benefits from adopting ECSR, the total profit can be arise if production does not cause severe environmental damage.

Whether implementing ECSR can enhance environmental quality successful is the important concern for the government. Hence we show the difference of the amount of pollutant between with and without adopting ECSR as follows:

$$D(E)^C - D(E)^N = -\frac{3\phi^2}{8} < 0. \tag{17}$$

The negative sign of (17) means that the environmental quality indeed improves by implementing ECSR.

From the discussion above, we know that implementing ECSR may obtain the win-win situation where the environmental quality and the multi-product firm's profit improve simultaneously.

Next, we want to know that does implementing ECSR also possible benefit for both consumer and social welfare. Since there are two group of consumer in final market, the consumer surplus should be the sum of two markets' consumer surplus, i.e. $CS \equiv CS_A + CS_B$. By comparing the two levels of consumer surplus with and without adopting ECSR, the difference of two levels of consumer surplus is

$$CS^C - CS^N = \frac{\phi}{64}(-10A + 6B + 5\phi + 4c_1) > (<)0, \quad if\ \phi > (<)\phi^{cs}, \qquad (18)$$

where $\phi^{cs} \equiv 2A - B - (4/5)c_1$. Comparing the critical values of ϕ^{cs} and the non-negative output condition $\bar{\phi}$, we find that $\phi^{cs} > (<)\bar{\phi}$ if $A - (2/3)B - (6/15)C_1 > (<)0$. It implies that if the market size of market B is greater, then the consumer surplus with implementing ECSR is more likely higher than that without implementing ECSR.

Now, we analyze the effect of adopting ECSR on social welfare. The social welfare is the sum of the multi-product firm's total profit and two markets' consumer surplus minus the environmental damage, which is

$$SW = \pi_A + \pi_B + CS_A + CS_B - D(E) .$$

Similarly, comparing the levels of social welfare with and without implementing ECSR, we can obtain the difference of two values of social welfare as:

$$\Delta SW \equiv SW^{CSR} - SW^{NCSR} = \frac{\phi}{64}(-14A + 2B + 19\phi + 12c_1) . \qquad (19)$$

We find that if the marginal environmental damage is sufficiently high, then the social

welfare can be improved when the multi-product firm adopts ECSR. In addition, we find that the market size is also an important factor which influences the social welfare. Therefore, we use Figure 2 to find the relationship among the two market sizes and the difference of social welfares with and without implementing ECSR. According to (9), the non-negative output condition of q_A and q_B are $3A-B-3\alpha\phi-2c_1\geq 0$ and $3B-A+\phi-2c_1\geq 0$, respectively.

The dash lines in Figure 2 are the zero-output conditions, so the reasonable range for non-negative output is the gray area. The solid line in Figure 2 creates two situations. The area of LHS (RHS) for the solid line is ΔSW > (<) 0, which means that the social welfare level with implementing ECSR is higher (lower) than that without implementing ECSR. Because the reasonable range for non-negative output is gray area, we find that implementing ECSR may obtain a higher social welfare than the case without implementing ECSR if the size of market B is relatively high.

