研究ノート

Transboundary Pollution and Endogenous Decision-Making about Environmental Corporate Social Responsibility

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1. Introduction

Recently, global warming caused by greenhouse gas emissions has become an extremely important problem worldwide. Its attendant difficulties must be examined not only for each country but also for each region. Many firms engage in Environmental Corporate Social Responsibility（ECSR）in various fields in various countries(1). Recently, many people might be interested in ECSR activities by firms in various countries.

Theoretical studies of ECSR in recent years include those of Jinji（2013）, Lambertini and Tampieri（2015）, Liu et al.（2015）, Hirose et al.（2017）, Ee et al.（2018）, and Ohno（2019）. Jinji（2013）examines how corporate environmentalism in the home country affects home welfare when domestic and foreign governments impose emission taxes or provide export subsidies in an international oligopolistic market(2). The study shows that home welfare might be lower when the home firm is environmentally conscious than when it is a profit maximizer when emission taxes and export subsidies are when available and transboundary pollution exists.

Lambertini and Tampieri（2015）study how socially responsible behavior affects firms' profits and social welfare when production entails an environmental externality using a model of Cournot oligopoly. They consider a CSR firm which

not only pursues profits but which also monitors all pollution produced by the industry and which is sensitive to consumer surplus. Here, they specifically examine the weight that a CSR firm assigns to consumer surplus. They demonstrate that the CSR firm might obtain higher profits than its profit-seeking competitors and might achieve a higher level of social welfare when the market size is sufficiently large.

Liu et al.（2015）study competition structure effects on a firm's incentives of adopting certified ECSR using a differentiated duopoly model(3). 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）consider 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）demonstrate that, in symmetric duopolies, for strategic complements, the second mover has advantages under the stability condition. However, they do not consider the ECSR. Conclusions with regard to the first-mover advantage in Hirose et al.（2017）differ from those explained by Gal-Or（1985）or by Dowrick（1986）.

Ee et al.（2018）use a general-equilibrium framework to study how ECSR investments affect wage inequality between skilled and unskilled workers. Here, they consider a two-sector economy with agricultural and manufacturing sectors in which ECSR activities are executed by skilled labor. They report that an increase in ECSR investment can widen wage inequality between skilled and unskilled workers in the short run case. However, in the long run case, an increase in ECSR investment causes the firms to exit. This can narrow wage inequality between skilled and unskilled workers. Furthermore, they investigate these two theoretical predictions empirically.

Ohno（2019）examines whether promotion of ECSR by firms improves environmental conditions in the country under circumstances that include international trade and transboundary pollution. He demonstrates that 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. However, when transboundary pollution exists, irrespective of 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.

Although Jinji（2013）, Lambertini and Tampieri（2015）, Ee et al.（2018）, and Ohno（2019）examine ECSR theoretically, they do not investigate a firm's endogenous decision making related to ECSR in each country under circumstances that include international trade and transboundary pollution. Unlike reports described by Liu et al.（2015）and by Hirose et al.（2017）, we consider transboundary pollution in an open economy and in an asymmetric country in which the degree of marginal environmental damage differs among countries.

We analyze the firm's endogenous decision-making related to ECSR in each country in an open economy under situations in which transboundary pollution exists or does not exist. These analyses yield the following main results. First, the output of a good in one's own country at equilibrium decreases（increases）with the promotion of ECSR in one's own（other）country. Secondly, when the level of ECSR in another country is higher（lower）than that in one's own country, then the output of the good in one's own country at equilibrium will decrease（increase）with the degree of transboundary pollution. Whether transboundary pollution exists or does not exist, the firm in each country does not adopt ECSR at equilibrium.

2. Model

We consider a world with two countries: country 1 and country 2. Each country has homogeneous residents and one firm. Residents of 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. 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.

$$P = a - q_i - q_j \tag{1}$$

Therein, P denotes the market price in each country. Term q_i represents the demand for the good in country i $(i = 1,2)$.

