研究ノート

Environmental Corporate Social Responsibility and Environmental Tax under Asymmetric Emission Spillovers

Tadahisa Ohno

1. Introduction

Global warming, particularly the emission of greenhouse gases（GHG）by many countries, constitutes a daunting problem. The GHG emissions from one country affect not only that country but also neighboring and even distant countries. Governments in many countries induce various environmental policies such as direct regulation and environmental taxes to address difficulties of increasing GHG emissions. However, recently, many firms in many countries promote activities of Environmental Corporate Social Responsibility（ECSR）. In accordance with these activities, the firm might produce a good considering not only the profit but also its associated environmental damage. Regarding transboundary pollution, the conditions of transboundary pollution might be regarded as various cases for each country because the conditions of transboundary pollutions are affected by weather conditions. Therefore, when studying ECSR and environmental policies under circumstances in which transboundary pollution exists, one must consider various cases of emission spillovers.

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）analyzes how corporate environmentalism in a home country affects domestic welfare when domestic

and foreign governments impose emission taxes or provides export subsidies in an international oligopoly market. The study demonstrates that domestic welfare might be lower when the domestic firm is environmentally conscious than when it is a profit maximizer under conditions in which emission taxes and export subsidies are both available and when transboundary pollution exists.

Lambertini and Tampieri（2015）use a model of Cournot oligopoly to examine how socially responsible behavior affects firms' profits and social welfare when production entails an environmental externality. They consider a CSR firm that not only pursues profits but which also monitors all pollution produced by an industry and which is sensitive to consumer surplus. They specifically examine the weight which 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）use a differentiated duopoly model to examine 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 demonstrate 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. Their main result is that only the follower adopts ECSR in equilibrium; a first-mover advantage is apparent.

Ee et al.（2018）use a general equilibrium framework to examine how ECSR investments affect wage inequality between skilled and unskilled workers. They consider a two-sector economy with agricultural and manufacturing sectors in which ECSR activities are performed 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 empirically examine these two theoretical predictions.

Ohno（2019）investigates 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, 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 these earlier studies examine ECSR, they do not investigate the effects of promoting ECSR and imposing environmental taxes on environmental damage in each country under circumstances in which asymmetric emission spillovers exist. Jinji（2013）examines ECSR under circumstances in which domestic and foreign governments impose emission taxes or provide export subsidies in an international oligopoly market. Unlike the study described by Jinji（2013）, we consider asymmetric emission spillovers in an open economy(2).

We study the ECSR activities of a monopoly polluting firm and the introduction of environmental taxes in each country in an open economy under conditions in which asymmetric emission spillovers exist or do not exist. We analyze how ECSR promotion by a monopoly polluting firm in each country affects environmental damage while considering the various cases of emission spillovers. Moreover, we investigate how introduction of environmental taxes by the government in each country affects environmental damage considering the various cases of emission spillovers.

These analyses yield the following main results. First, when the environmental

tax rate in one's own country or the other country is higher, the environmental damage in the other（own）country decreases, at equilibrium, under circumstances in which transboundary pollution exists in one's own（other）country and does not exist in the other（own）country. Secondly, promotion of ECSR in the other（own）country decreases the environmental damage in the other（own）country, at equilibrium, under circumstances in which transboundary pollution exists in one's own（other）country and does not exist in the other（own）country.

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. Production of the good produces environmental pollution. Firms' emissions might lead to transboundary spillovers. The inverse demand function of the good is assumed as presented below.

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

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 equal among the countries. The cost function of the firm in country i is C（q_i）$=cq_i$. The government in country i imposes an environmental tax on the firm in country i. 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.

Profit of the firms in country i is $\pi_i = Pq_i - cq_i - t_i q_i$. Therein, t_i denotes the

environmental tax rate in country *i*. From eq. (1), the firm profit in country *i* is

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

For this analysis, it is assumed that $A \equiv a - c$ (>0). Here, we assume that parameter A is sufficiently large. This assumption means that the willingness to pay for the good is sufficiently large. The total quantity of emissions in country *i* is

$$s_i = (1 - \lambda_i)q_i + \lambda_j q_j. \quad (3)$$

In eq. (3), term s_i denotes the total quantity of the emissions in country *i*. Parameter λ_i represents the degree of spillover effects in country *i* ($0 \leq \lambda_i \leq 1$).

The extent of the environmental damage is assumed as

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

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

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) and the environmental damage in country *i* eq. (4), the firm's objective function in country *i* is calculable as presented below.

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

3. Firm Decision

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

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

The first-order condition can be derived as presented below.