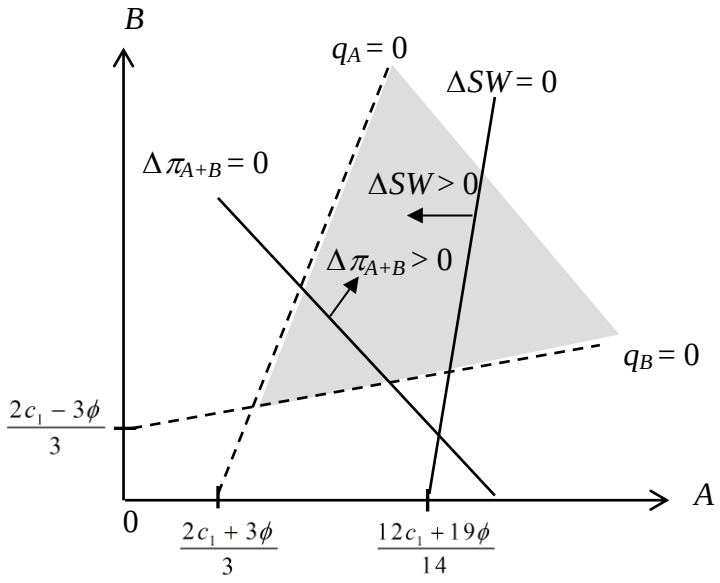

Figure 2 The difference of social welfare levels between with and without implementing ECSR

From the results of Figure 1, 2 and (17), we can obtain Proposition 3 as follows.

Proposition 3 *If production causes the severe environmental damage or the size of market B is the relatively high, implementing ECSR can obtain the triple-win (win-win-win) situation where the multi-product firm's total profit, the environmental quality and the social welfare improve simultaneously.*

The intuition is as follows. Implementing ECSR gives the multi-product downstream firm an incentive to reduce the output and leads to a lower input price which definitely increases market B's profit and consumer surplus. The market A's profit and consumer surplus also may be increased if environmental damage is mild. Meanwhile, the environmental quality always be improved by implementing ECSR. These give the positive effects on social welfare. However, the upstream firm's profit with implementing ECSR decreases which has a negative effect on social welfare. According to the discussion above, we know that if the environmental damage is severe, then the environmental improvement effect is stronger. Therefore, the social welfare will be improve. Similarly, if the size of market B is relatively high, then the increment of the profit and consumer surplus of market B is large. Thus, the social welfare will increase. To sum up, adopting ECSR is possible to obtain a higher total profit of the multi-product firm, social welfare and a better environmental quality, which is the triple-win (win-win-win) situation.

5. Discussion

In reality, the firm usually needs to compete with the foreign competitors because of thriving international trade. Therefore, this section establishes an open economy to discuss whether the multi-product firm can still benefit from implementing ECSR.

Assume that there is a domestic and a foreign firm, which are denoted by firm *h* and firm *f*, in the market. The domestic firm (firm *h*) is a multi-product firm who

produces product A and B. Firm *f* only produces product A and competes with firm *h* in market A. The final output and the marginal production cost of firm *f* denoted by q_f and c_f. One unit of final output requires one unit of input which produced by the foreign upstream firm (firm 2). Firm 2 sets the input price as w_2 and suffer a per unit cost c_2.

The two stage game establishes as follows. In stage 1, the two upstream firms decide the optimal price to maximize their profits. In stage 2, given the input price, two downstream firms engage in Cournot competition in market A. Meanwhile, firm *h* chooses a monopolistic output in market B. we use backward induction to obtain the subgame perfect equilibrium. In order to make it more clarify, we show the market structure and game stages in Figure 3.

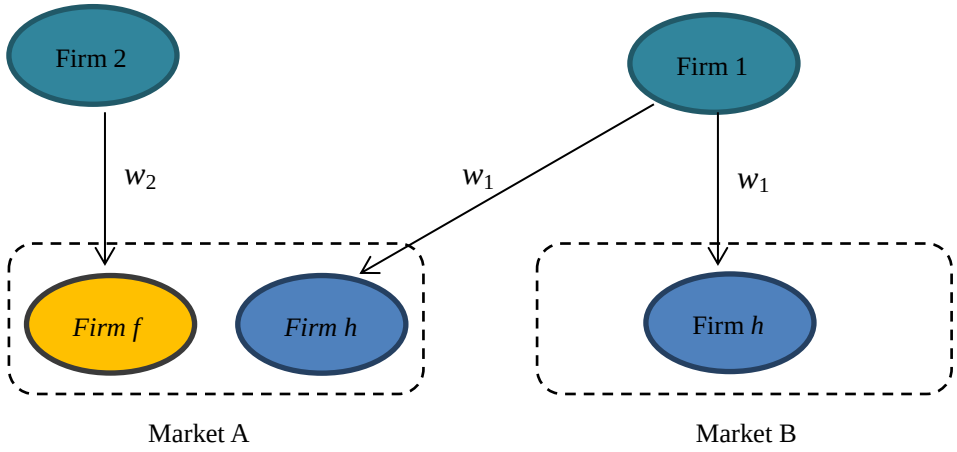

Figure 3 The market structure of open economy

From above setting, the two downstream firms' and the two upstream firms' profits can be shown as:

