研究ノート

Transboundary Pollution and Environmental Corporate Social Responsibility in an Open Economy

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1. Introduction

Global warming has come to present severe difficulties to society worldwide. Firms must therefore consider not only their profits but also environmental conditions in every country.

Recently, many firms have become engaged in corporate social responsibility（CSR）efforts in various fields in many countries. A KPMG（2017）survey of CSR reports worldwide, particularly addressing a worldwide sample of 4900 companies comprising the top 100 companies by revenue in 49 countries, revealed that around three quarters of the 4900 companies issue CSR reports（KPMG, 2017, p.4, p.9）. Regarding CSR reporting rates by sector, of Oil and Gas companies, 81% reported, as did 81% of those in Chemicals and 80% in Mining in 2017. Sectors with high environmental impact such as oil and gas and mining have high CR reporting rates（KPMG, 2017, p.20）. Recently, many firms engage in Environmental Corporate Social Responsibility（ECSR）in various fields in many countries. Given this background, we specifically examine ECSR in this study.

Recently, international trade has been active in many countries. Furthermore, transboundary pollution such as that of PM 2.5 has become an important environmental problem. Therefore, when discussing ECSR effects,

one must consider international trade and transboundary pollution. Accordingly, we investigate whether the promotion of ECSR by firms improves environmental conditions in the country under circumstances that include international trade and transboundary pollution.

Many reports describe studies examining ECSR. Theoretical studies of ECSR in recent years include those of Liu et al.（2015）and Hirose et al.（2017）. Liu et al.（2015）use a differentiated duopoly model to analyze competition structure effects on a firm's incentives of adopting certified ECSR[(1)]. They demonstrate that, to induce firms to adopt certified ECSR, the certifier will set a standard lower than the optimal one. Moreover, they show that the standard in Cournot competition is higher than that in Bertrand competition.

Hirose et al.（2017）reported a model in which two firms choose whether to adopt ECSR policies and then choose their prices sequentially. They demonstrate that only the follower adopts ECSR in equilibrium: a first-mover advantage is apparent. Gal-Or（1985）and Dowrick（1986）demonstrated that, in symmetric duopolies, for strategic complements, the second mover represents benefits under the stability condition. However, they do not consider the ECSR. The conclusions with regard to the first-mover advantage in Hirose et al.（2017）differ from those presented by Gal-Or（1985）and Dowrick（1986）.

However, they do not consider transboundary pollution in an open economy. Accordingly, they do not examine relations between a firm's decision to adopt ECSR and the environmental conditions in each country under situations with transboundary pollution.

Theoretical studies of CSR and international markets in recent years include those of Wang et al.（2012）, Chang et al.（2014）, and Liu（2018）. Wang et al.（2012）examine how strategic tariff policy and welfare are

affected by the consumer-friendly initiatives of foreign exporting firms[2]. They demonstrate that a consumer-friendly initiative increases output levels of goods and engenders a lower market price. Furthermore, a favorable lower tariff rate will be realized by consumer-friendly initiatives in their studies. Accordingly, they report that a consumer-friendly initiative is not only beneficial for foreign exporting firms, but also for the government and consumers of the importing country.

Chang et al. (2014) assess the welfare implications of CSR in international markets under imperfect competition. They show that the CSR initiatives of domestic and foreign firms lead to the dominant strategy in an import-competing duopolistic market. Furthermore, they demonstrate that the feasibility of tariff reduction by the government of an importing country rises when both domestic and foreign firms launch CSR initiatives. In their model, they assume that firms decide whether to adopt CSR, but they do not analyze situations in which government chooses the degree of CSR.

Liu et al. (2018) use an international oligopoly model to examine the optimal degree of CSR promotion and its optimal tariff rate imposed on the foreign firm. Especially, they specifically examine the distortion of taxation or the shadow cost of tariff revenue, and analyze how this cost of taxation affects the optimal degree of CSR promotion and its optimal tariff rate. They describe that the government steps up efforts to promote CSR for lower taxation and chooses to raise tariffs and impose high costs of taxation.