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

$$\pi_i = Aq_i - q_i^2 - q_i q_j. \tag{2}$$

For this analysis, it is assumed that $A \equiv a - c$ (>0). Here we assume that parameter A is sufficiently large. The analyses presented herein are made 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

$$s_i = (1 - \lambda)q_i + \lambda q_j. \tag{3}$$

In eq. (3), 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

$$D_i(q_i, q_j) = \alpha_i s_i = \alpha_i\{(1-\lambda)q_i + \lambda q_j\}. \quad (4)$$

In that equation, α_i stands for the degree of marginal environmental damage in country *i* based on the assumption that $(0 \leq \alpha_i \leq 1)$.

The firm in country *i* aims at maximizing its objective function, denoted as

$$V_i = \pi_i - \theta_i D_i. \quad (5)$$

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 profit of the firm in country *i* eq. (2), the firm's objective function in country *i* is calculable as

$$V_i = Aq_i - q_i^2 - q_i q_j - \theta_i \alpha_i\{(1-\lambda)q_i + \lambda q_j\}. \quad (6)$$

Using a two-stage game, endogenous decision-making can be analyzed with regard to ECSR in each country under situations in which transboundary pollution exists or does not exist. The time line is the following. In the first stage, a monopoly polluting firm in each country chooses whether to adopt ECSR policies, or not. In the second stage, the firm in each country determines a good amount of output. Herein, we specifically consider asymmetric countries in which the degree of marginal environmental damage differs among countries.

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

$$\max_{q_i} V_i = \pi_i - \theta_i D_i.$$

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

$$\frac{dTR_i}{dq_i} = c + \theta_i \frac{dD_i}{dq_i} \quad (7)$$

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. (7) is the sum of total revenues' marginal increase from the supply of the good in country *i*. The left-hand side of eq. (7) is the marginal

benefit from the good in country *i*.

The right-hand side of eq.（7）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.（7）signifies the marginal cost from the good in country *i*.

One can regard eq.（7）as 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* chooses the output of the good to meet eq.（7）given the output of the good in the other country.

The output of the good in country *i* which meets eq.（7）in each country is the following.

$$q_i^r = \frac{A - q_j - \theta_i \alpha_i (1-\lambda)}{2} \tag{8}$$

Here, the output of the good in country *i* is denoted as q_i^r. Equation（8）represents the best reaction function of the firm in country *i* on the level of output of private goods, which is decided by the firm in country *j*.

From eq.（8）, the output of the good in country *i* at equilibrium is inferred as the following(4).

$$q_i^* = \frac{A + \theta_j \alpha_j (1-\lambda) - 2\theta_i \alpha_i (1-\lambda)}{3} \tag{9}$$

The comparative statics of the output of equilibrium to the degree of ECSR is the following.

$$\frac{dq_i^*}{d\theta_i} = -\frac{2\alpha_i(1-\lambda)}{3} < 0 \tag{10}$$

$$\frac{dq_i^*}{d\theta_j} = \frac{\alpha_j(1-\lambda)}{3} > 0 \tag{11}$$

Accordingly, one obtains the following proposition.

Proposition 1

The output of a good in one's own country at equilibrium decreases（increases）with the promotion of ECSR in one's own（other）country.

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

$$\frac{dq_i^*}{d\lambda} = \frac{-\theta_j\alpha_j+2\theta_i\alpha_i}{3} \tag{12}$$

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

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

If $\theta_j > \frac{2\alpha_i}{\alpha_j}\theta_i$, 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.

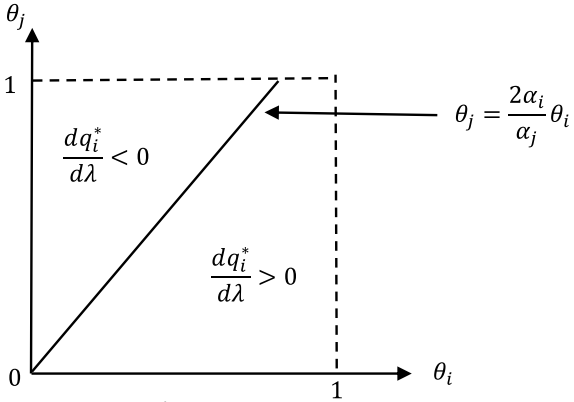

Figure 1

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

Proposition 2

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

The interpretation of proposition 2 is the following.

