Strategic Environmental and Trade Policies in an Environmental Mixed Duopoly*

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Abstract

The effects of corporate environmentalism or self-regulation are examined in the context of strategic environmental and trade policies. An environmentally conscious home firm competes with a private profit maximizing foreign firm in a third-country market. The production of goods causes pollution. The home and the foreign governments non-cooperatively set emission taxes and export subsidies. It is shown that if pollution is purely local or the environmental consciousness of the home firm is weak, the environmental consciousness of the home firm has no effects on welfare and pollution. If pollution is at least partially transboudary and the environmental consciousness of the home firm is sufficiently strong, home welfare is lower compared to the case where the home firm is the profit maximizer. Moreover, a symmetric reduction in export subsidies may not be in the interest of the home country because it may reduce home welfare by shifting rents from the home to the foreign country.

Keywords: corporate environmentalism; environmental mixed duopoly; self-regulation; strategic environmental and trade policy.

JEL classification: F12; F13; Q28.

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1 Introduction

Corporate environmentalism is a growing phenomenon in developed countries. In the standard economics framework, private firms care about the environment only when environmental regulations are implemented. In the real world, by contrast, firms emphasize more and more that they care about the environment and that their products and production processes are environmentally friendly. For example, major Japanese oil companies, such as Cosmo Oil, Nippon Oil, Showa Shell, implement their own environmental activities, including the compression of gases associated with oil production in oil fields and reinjection of them into the ground and the reduction in emissions at oil refineries.[1] Another example is that the chemical industry associations in 47 countries participate in a voluntary program called "Responsible Care" designed to improve the industry's environmental, safety, and health performance under the initiative of International Council of Chemical Associations (ICCA).[2] Under this initiative chemical industry associations conduct their own environmental activities to reduce emissions and wastes and enhance recycling.

In the literature, this phenomenon is analyzed in the framework of *self-regulation* or *voluntary environmental agreements* (Lutz, Lyon, and Maxwell, 2000; Maxwell, Lyon, and Hackett, 2000; Poyago-Theotoky, 2000; Conrad, 2001).[3] The existing papers have shown that profit-maximizing firms which do not really care about the environment voluntarily reduce their emission levels, because they rationally anticipate the government's actions in the form of introducing or tightening environmental regulations and try to weaken the forthcoming regulations by voluntarily committing to environmentally friendly actions (Lutz, Lyon, and Maxwell, 2000; Poyago-Theotoky, 2000; Conrad, 2001). A key element is that firms move before

[1] The details on their environmental activities can be found on their web sites. Cosmo Oil: http://www.cosmo-oil.co.jp/eng/index.html, Nippon Oil: http://www.eneos.co.jp/, Showa Shell: http://www.showa-shell.co.jp/english/index.html.

[2] Responsible Care was first established by Canadian Chemical Producers Association in 1985. The U.S. Chemical Manufacturers Association and the British Chemical Industries Association followed with similar programs in 1989 (Lyon and Maxwell, 2001). For details, see ICCA's web site: http://www.icca-chem.org/.

[3] Lyon and Maxwell (2001) provides an excellent survey on this issue.

the government decides environmental regulations.[4] The self-regulation in this case tends to reduce social welfare. Another possible motive for firms to conduct self-regulation is that voluntary abatement preempts political action by consumers for tougher environmental regulations (Maxwell, Lyon, and Hackett, 2000). Although the preemptive self-regulation leads to a weaker environmental regulation and hence a higher emission, Maxwell, Lyon, and Hackett (2000) show that social welfare under preemption can be higher if the reduction in regulatory and legislative costs are taken into account.

This present paper explores another channel of corporate environmentalism. Unlike the existing papers that assume firms maximize private profits, I ask what if firms *do* really care about the environment. Is it always desirable for the economy that private firms voluntarily care about the environment? In order to address this issue, I construct a model in which one firm that takes environmental damages into account competes with one usual firm that maximizes private profits in the framework of the third-market trade model with strategic environmental and trade policies.[5] The basic set-up of the model follows that in Walz and Wellisch (1997). I extend their model in the way that one of the two firms includes global environmental damages in its objective function and examine whether any different implications can be obtained.

The model in this paper can be considered as an extension of a mixed duopoly, in which a welfare maximizing public firm interacts with a profit maximizing private firm (See, for example, Cremer, Marchand, and Thisse, 1989; De Fraja and Delbono, 1989; Matsumura, 1998; Matsushima and Matsumura, 2003a, b). The main difference from the standard model of mixed duopoly is that in my model one firm maximizes the sum of private profits and the *environmental quality* rather than

[4]Petrakis and Xepapadeas (1999) also show that firm's precommitment to environmental innovation induces overinvestment in abatement, which lowers the emission tax. However, they argue this issue as the credibility of environmental regulations.