Although studies such as these examine CSR in an open economy, they do not consider situations in which polluting firms and transboundary pollution exist. They do not analyze the effects of firm adoption of ECSR for environmental conditions in a country with transboundary pollution.

Given the background of research efforts such as this, situations are analyzed in which a polluting firm decision of whether to adopt ECSR in

each country affects the environmental conditions in the country under scenarios that include transboundary pollution. This paper presents the following conclusions. When the level of ECSR in one's own country is higher (lower) than that in the other country, the output of the good in the own country at equilibrium increases (decreases) with the degree of transboundary pollution. When transboundary pollution does not exist, whether another country's firm adopts or does not adopt ECSR, the firm's adoption of ECSR worsens the environmental conditions in the country under an open economy. When transboundary pollution exists, whether the other country's firm adopts or does not adopt ECSR, the firm's adoption of ECSR improves the environmental conditions in the country under an open economy.

Most reported studies present the conclusion that ECSR promotes overall social welfare and improves environmental conditions. By contrast, we demonstrate that ECSR worsens environmental conditions in an open economy.

2. Model

We consider a world with two homogeneous countries: country 1 and country 2. Each country has homogeneous residents and one firm. Residents in each country are standardized to one unit. Furthermore, because of the assumption of short-term economic conditions, no international migration occurs. We consider an open economy. Each firm produces a private good. Each resident demands the private good in international markets[3]. The production of the good produces environmental pollution. Firms' emissions have transboundary spillovers. The inverse demand function of the good is assumed as presented below.

$$P = a - q_i - q_j \quad (1)$$

Therein, P denotes the market price in each country. Term q_i represents the demand for the good in country i $(i = 1,2)$. Under this inverse demand function, the consumers' surplus in the market is expressed as

$$CS = \frac{1}{2}(q_i + q_j)^2. \quad (2)$$

Considering symmetric countries, the consumers' surplus in country i is expressed as shown below.

$$CS_i = \frac{1}{4}(q_i + q_j)^2 \quad (3)$$

This paper presents analyses based on the assumption that the marginal cost of the firm in country i to supply the private good equals c. This marginal cost is the same level among the countries. The cost function of the firm in country i is $C(q_i) = cq_i$.

Profit of the firm in country i is $\pi_i = Pq_i - cq_i$. From eq. (1), the firm profit in country i is

$$\pi_i = Aq_i - q_i^2 - q_i q_j. \quad (4)$$

For this analysis, it is assumed that $A \equiv a - c\,(>0)$. The analyses presented herein are conducted on the assumption that if the output of the firm in country i is q_i, then emissions in country i are q_i. Consequently, the total quantity of emissions in country i is

$$s_i = (1 - \lambda)q_i + \lambda q_j. \quad (5)$$

In eq. (5), term s_i denotes the total quantity of the emissions in country i. Parameter λ represents the degree of spillover effects $(0 \leq \lambda \leq 1)$.

The extent of the environmental damage is assumed as

$$D(q_i, q_j) = \alpha s_i = \alpha\{(1 - \lambda)q_i + \lambda q_j\}. \quad (6)$$

In that equation, α stands for the degree of marginal environmental damage; $4\alpha < A$ is assumed as $(0 \leq \alpha \leq 1)$. Furthermore, α is the same in both countries. This assumption means that the willingness to pay for the

good is greater than the marginal environmental damage.

The firm's objective function in country i is the following[4].

$$V_i = \pi_i + \theta_i(CS_i - D_i) \tag{7}$$

The firm in country i aims at maximizing the objective function. Here, θ_i represents the level of environmental corporate social responsibility (ECSR) based on the assumption that $0 \leq \theta_i \leq 1$. Using the consumers' surplus in country i, eq. (3) and the profit of the firm in country i eq. (4), the firm's objective function in country i is calculable as shown below:

$$V_i = Aq_i - q_i^2 - q_i q_j + \theta_i \left[\frac{1}{4}\left(q_i + q_j\right)^2 - \alpha\{(1-\lambda)q_i + \lambda q_j\}\right]. \tag{8}$$