First, for $\theta_j \leq \frac{2\alpha_i}{\alpha_j}\theta_i$, from eq.（8）, the reaction curves in the respective countries are depicted as the following figure.

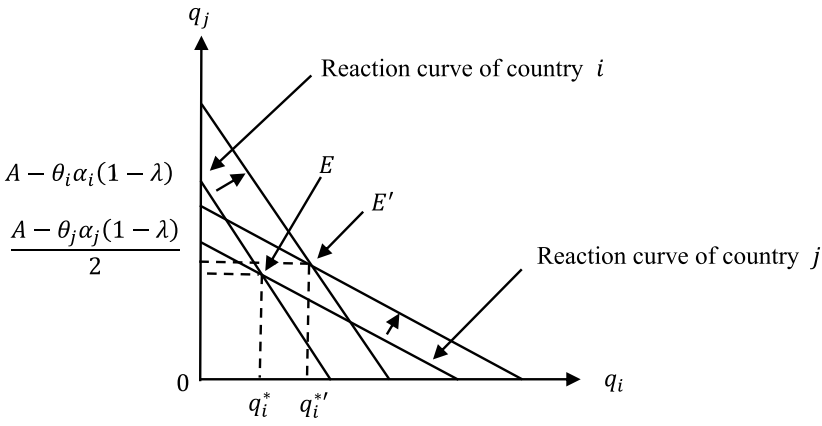

Figure 2

As shown in Figure 2, when the amount 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 greater than that of the country *j* reaction curve. Consequently, for $\theta_j \leq \frac{2\alpha_i}{\alpha_j}\theta_i$, when the degree of transboundary pollution increases, the output of the good in country *i* at equilibrium can be expected to increase.

For $\theta_j > \frac{2\alpha_i}{\alpha_j}\theta_i$, from eq. (8), the reaction curves in each country are depicted as shown below.

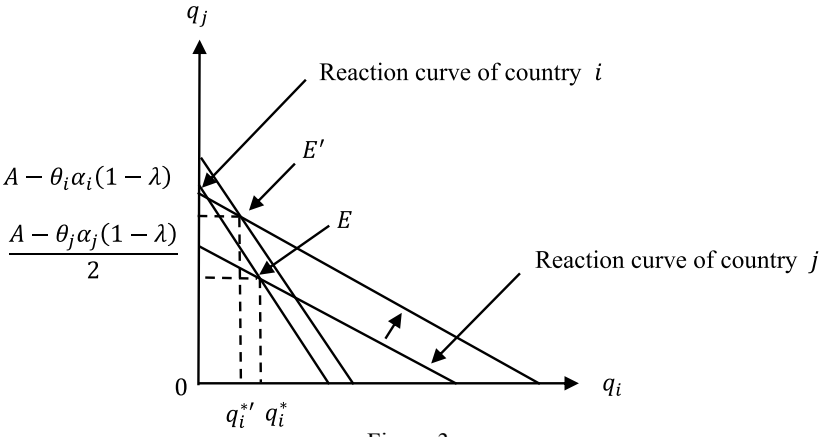

Figure 3

When the degree of transboundary pollution is high, then 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 $\theta_j > \frac{2\alpha_i}{\alpha_j}\theta_i$, when the degree of transboundary pollution increases, the output of the good in country *i* at equilibrium will decrease.

Although this result is similar to that reported by Ohno (2019), Ohno (2019) does not consider an asymmetric country in which the degree of marginal environmental damage differs among countries. This result is dependent on the level of marginal environmental damage in one's own country and in another country.

4. Decision of ECSR

This section presents analysis of endogenous decision making with regard to ECSR activities in each country. We consider situations in which transboundary

pollution does not exist（$\lambda = 0$）and situations in which transboundary pollution exists（$\lambda = 1$）.