[5]The study on strategic trade policies is pioneered by Brander and Spencer (1985). The literature on strategic environmental policies include Conrad (1993), Barrett (1994), Kennedy (1994a, b), Wlaz and Wellisch (1997), Tanguay (2001), and Burguet and Sempere (2003).

social welfare. I call this firm as *environmentally conscious firm* and the market structure as *environmental mixed duopoly*.

The main results in this paper are as follows. I show that effects of the existence of the environmentally conscious firm crucially depend on whether pollution is local or transboundary. First, when pollution is purely local, then the existence of the environmentally conscious firm has no effect on social welfare and pollution level, compared to those in the case where both firms maximize their private profits. This is because environmentally friendly actions are fully offset by adjustments in the environmental regulation. Second, when pollution is at least partially transboundary, if the degree of the environmental consciousness of the firm is very strong, social welfare of the country in which the environmentally conscious firm is located is reduced by the existence of the firm, compared to the case in which the firm is the usual profit maximizer. Moreover, trade liberalization in the form of a symmetric reduction in export subsidies may reduce social welfare of the country in which the environmentally conscious firm is located.

The rest of the paper is organized in the following way. Section 2 sets up the model. Section 3 analyzes the effects of the existence of the environmentally conscious firm on social welfare in the context of strategic environmental and trade policies. Section 4 examines welfare effects of trade liberalization in the presence of corporate environmentalism. Section 5 concludes.

2 The Model

I examine a model in which a home and a foreign firm export a homogenous good to a third market. An asterisk is used to represent a foreign variable. The basic set-up of the model follows that in Walz and Wellisch (1997). The production of each output unit x and x^* causes a constant per unit emission e. Each firm can reduce the emission by abatement efforts. In order to reduce the fraction $a \in [0, 1]$ per emission unit, the firm incurs abatement cost $c(a)e$ per output unit, where $c'(a) > 0$

and $c''(a) > 0$. The home and the foreign governments impose an emission tax t and t^*, respectively, on each unit of the remaining emissions and also provide an export subsidy per output unit s and s^*, respectively. A key assumption is that the emission tax must be non-negative, i.e., $t, t^* \geq 0$. This is because an emission *subsidy* is politically infeasible. The export subsidy, on the other hand, can be positive or negative, which means that an export tax is not ruled out.

The home firm is *environmentally conscious*. That is, it takes (either partially or fully) into account the global environmental damages. The home firm's objective function is hence given by

$$\pi - \theta(D + D^*), \tag{1}$$

where π is private profits, $\theta \in [0, 1]$ represents the home firm's degree of environmental consciousness (which is exogenously given), and

$$D = d(e(1-a)x + \alpha e(1-a^*)x^*) \tag{2}$$

$$D^* = d(e(1-a^*)x^* + \alpha e(1-a)x) \tag{3}$$

are environmental damages in the home and the foreign country, respectively, where $d > 0$ represents the marginal environmental damage and $\alpha \in [0, 1]$ measures how much the local environment is affected by the emission in the other country.[6] If $\alpha = 0$, pollution is local. If $\alpha = 1$, on the other hand, pollution is perfectly transboundary. The foreign firm is the usual private profit maximizer and maximizes its private profits π^*.

The structure of the game is as follows. In stage 1, the home and the foreign governments simultaneously choose their emission taxes and export subsidies. In stage 2, the two firms compete in quantities. The solution concept is subgame perfect Nash equilibrium.

[6] I use a linear damage function for simplicity. The qualitative results do not change even if a more general function is used, except for some more conditions are required.

3 Corporate Environmentalism with Strategic Environmental and Trade Policies

3.1 Firm behaviour

I start with examining stage 2. The home and the foreign firms' private profits are respectively given by

$$\pi = R(x, x^*) - C(x) + \{s - c(a)e - te(1-a)\}x, \tag{4}$$

$$\pi^* = R^*(x, x^*) - C(x^*) + \{s^* - c(a^*)e - t^*e(1-a^*)\}x^*, \tag{5}$$

where $R(x, x^*)$ and $C(x)$ (and $R^*(x, x^*)$ and $C(x^*)$, respectively) denote the home firm's (the foreign firm's, respectively) revenue and cost functions, respectively. I assume that $R_x > 0$, $R_{x^*} < 0$, $R_{xx} < 0$, and $R_{xx^*} < 0$, whereby subscripts stand for partial derivatives, i.e., $R_x \equiv \partial R(x, x^*)/\partial x$, $R_{xx^*} \equiv \partial^2 R(x, x^*)/\partial x \partial x^*$, and so on. The last inequality implies that the outputs are *strategic substitutes*. I also assume that $C'(\cdot) > 0$ and $C''(\cdot) \geq 0$. I assume corresponding conditions for the foreign revenue and cost functions.