3. Firm Decision and ECSR

The firm in country i determines the output of the good to maximize the firm's objective function V_i. Accordingly, the problem of the firm in country i is

$$\max_{q_i} V_i = \pi_i + \theta_i(CS_i - D_i).$$

We can derive the first-order condition as presented below.

$$\frac{dTR_i}{dq_i} + \theta_i \frac{dCS_i}{dq_i} = c + \theta_i \frac{dD_i}{dq_i} \tag{9}$$

Here, the total revenue of the firm in country i is $(TR_i \equiv (a - q_i - q_j)q_i)$. The left-hand side of eq. (9) is the sum of the marginal increase in total revenues and the marginal increase in consumers' surplus from the supply of the good in country i. The left-hand side of eq. (9) stands for the marginal benefit from the good in country i.

The right-hand side of eq. (9) represents the sum of the cost and marginal increase of environmental damage from the supply of the good in country i. Therefore, the right-hand side of eq. (9) signifies the marginal cost from the good in country i.

Therefore, eq. (9) is the condition under which the marginal benefit from

the good equals the marginal cost from the good in country *i*. The firm in country *i* determines the output of the good to meet eq. (9) given the output of the good in the other country.

The output of the good in country *i* which satisfies eq. (9) in each country is the following.

$$q_i^r = \frac{2A+q_j(\theta_i-2)-2\alpha(1-\lambda)\theta_i}{4-\theta_i} \tag{10}$$

Here, the output of the good in country *i* is denoted as q_i^r. Equation (10) represents the best reaction function of the firm in country *i* on the output of private goods, which are decided by the firm in country *j*.

From eq. (10), the output of the good in country *i* at equilibrium is the following [5].

$$q_i^* = \frac{2A(4-\theta_j)+(\theta_i-2)\{2A-2\alpha(1-\lambda)\theta_j\}-2\alpha(1-\lambda)\theta_i(4-\theta_j)}{(4-\theta_i)(4-\theta_j)-(\theta_j-2)(\theta_i-2)} \tag{11}$$

With regard to output q_i^*, the results of comparative static analyses indicate the following.

$$\frac{dq_i^*}{d\lambda} = \frac{2\alpha\theta_j(\theta_i-2)+2\alpha\theta_i(4-\theta_j)}{(4-\theta_i)(4-\theta_j)-(\theta_j-2)(\theta_i-2)} \tag{12}$$

From Eq. (12), one can obtain the following results.

If $\theta_i \geq \frac{1}{2}\theta_j$, then $\frac{dq_i^*}{d\lambda} \geq 0$.

If $\theta_i < \frac{1}{2}\theta_j$, then $\frac{dq_i^*}{d\lambda} < 0$.

From the relations associated with the above conditions of the level of ECSR in each country and the sign of $\frac{dq_i^*}{d\lambda}$, the following figure is obtainable.

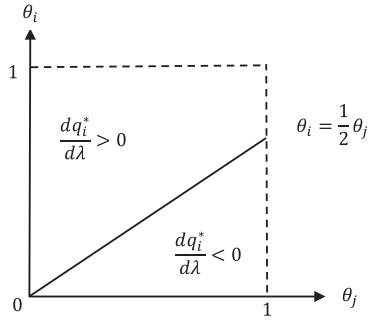

Figure 1

As figure shows 1, one can obtain the following proposition.

Proposition 1

When the level of ECSR in country i is higher than that in country j, $\theta_i \geq \frac{1}{2}\theta_j$*, the output of the good in country i at equilibrium increases with the degree of transboundary pollution.*

When the level of ECSR in country i is lower than that in country j, then $\theta_i < \frac{1}{2}\theta_j$*, the output of the good in country i at equilibrium decreases with the degree of transboundary pollution.*

The interpretation of proposition 1 is the following.

First, for $\theta_i \geq \frac{1}{2}\theta_j$, from eq. (10), the reaction curves in the respective countries are depicted as the following figure.