4.1 Decision of ECSR（Transboundary pollution does not exist）

First, we consider the case in which transboundary pollution does not exist（$\lambda = 0$）. For these situations, the output of the good in country *i* at equilibrium is the following.

$$q_i^* = \frac{A+\theta_j\alpha_j-2\theta_i\alpha_i}{3} \quad (13)$$

The firm's objective function in country *i* at equilibrium is calculable as shown below.

$$V_i = \left(\frac{A+\theta_j\alpha_j-2\theta_i\alpha_i}{3}\right)^2 \quad (14)$$

When both the firm in country 1 and the firm in country 2 adopt ECSR（$\theta_1 = 1$ and $\theta_2 = 1$）, each firm's objective function in country *i* at equilibrium is the following.

$$V_i^{11} = \left(\frac{A+\alpha_j-2\alpha_i}{3}\right)^2 \quad (15)$$

When neither the firm in country 1 nor the firm in country 2 adopts ECSR（$\theta_1 = 0$ and $\theta_2 = 0$）, the firm's objective function in country *i* at equilibrium is the following.

$$V_i^{00} = \left(\frac{A}{3}\right)^2 \quad (16)$$

When the firm in country 1 adopts ECSR but the firm in country 2 does not adopt ECSR（$\theta_1 = 1$ and $\theta_2 = 0$）, the objective function of the firm in country 1 at equilibrium is the following.

$$V_1^{10} = \left(\frac{A-2\alpha_1}{3}\right)^2 \quad (17)$$

When the firm in country 1 adopts ECSR but the firm in country 2 does not adopt ECSR ($\theta_1 = 1$ and $\theta_2 = 0$), the objective function of the firm in country 2 at equilibrium is the following.

$$V_2^{10} = \left(\frac{A+\alpha_1}{3}\right)^2 \tag{18}$$

When the firm in country 1 does not adopt ECSR but the firm in country 2 adopts ECSR ($\theta_1 = 0$ and $\theta_2 = 1$), the objective function of the firm in country 1 at equilibrium is

$$V_1^{01} = \left(\frac{A+\alpha_2}{3}\right)^2. \tag{19}$$

When the firm in country 1 does not adopt ECSR but the firm in country 2 adopts ECSR ($\theta_1 = 0$ and $\theta_2 = 1$), the objective function of the firm in country 2 at equilibrium is the following.

$$V_2^{01} = \left(\frac{A-2\alpha_2}{3}\right)^2 \tag{20}$$

The payoff matrix of the game is the following.

If λ=0

	$\theta_2 = 1$	$\theta_2 = 0$
$\theta_1 = 1$	V_1^{11}, V_2^{11}	V_1^{10}, V_2^{10}
$\theta_1 = 0$	V_1^{01} V_2^{01}	V_1^{00} V_2^{00}

Figure 4

From Figure 4, the firm does not choose to adopt ECSR in each country at equilibrium ($\theta_1^* = 0$ and $\theta_2^* = 0$).

Accordingly, the following proposition is obtainable.

Proposition 3

When transboundary pollution does not exist, the firm does not choose to adopt ECSR at equilibrium in each country under an open economy.

Proposition 3 shares that firms in each country will not adopt ECSR at equilibrium because consideration of environmental damage imposes a burden on firms in the respective countries.

4.2 Decision of ECSR（Transboundary pollution exists）

Next, we consider the case in which transboundary pollution exists（λ=1）. For these situations, the output of the good in country *i* at equilibrium is the following.

$$q_i^* = \frac{A}{3} \tag{21}$$

The firm's objective function in country *i* at equilibrium is calculable as

$$V_i = \frac{A(A-3\theta_i\alpha_i)}{9}. \tag{22}$$

When both the firm in country 1 and the firm in country 2 adopt ECSR（$\theta_1 = 1$ and $\theta_2 = 1$）, objective function of the firm in country *i* at equilibrium is

$$V_i^{11} = \frac{A(A-3\alpha_i)}{9}. \tag{23}$$

When neither the firm in country 1 nor the firm in country 2 adopts ECSR（$\theta_1 = 0$ and $\theta_2 = 0$）, the objective function of the firm in country *i* at equilibrium is the following.