$$\Omega_h(q_A, q_f, q_B, w_1, w_2) = \pi_A(q_A, q_f, w_1, w_2) - \alpha D(E(q_A, q_f, w_1, w_2)) + \pi_B(q_B, w_1, w_2), \quad (20)$$

$$\pi_f(q_A, q_f, w_1, w_2) = \left[p_A(q_A, q_f, w_1, w_2) - c_f - w_2 \right] q_f, \quad (21)$$

$$\pi_1(w_1, w_2) = (w_1 - c_1)\left[q_A(w_1, w_2) + q_B(w_1, w_2)\right], \tag{22}$$

$$\pi_2(w_1, w_2) = (w_2 - c_2)\, q_f(w_1, w_2), \tag{23}$$

It is worth to note that we adopt the setting of ECSR as Lambertini and Tampieri (2015) who assume that the firm who implements ECSR only concerns about the pollutant which generates by itself and does not care about the pollutant which generate by others. Therefore, the damage function for the multi-product firm who implementing ECSR is $D(E)=\phi q_A$.[10] Note that the pollutant generates in the process of producing. Firm f produces the output in its own country and exports to the market A in domestic country. To focus on the effect of competitiveness on the multi-product firm's profit with ECSR, we assume that there is no cross border pollution.

In order to compare the results in open economy with that in closed economy, we adopt the same explicit form. Note that the inverse demand function in market A now is $p_A = a - q_A - q_f$. In addition, we assume that the production cost of the downstream firm is zero for simplify.[11]

From (20) and (21), maximizing the two downstream firms' profit function can obtain the equilibrium outputs: $q_A = (A - 2\alpha\phi d - 2w_1 + w_2)/3$, $q_f = (A - 2w_2 - w_1 + \alpha\phi d)/3$, $q_B = (B - w_1)/2$. Substituting the equilibrium outputs into (17) and (18) and differencing them, the equilibrium input prices are:

$$w_1 = \frac{5A + 6B - 7\alpha\phi + 7c_1 + 2c_2}{27}, \tag{24}$$

$$w_2 = \frac{16A + 3B + 10\alpha\phi + 7c_1 + 28c_2}{54}. \tag{25}$$

Comparing to the equilibrium input price without ECSR ($\alpha = 0$), we find that the

[10] This is because the firm who implements ECSR can decide its output level and so as the pollutant level. However, it cannot decide its rival's output and pollutant levels.

[11] The result only has quantitative changes does not has qualitative changes.

multi-product firm who implementing ECSR ($\alpha > 0$) faces a lower input price and its rival even suffers a higher input price. This benefit gives the downstream firm more incentive to become a firm who cares about ECSR.

From (24) and (25), the equilibrium outputs, profits of two downstream firms are

$$q_A = \frac{50A - 21B - 70\alpha\phi - 49c_1 + 20c_2}{162}, \quad q_B = \frac{21B - 5A + 7\alpha\phi - 14c_1 - 2c_2}{54},$$

$$q_f = \frac{16A + 3B + 10\alpha\phi + 7c_1 - 26c_2}{81},$$

$$\pi_A = \frac{(50A - 21B + 92\alpha\phi - 49c_1 + 20c_2)(50A - 21B - 70\alpha\phi - 49c_1 + 20c_2)}{26244},$$