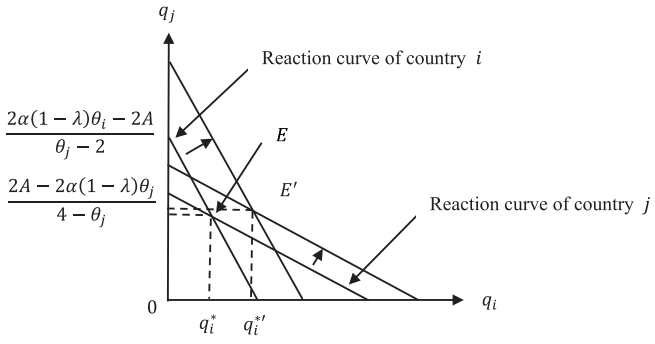

Figure 2

As shown in Figure 2, when the degree of transboundary pollution is large, both the country *i* reaction curve and the country *j* reaction curve are shifted upward. Here, the effects of shift of the country *i* reaction curve are larger than that of the country *j* reaction curve. Consequently, for $\theta_i \geq \frac{1}{2}\theta_j$, when the degree of transboundary pollution increases, the output of the good in country *i* at equilibrium will increase.

For $\theta_i < \frac{1}{2}\theta_j$, from eq. (10), the reaction curves in each country are depicted as shown below.

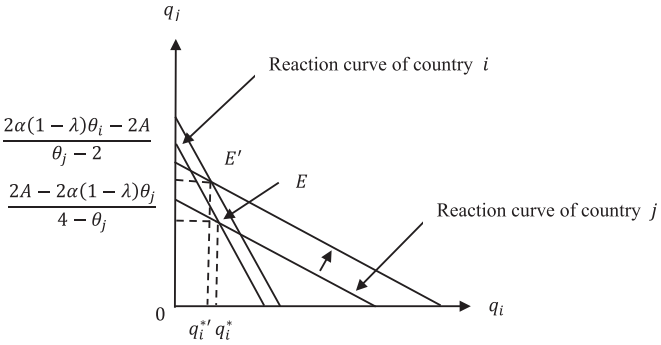

Figure 3

When the degree of transboundary pollution is large, both the country i reaction curve and the country j reaction curve shift upward. Here, the effects of the shift of the country j reaction curve are greater than that of the country i reaction curve. Consequently, in the case of $\theta_i < \frac{1}{2}\theta_j$, when the degree of transboundary pollution increases, the output of the good in country i at equilibrium is expected to decrease.

4. ECSR Effects

This section presents analysis of the effects of ECSR in each country on the environmental conditions. We consider the situations in which transboundary pollution does not exist ($\lambda = 0$) and situations in which transboundary pollution exists ($\lambda = 1$). How does a firm's adoption of ECSR affect the environmental conditions in the country under an open economy?

4.1 ECSR Effects (Transboundary pollution does not exist)

First, we consider the case in which transboundary pollution does not exist

($\lambda = 0$). For these situations, we assume that $\theta_j = 1$. Country i environmental damage is the following if country i chooses $\theta_i = 1$.

$$D_i^{11} = \frac{A\alpha - \alpha^2}{2} \tag{13}$$

Country i environmental damage is the following if country i chooses $\theta_i = 0$.

$$D_i^{10} = \frac{A\alpha + 2\alpha^2}{5} \tag{14}$$

Next, the level of environmental damage D_i^{11} and the level of environmental damage D_i^{10} are compared. The levels of environmental damage can be compared according to the equation presented below.

$$D_i^{11} - D_i^{10} = \frac{\alpha(3A - 9\alpha)}{10} \tag{15}$$

From Eq. (15), it is readily apparent that if $A \geq 3\alpha$, then $D_i^{11} \geq D_i^{10}$. Here, from the assumption of $4\alpha < A$, $D_i^{11} \geq D_i^{10}$ is realized.