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

In that equation, 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 marginal cost of the production of the good and the environmental tax and marginal increase of environmental damage from the supply of the good in country *i*. The right-hand side of eq.（7）stands for the marginal cost from the good in country *i*.

Therefore, eq.（7）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.（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

$$q_i^r = \frac{A - q_j - t_i - \theta_i \alpha_i (1 - \lambda_i)}{2} \quad (8)$$

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 amount of output of private goods, which are decided by the firm in country *j*.

From the eq.（8）, the output of the good in country *i*, at equilibrium, is the following(3).

$$q_i^* = \frac{A + \theta_j \alpha_j (1 - \lambda_j) - 2\theta_i \alpha_i (1 - \lambda_i) + t_j - 2t_i}{3} \quad (9)$$

4. Effects of ECSR and the Environmental Tax

We analyze the case in which spillover effects do not exist in either country ($\lambda_1 = 0$, $\lambda_2 = 0$).

From eq. (9), the output of the good in country 1, at equilibrium, is

$$q_1^* = \frac{A+\theta_2\alpha_2-2\theta_1\alpha_1+t_2-2t_1}{3} . \quad (10)$$

From eq. (9), the output of the good in country 2, at equilibrium, is

$$q_2^* = \frac{A+\theta_1\alpha_1-2\theta_2\alpha_2+t_1-2t_2}{3} . \quad (11)$$

From eq. (10), the environmental damage in country 1, at equilibrium, is

$$D_1^* = \frac{A\alpha_1+\theta_2\alpha_2\alpha_1-2\theta_1\alpha_1^2+\alpha_1t_2-2\,\alpha_1t_1}{3} . \quad (12)$$

From eq. (11), the environmental damage in country 2, at equilibrium, is

$$D_2^* = \frac{A\alpha_2+\theta_1\alpha_1\alpha_2-2\theta_2\alpha_2^2+\alpha_2t_1-2\,\alpha_2t_2}{3} . \quad (13)$$

From Eq. (12), with regard to environmental damage D_1^*, the results of comparative static analyses of the environmental tax indicate the following.

$$\frac{dD_1^*}{dt_1} = -\frac{2}{3}\alpha_1 < 0 \quad (14)$$

$$\frac{dD_1^*}{dt_2} = \frac{\alpha_1}{3} > 0 \quad (15)$$

The interpretation of eq. (14) is the following. The higher the environmental tax rate in one's own country is set, the greater the degree to which the output of the good in the country decreases, at equilibrium. The decrease of the output in one's own country decreases emissions in one's own country because transboundary pollution does not exist. Accordingly, the higher environmental tax rate in one's own country decreases environmental damage.

The interpretation of eq. (15) is the following. The higher the environmental

tax rate in the other country becomes, the greater the degree to which the output of the good in one's own country increases, at equilibrium. The increase of the output in one's own country increases the emissions in one's own country because transboundary pollution does not exist. Accordingly, the higher the environmental tax rate in the other country becomes, the more the environmental damage in one's own country increases.

From Eq. (12), with regard to environmental damage D_1^*, the results of comparative static analyses of the promotion of ECSR indicate the following.

$$\frac{dD_1^*}{d\theta_1} = -\frac{2\alpha_1^2}{3} < 0 \qquad (16)$$

$$\frac{dD_1^*}{d\theta_2} = \frac{\alpha_1\alpha_2}{3} > 0 \qquad (17)$$

The interpretation of eq. (16) is the following. The promotion of ECSR in one's own country decreases the output of the good in the country, at equilibrium. The decrease of the output in one's own country decreases the emissions in one's own country because transboundary pollution does not exist. Accordingly, the promotion of ECSR in one's own country decreases the environmental damage in the country, at equilibrium.

The interpretation of eq. (17) is the following. The promotion of ECSR in the other country increases the output of the good in one's own country, at equilibrium. The increase of the output in one's own country increases the emissions in the country because transboundary pollution does not exist. Accordingly, the promotion of ECSR in the other country increases the environmental damage in one's own country, at equilibrium.

Next, we analyze the case in which spillover effects exist in each country (λ_1= 1 , λ_2= 1).