$$\pi_B = \frac{(5A - 21B - 7\alpha\phi + 14c_1 + 2c_2)^2}{2916},$$

$$\pi_f = \frac{(16A + 3B - 10\alpha\phi + 7c_1 - 26c_2)^2}{6561}.$$

Note that the non-negative output condition requires: $\alpha\phi < (50A - 21B - 49c_1 + 20c_2)/162 \equiv \bar{\phi}'$. Now, we attempt to analyze how the intense of competitiveness affects the benefit of the multi-product firm who adopts ECSR. To compare with the results in monopoly case, we consider the two extreme situations: the multi-product firm does not adopt ECSR ($\alpha = 0$), and the multi-product firm very cares about ECSR and gives the same weight on its profit and ECSR ($\alpha = 1$).

The superscript of NCSR (CSR) represents the case of $\alpha = 0$ ($\alpha = 1$). The difference of the profits for the multi-product firm between implementing and not implementing ECSR are

$$\pi_A^{CSR} - \pi_A^{NCSR} = \frac{\phi}{13122}(550A - 231B - 3220\phi - 539c_1 + 220c_2) > (<)0, \quad if \quad \phi < (>)\phi_A' \quad (21)$$

$$\pi_B^{CSR} - \pi_B^{NCSR} = \frac{7\phi}{2916}(42B - 10A + 7\phi - 28c_1 - 4c_2) > 0 \quad (22)$$

$$\left(\pi_A^{CSR}+\pi_B^{CSR}\right)-\left(\pi_A^{NCSR}+\pi_B^{NCSR}\right)$$
$$=\frac{\phi}{26244}\left(470A+2184B-5999\phi-2842c_1+188c_2\right)>(<)0,\quad if\ \ \phi<(>)\hat{\phi}' \tag{23}$$

$$\pi_f^{CSR}-\pi_f^{NCSR}=\frac{20\phi}{6561}\left(16A+3B+5\phi+7c_1-26c_2\right)>0 \tag{24}$$

where $\phi_A' \equiv (550A-231B-539c_1+220c_2)/3220$, $\hat{\phi}' \equiv (470A+2184B - 2842c_1 + 188c_1) / 5999$. Comparing the critical values in open economy (ϕ_A' and $\hat{\phi}'$) and that in closed economy (ϕ_A and $\hat{\phi}$), we find that $0 < \phi_A' < \phi_A$ and $\hat{\phi}' < \hat{\phi}$. Figure 3 (a) – (d) shows the effect of implementing ECSR on the multi-product firm and foreign firm's profits.

Figure 3 (a) shows that the critical value of ϕ_A shifts to the left. It means that the benefit of adopting ECSR for the multi-product firm is smaller. However, the multi-product firm's profit in market A still may increase by adopting ECSR if the marginal environmental damage is sufficiently low, i.e., $\hat{\phi}' < \hat{\phi}$.