Next, we assume that $\theta_j = 0$. Country i environmental damage is the following if country i chooses $\theta_i = 1$.

$$D_i^{01} = \frac{3A\alpha - 4\alpha^2}{5} \tag{16}$$

The country i environmental damage is the following if country i chooses $\theta_i = 0$.

$$D_i^{00} = \frac{A\alpha}{3} \tag{17}$$

Next we compare the level of environmental damage D_i^{01} and the level of environmental damage D_i^{00}. The level of environmental damage can be compared according to the equation presented below.

$$D_i^{01} - D_i^{00} = \frac{\alpha(4A - 12\alpha)}{15} \tag{18}$$

From Eq. (18), it is readily apparent that if $A \geq 3\alpha$, then $D_i^{01} \geq D_i^{00}$. Here, from the assumption of $4\alpha < A$, $D_i^{01} \geq D_i^{00}$ is realized.

Accordingly, the following proposition is obtainable.

Proposition 2

When transboundary pollution does not exist, whether another country's firm chooses to adopt or not adopt ECSR, a firm's adoption of ECSR

worsens the environmental conditions in the country under an open economy.

The interpretation of proposition 2 is the following. The output of a good in the own country affects the environmental damage in the own country because the transboundary pollution does not exit ($\lambda = 0$). First, we consider the situation in which another firm does not adopt ECSR ($\theta_j = 0$). In this situation, when the firm in country *i* does not adopt ECSR, the output of the good in country *i* at equilibrium is the following.

$$q_i^{*0} = \frac{A}{3} \tag{19}$$

If the firm in country *i* adopts ECSR, then the output of the good in country *i* at equilibrium is the following.

$$q_i^{*1} = \frac{3A-4\alpha}{5} \tag{20}$$

Based on eq. (19) and eq. (20), the output of the good at equilibrium can be compared according to the equation below.

$$q_i^{*1} - q_i^{*0} = \frac{4(A-3\alpha)}{15} > 0 \tag{21}$$

Accordingly, when another country's firm does not adopt ECSR, a firm's adoption of ECSR increases the output of the good in the country at equilibrium.

We consider a situation in which another firm adopts ECSR ($\theta_j = 1$). In this situation, when the firm in country *i* does not adopt ECSR, the output of the good in country *i* at equilibrium is the following.

$$q_i^{*0} = \frac{A+2\alpha}{5} \tag{22}$$

If the firm in country *i* adopts ECSR, then the output of the good in country *i* at equilibrium is the following.

$$q_i^{*1} = \frac{A-\alpha}{2} \tag{23}$$

Using eq. (22) and eq. (23) one can compare the output of the good at equilibrium according to the equation below.

$$q_i^{*1} - q_i^{*0} = \frac{3(A-3\alpha)}{10} > 0 \tag{24}$$

Accordingly, when another country's firm adopts ECSR, a firm's adoption of ECSR increases the output of the good in the country at equilibrium.

4.2 ECSR Effects（Transboundary pollution exists）

Next, we consider the case in which transboundary pollution exists（$\lambda = 1$）. For these situations, we assume that $\theta_j = 1$. Country i environmental damage is the following if country i chooses $\theta_i = 1$.

$$D_i^{11} = \frac{A\alpha}{2} \tag{25}$$

The country i environmental damage is the following if country i chooses $\theta_i = 0$.

$$D_i^{10} = \frac{3A}{5} \tag{26}$$

Next, we compare the level of environmental damage D_i^{11} and the level of environmental damage D_i^{10}. Comparison of those levels of environmental damage can be done according to the equation below.

$$D_i^{11} - D_i^{10} = -\frac{A\alpha}{10} < 0 \tag{27}$$

Next, $\theta_j = 0$ can be assumed. The country i environmental damage is the following if country i chooses $\theta_i = 1$.

$$D_i^{01} = \frac{A\alpha}{5} \tag{28}$$

Country i environmental damage is the following if country i chooses $\theta_i = 0$.

$$D_i^{00} = \frac{A\alpha}{3} \tag{29}$$

Next the level of environmental damage D_i^{01} and the level of environmental damage D_i^{00} are compared. That can be done according to the equation presented below.

$$D_i^{01} - D_i^{00} = -\frac{2A\alpha}{15} < 0 \tag{30}$$

Accordingly, one obtains the following proposition.