$$V_i^{00} = \frac{A^2}{9} \tag{24}$$

When the firm in country 1 adopts ECSR but the firm in country 2 does not adopt ECSR（$\theta_1 = 1$ and $\theta_2 = 0$）, the objective function of the firm in country 1 at equilibrium is shown below.

$$V_1^{10} = \frac{A(A-3\alpha_1)}{9} \tag{25}$$

When the firm in country 1 adopts ECSR but the firm in country 2 does not adopt ECSR ($\theta_1 = 1$ and $\theta_2 = 0$), the objective function of the firm in country 2 at equilibrium is presented as follows.

$$V_2^{10} = \frac{A^2}{9} \tag{26}$$

When the firm in country 1 does not adopt ECSR but the firm in country 2 adopts ECSR ($\theta_1 = 0$ and $\theta_2 = 1$), the objective function of the firm in country 1 at equilibrium is shown below.

$$V_1^{01} = \frac{A^2}{9} \tag{27}$$

When the firm in country 1 does not adopt ECSR but the firm in country 2 adopts ECSR ($\theta_1 = 0$ and $\theta_2 = 1$), the objective function of the firm in country 2 at equilibrium is the following.

$$V_2^{01} = \frac{A(A-3\alpha_2)}{9} \tag{28}$$

The payoff matrix of the game is the following.

If $\lambda = 1$

	$\theta_2 = 1$	$\theta_2 = 0$
$\theta_1 = 1$	V_1^{11}, V_2^{11}	V_1^{10}, V_2^{10}
$\theta_1 = 0$	V_1^{01} V_2^{01}	V_1^{00} V_2^{00}

Figure 5

As inferred from the results depicted in Figure 5, the firm does not choose to adopt ECSR in each country at equilibrium ($\theta_1^* = 0$ and $\theta_2^* = 0$).

Accordingly, the following proposition is obtainable.

Proposition 4

When transboundary pollution exists, the firm does not choose to adopt ECSR at equilibrium in each country under an open economy.

Proposition 4 indicates that no firm in any country will adopt ECSR at equilibrium because consideration of environmental damage imposes a burden on the firms in the respective countries.

5. Concluding Remarks

We analyze the firm's endogenous decision-making related to ECSR in each country in an open economy under situations in which transboundary pollution exists or does not exist.

These analyses lead to the following main results. First, the output of a good in one's own country at equilibrium decreases（increases）with the promotion of ECSR in one's own（other）country.

Secondly, when the level of ECSR in another country is higher（lower）than that in one's own country, the output of the good in one's own country at equilibrium will decrease（increase）with the degree of transboundary pollution. Thirdly, whether transboundary pollution exists or does not exist, the firm in each country does not adopt ECSR at equilibrium.

These analyses do not incorporate consideration of the effects of increasing demand of a good from promotion of ECSR. The ECSR activities of firms might increase the demand for the good. Accordingly, it is necessary to consider the effects of increasing demand for a good from promotion of ECSR in our model in the future. These analyses rely on the assumption of circumstances under which the degrees of transboundary pollution which affects from one country to another country are similar among countries. We assume symmetric emission's spillover

effects in our model. Accordingly, our future analyses will examine firms' endogenous decision-making related to ECSR in countries under asymmetric emission spillover effects.

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（1）The CR reporting rates by sector in 2017 were 81% for oil and gas, 81% for chemicals, and 80% for mining（KPMG, 2017, p.20）.

（2）Other theoretical studies of CSR and international markets in recent years include those of Wang et al.（2012）, Chang et al.（2014）, and Liu et al.（2018）. Wang et al.（2012）study how consumer-friendly initiatives of foreign exporting firms affect strategic tariff policy and welfare. Chang et al.（2014）examine the welfare implications of CSR in international markets under imperfect competition. Liu et al.（2018）examine the optimal degree of CSR promotion using an international oligopoly model.

（3）Liu et al.（2015）follow Manasakis et al.（2013）and consider an NGO certifier, which serves as a credible information disclosure mechanism of a firm’s ECSR.

（4）From the assumption that parameter A is sufficiently large, the sign of Eq.（9）is positive.