From eq. (9), the output of the good in country 1, at equilibrium, is

$$q_1^* = \frac{\mathrm{A}+t_2-2t_1}{3} \ . \qquad (18)$$

From eq. (9), the output of the good in country 2, at equilibrium, is

$$q_2^* = \frac{A+t_1-2t_2}{3} \quad . \tag{19}$$

From eq. (19), the environmental damage in country 1, at equilibrium, is

$$D_1^* = \frac{A\alpha_1+\alpha_1 t_1-2\,\alpha_1 t_2}{3} \quad . \tag{20}$$

From eq. (18), the environmental damage in country 2, at equilibrium, is

$$D_2^* = \frac{A\alpha_2+\alpha_2 t_2-2\,\alpha_2 t_1}{3} \quad . \tag{21}$$

From Eq. (20), with regard to environmental damage D_1^*, the results of comparative static analyses about the environmental tax indicate the following.

$$\frac{dD_1^*}{dt_1} = \frac{\alpha_1}{3} > 0 \tag{22}$$

$$\frac{dD_1^*}{dt_2} = -\frac{2\alpha_1}{3} < 0 \tag{23}$$

From eq. (22) and eq. (23), one can obtain the following proposition.

Proposition 1

When the environmental tax rate in one's own country (another country) is higher, the environmental damage in own country increases (decreases), at equilibrium, under conditions in which transboundary pollution exists.

The interpretation of proposition 1 is the following. In the case in which spillover effects exist in each country (λ_1= 1 , λ_2= 1). The emissions in the other country affect the environmental damage in one's own country.

The higher the environmental tax rate in one's own country becomes, the more the output of the good in the other country increases, at equilibrium. The increase of the output in the other country increases the emissions in one's own country because transboundary pollution exists. Accordingly, the higher the environmental

tax rate in one's own country becomes, the greater the degree to which the environmental damage in one's own country increases.

The higher the environmental tax rate in the other country becomes, the greater the degree to which the output of the good in the other country decreases, at equilibrium. The decrease of the output in the other country decreases the emissions in one's own country because transboundary pollution exists. Accordingly, the higher the environmental tax rate in the other country becomes, the greater the degree to which the environmental damage in one's own country decreases.

Next, we analyze the case in which spillover effects exist in country 1 and do not exist in country 2 ($\lambda_1 = 1$, $\lambda_2 = 0$).

From eq. (9), the output of the good in country 1, at equilibrium, is

$$q_1^* = \frac{A+\theta_2\alpha_2+t_2-2t_1}{3} \ . \tag{24}$$

From eq. (9), the output of the good in country 2, at equilibrium, is

$$q_2^* = \frac{A-2\theta_2\alpha_2+t_1-2t_2}{3} \ . \tag{25}$$

From eq. (4), the environmental damage in country 1, at equilibrium, is

$$D_1^* = 0 \ . \tag{26}$$

From eq. (24) and eq. (25), the environmental damage in country 2, at equilibrium, is

$$D_2^* = \frac{2A\alpha_2-\theta_2\alpha_2^2-\alpha_2t_1-\alpha_2t_2}{3} \ . \tag{27}$$

From eq. (27), with regard to environmental damage D_2^*, the results of comparative static analyses of the environmental tax indicate the following.

$$\frac{dD_2^*}{dt_1} = -\frac{\alpha_2}{3} < 0 \tag{28}$$

$$\frac{dD_2^*}{dt_2} = -\frac{\alpha_2}{3} < 0 \tag{29}$$

From eq. (28) and eq. (29), one can obtain the following proposition.

Proposition 2

When the environmental tax rate in one's own country or the other country is higher, the environmental damage in the other country, at equilibrium, decreases under conditions in which transboundary pollution exists in one's own country and does not exist in the other country.

The interpretation of proposition 2 is the following. We consider a situation in which transboundary pollution exists in one's own country and does not exist in the other country. The emission does not exist in one's own country in this situation. Furthermore, then, the emissions of one's own and the other country exist in the other country. The increase of the environmental tax rate in one's own country has two effects. First, the increase of environmental tax rate in one's own country decreases the output in one's own country. Second, the increase of environmental tax rate increases the output in the other country. Here, the first effect is greater than the second effect. Accordingly, the higher the environmental tax rate in one's own country becomes, the greater the degree to which the environmental damage in the other country decreases.

However, the increase of environmental tax rate in the other country has two effects. First, the increase of the environmental tax rate in the other country decreases the output in the other country. Second, the increase of the environmental tax rate increases the output of the good in one's own country. Here, the first effect is greater than the second effect. Accordingly, the higher the environmental tax rate in the other country becomes, the greater the degree to which the environmental damage in the other country decreases.

From eq. (27), with regard to environmental damage D_2^*, the results of comparative static analyses of the promotion of ECSR indicate the following.

$$\frac{dD_2^*}{d\theta_2} = -\frac{\alpha_2^2}{3} < 0 \qquad (30)$$

From eq. (30), one can obtain the following proposition.

Proposition 3

Promotion of ECSR in the other country decreases the environmental damage in the other country, at equilibrium, under conditions in which transboundary pollution exists in one's own country and does not exist in the other country.