Proposition 3

When transboundary pollution exists, whether the other country's firm

adopts or does not adopt ECSR, the firm's adoption of ECSR improves the environmental conditions in the country under an open economy.

The interpretation of proposition 3 is the following. The output of a good in the own country affects the environmental damage in another country because transboundary pollution exists $(\lambda = 1)$. First, we consider the situation in which another firm does not adopt ECSR $(\theta_j = 0)$. In this situation, when the firm in country *i* does not adopt ECSR, the output of the good in country *i* at equilibrium is the following.

$$q_i^{*0} = \frac{A}{3} \tag{31}$$

The firm in country *i* adopts ECSR, the output of the good in country *i* at equilibrium is the following.

$$q_i^{*1} = \frac{3A}{5} \tag{32}$$

In light of eq. (31) and eq. (32), comparison of the output of the good at equilibrium can be done according to the equation below.

$$q_i^{*1} - q_i^{*0} = \frac{4A}{15} > 0 \tag{33}$$

Accordingly, when another country's firm does not adopt ECSR, a firm's adoption of ECSR increases the output of the good in the country at equilibrium. Here, because the strategic substitute exists in the goods market, the increase of the output of the good in the own country decreases the output of the good in the other country. Accordingly, the decrease of the output of good in the other country might decrease the environmental damage in the own country because transboundary pollution exists $(\lambda = 1)$.

By contrast, we consider a situation in which another firm adopts ECSR $(\theta_j = 1)$. In this situation, when the firm in country *i* does not adopt ECSR, the output of the good in country *i* at equilibrium is the following.

$$q_i^{*0} = \frac{A}{5} \tag{34}$$

If the firm in country *i* adopts ECSR, then the output of the good in

country i at equilibrium is the following.

$$q_i^{*1} = \frac{A}{2} \tag{35}$$

We compare eq.（34）and eq.（35）Comparison of the output of the good at equilibrium can be done according to the equation below.

$$q_i^{*1} - q_i^{*0} = \frac{3A}{10} > 0 \tag{36}$$

Accordingly, when another country's firm adopts ECSR, a firm's adoption of ECSR increases the output of the good in the country at equilibrium. Here, because the strategic substitute exists in the goods market, the increase of the output of the good in the own country decreases the output of the good in the other country. Accordingly, the decrease of the output of good in the other country might decrease the environmental damage in the own country because transboundary pollution exists（$\lambda = 1$）.

5. Concluding Remarks

This report described an analysis of ECSR effects in each country in an open economy under situations in which transboundary pollution exists. Especially, these analyses elucidated relations between a firm's adoption of ECSR in each country and transboundary pollution. Furthermore, we examine the effects of firm adoption of ECSR in each country on environmental conditions in an open economy.

This paper presents the following main conclusions. When the level of ECSR in the own country is higher（lower）than that in the other country, the output of the good in the own country at equilibrium increases（decreases）with the degree of transboundary pollution. When transboundary pollution does not exist, whether another country's firm adopts or does not adopt ECSR, a firm's adoption of ECSR worsens the environmental conditions in the country under an open economy.

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（1）Manasakis et al.（2013）examine a credible information disclosure mechanism for

a sustainable CSR-related goods market. Liu et al.（2015）follow Manasakis et al.（2013）and consider an NGO certifier, which serves as a credible information disclosure mechanism of the firm's ECSR.

（2）This model examines the consumer-friendly initiative of foreign exporting firms in an international duopoly according to the treatment reported by Brander and Spencer（1985）.

（3）The model setting of international markets is similar to that described by Ohno（2016）. Focusing on international trade under transboundary pollution, Ohno（2016）presents analyses of privatization of a polluting firm in individual countries.

（4）The model setting of ECSR in the objective function is similar to that described by Fukuda and Ouchida（2017）.

（5）From the assumption of $4\alpha < A$, the sign of Eq.（11）is positive.