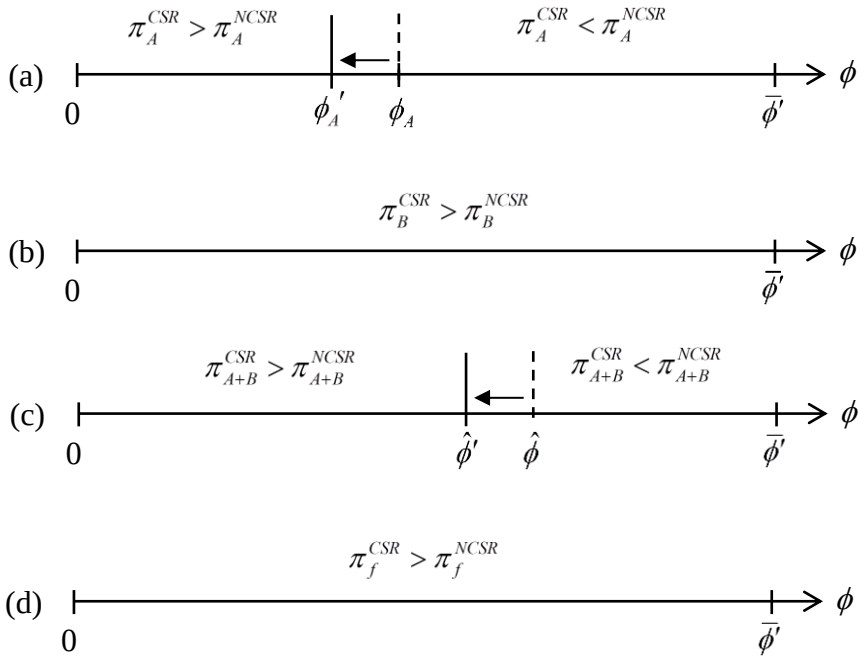

Figure 4. The impact of adopting ECSR on the profits of the multi-product firm in open economy

Note that from Figure 3 (b) and (d), we know that implementing ECSR of the multi-product firm not only can benefit its profit in market B but also benefit its rival—the foreign competitor. From Figure 3 (c), we find that an increase in the competitiveness decrease the magnitude of the multi-product firm's benefit by implementing ECSR. However, the multi-product firm still can benefit from adopting ECSR if the marginal environmental damage is sufficiently low, i.e. $\hat{\phi}' < \hat{\phi}$. These results are summarized in Proposition 4.

Proposition 4 *A rise in the degree of competitiveness decrease the downstream multi-product firm's benefit of implementing ECSR. However, the downstream multi-product firm' still can benefit by implementing ECSR if* $\phi < \bar{\phi}'$.

The intuition is as follows. When the multi-product firm cares about ECSR and thus decreases its output, firm f would increase its output level at the same time. This is because two firms engage in quantity competition and the competition property is strategic substitution. Therefore, the magnitudes of ECSR effect (the output reducing effect) and vertical market effect are different with that in the closed economy. An increase in the number of competitor increases the negative ECSR effect and decreases the positive vertical market effect (the input price reducing effect). Therefore, the benefit for implementing ECSR reduces.

5. Concluding remarks

Multi-product firms are ubiquitous in most of industries, such as the computer

industry, automotive industry and furniture industry. In addition, ECSR has drawn a great attention recently because the problems of climate change and global warming are getting more serious. In practice, it is quite common to see that the multi-product firm implements ECSR. Therefore, this paper investigates the impact of implementing ECSR by the multi-product firm on equilibrium outcomes and finds some interesting results which are very different with that of the setting of single-product firm.

First, in the popular view, the profit-maximization firm does not have an incentive to implement environmental oriented CSR. Therefore, the government usually needs to set some requirements for profit-maximization firm to adopt ECSR. However, we find that implementing ECSR by the multi-product firm can increase its total profit when the production process of polluting industry causes mild environmental damage. Therefore, it is possible for the multi-product firm to adopt ECSR voluntarily even the multi-product firm is pure profit-maximization.

Second, the consideration of the upstream firm when it faces the downstream multi-product firm is different with that when it faces the downstream single-product firm. The upstream firm reduces the input price if the downstream multi-product firm implements ECSR. Moreover, the double marginalization problem in non-polluting industry can be alleviated by adopting ECSR.

Lastly, the environmental quality and social welfare are important concerns for the government. We show that implementing ECSR by the multi-product firm increases not only environmental quality but also social welfare no matter the degree of marginal environmental damage. It is worthy to mention that implementing ECSR can obtain the triple-win situation if the production process causes mild environmental damage.

We conclude with some suggestion for future research. First, our framework

might be used to study the upstream market structure as oligopoly. If the upstream market is more competitive, the magnitude of a decrease in input price is greater. Our results are still obtained. Second, this paper assumes that the upstream firm adopts uniform pricing. However, the discrimination pricing is also popular in practice. Therefore, the further study can consider the possibility of adopting discrimination pricing for the upstream firm. Third, the final goods in market A and B are assumed to be independent. It can extend to the case that two products are substitute.

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