The interpretation of proposition 3 is the following. The promotion of ECSR in the other country has two effects. First, the promotion of ECSR increases the output in one's own country, at equilibrium. Second, the promotion of ECSR decreases the output in the other country, at equilibrium. Here, the second effect is larger than the first effect. Accordingly, the more ECSR activities in the other country promote, the more the environmental damage in the other country decreases.

Next, we analyze the case in which spillover effects exist in country 2 and do not exist in country 1 ($\lambda_1 = 0$, $\lambda_2 = 1$).

From eq. (9), the output of the good in country 1, at equilibrium, is

$$q_1^* = \frac{A - 2\theta_1\alpha_1 + t_2 - 2t_1}{3} \ . \qquad (31)$$

From eq. (9), the output of the good in country 2, at equilibrium, is

$$q_2^* = \frac{A + \theta_1\alpha_1 + t_1 - 2t_2}{3} \ . \qquad (32)$$

From eq. (31) and eq. (32), the environmental damage in country 1, at equilibrium, is

$$D_1^* = \frac{2A\alpha_1 - \theta_1\alpha_1^2 - \alpha_1 t_2 - \alpha_1 t_1}{3} \ . \qquad (33)$$

From eq. (4), the environmental damage in country 2, at equilibrium, is

$$D_2^* = 0 \ . \tag{34}$$

From eq. (33), with regard to environmental damage D_1^*, the results of comparative static analyses indicate the following.

$$\frac{dD_1^*}{dt_1} = -\frac{\alpha_1}{3} < 0 \tag{35}$$

$$\frac{dD_1^*}{dt_2} = -\frac{\alpha_1}{3} < 0 \tag{36}$$

From eq. (35) and eq. (36), one can obtain the following proposition.

Proposition 4

When the environmental tax rate in one's own country or in another country is higher, the environmental damage in one's own country, at equilibrium, decreases under conditions in which transboundary pollution exists in the other country and does not exist in one's own country.

The interpretation of proposition 4 is the following. We consider a situation in which transboundary pollution does not exist in one's own country, but exists in the other country. The emissions of one's own and the other country exist in one's own country. The increase of the environmental tax rate in one's own country has two effects. First, the increase of the environmental tax rate in one's own country decreases the output in one's own country. Second, the increase of the environmental tax rate in one's own country increases the output in the other country. Here, the first effect is greater than the second effect. Accordingly, the higher the environmental tax rate in one's own country becomes, the greater the degree to which the environmental damage in one's own country decreases.

However, an increase of environmental tax rate in the other country has two effects. First, the increase of environmental tax rate in the other country increases the output in one's own country. Second, the increase of environmental tax rate

in the other country decreases the output of the good in the other country. Here, the second effect is greater than the first effect. Accordingly, the higher the environmental tax rate in the other country becomes, the greater the degree to which the environmental damage in one's own country decreases.

From eq. (33), with regard to environmental damage D_1^*, the results of comparative static analyses indicate the following.

$$\frac{dD_1^*}{d\theta_1} = -\frac{\alpha_1^2}{3} < 0 \qquad (37)$$

From eq. (37), one can obtain the following proposition.

Proposition 5

Promotion of ECSR in one's own country decreases the environmental damage in one's own country, at equilibrium, under conditions in which transboundary pollution exists in the other country and does not exist in one's own country.

The interpretation of proposition 5 is the following. The promotion of ECSR in one's own country has two effects. First, the effects of promotion of ECSR in one's own country decrease the output in one's own country, at equilibrium. Second, the effect that the promotion of ECSR in one's own country increases the output in the other country, at equilibrium. Here, the first effect is greater than the second effect. Accordingly, the more ECSR activities in one's own country are promoted, the greater the degree to which environmental damage in one's own country decreases.

5. Concluding Remarks

This paper presented analyses of ECSR and environmental tax effects in each country in an open economy under circumstances in which asymmetric emission

spillovers exist. Especially, we examine the effects of firm adoption of ECSR and introduction of environmental taxation by the government in each country on environmental conditions considering the various cases of emission spillovers.

This paper presents the following main results. First, when the environmental tax rate in one's own country or the other country is higher, the environmental damage in the other（own）country, at equilibrium, decreases under circumstances in which transboundary pollution exists in one's own（other）country and does not exist in the other（own）country. Next, promotion of ECSR in the other（own）country decreases the environmental damage in the other（own）country, at equilibrium, under circumstances in which transboundary pollution exists in one's own（other）country and does not exist in the other（own）country.

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（1）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.

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

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