Since the home firm maximizes Eq. (1), the first-order conditions (FOCs) are given by $\pi_x - \theta(D_x + D_x^*) = 0$ and $\pi_a - \theta(D_a + D_a^*) = 0$, which respectively yield

$$R_x - C'(x) + s - c(a)e - te(1-a) - \theta d(1+\alpha)e(1-a) = 0 \tag{6}$$

$$t - c'(a) + \theta d(1+\alpha) = 0. \tag{7}$$

Second-order conditions (SOCs) are satisfied because $\pi_{xx} - \theta(D_{xx} + D_{xx}^*) = R_{xx} - C''(x) < 0$ and $\pi_{aa} - \theta(D_{aa} + D_{aa}^*) = -c''(a)ex < 0$. Since the foreign firm maximizes Eq. (5), the FOCs are given by

$$R_{x^*}^* - C'(x^*) + s^* - c(a^*)e - t^*e(1-a^*) = 0 \tag{8}$$

$$t^* - c'(a^*) = 0. \tag{9}$$

Similar to the home firm's, SOCs are satisfied.

Totally differentiate Eqs. (6) and (8) and use Eqs. (7) and (9) to yield

$$dx/dt = -e(1-a)dx/ds = e(1-a)\pi_{x^*x^*}^*/\Omega < 0, \tag{10}$$

$$dx/dt^* = -e(1-a^*)dx/ds^* = -e(1-a^*)\pi_{xx^*}/\Omega > 0, \quad (11)$$

$$dx^*/dt = -e(1-a)dx^*/ds = -e(1-a)\pi^*_{x^*x}/\Omega > 0, \quad (12)$$

$$dx^*/dt^* = -e(1-a^*)dx^*/ds^* = e(1-a^*)\pi_{xx}/\Omega < 0, \quad (13)$$

where $\Omega \equiv \pi_{xx}\pi^*_{x^*x^*} - \pi_{xx^*}\pi^*_{x^*x}$ is assumed to be positive for stability. These results are the same as those shown by Walz and Wellisch (1997).

3.2 Strategic environmental and trade policies

I now turn to stage 1. Social welfare in each exporting country consists of the domestic firm's private profits minus domestic environmental damages and social cost of export subsidy plus tax revenue from the emission tax. Thus, home welfare W is given by

$$W = \pi - D - sx + te(1-a)x. \quad (14)$$

The foreign welfare is defined in a similar way. Each government chooses the emission tax and the export subsidy to maximize its domestic social welfare, taking the other country's emission tax and export subsidy as given.

The FOCs for the home government are given by

$$\frac{dW}{ds} = (\pi_{x^*} - D_{x^*})\frac{dx^*}{ds} - s\frac{dx}{ds} + e(1-a)\frac{dx}{ds}\{t - d(1-\theta(1+\alpha))\} = 0 \quad (15)$$

$$\frac{dW}{dt} = -e(1-a)\frac{dW}{ds} - ex\frac{da}{dt}\{t - d(1-\theta(1+\alpha))\} \leq 0, \quad (16)$$

where Eqs. (6) and (7) are used. Similarly, the FOCs for the foreign government are given by

$$\frac{dW^*}{ds^*} = (\pi^*_x - D^*_x)\frac{dx}{ds^*} - s^*\frac{dx^*}{ds^*} + e(1-a^*)\frac{dx^*}{ds^*}(t^* - d) = 0 \quad (17)$$

$$\frac{dW^*}{dt^*} = -e(1-a^*)\frac{dW^*}{ds^*} - ex^*\frac{da^*}{dt^*}(t^* - d) \leq 0, \quad (18)$$

where Eqs. (8) and (9) are used. The foreign country's optimal non-cooperative emission tax, $\hat{t}^*$, is obtained by substituting Eq. (17) into Eq. (18):

$$\hat{t}^* = d. \quad (19)$$

The foreign country's optimal non-cooperative export subsidy, $\hat{s}^*$, is, on the other hand, obtained by substituting Eqs. (11) and (13) into Eq. (17):

$$\hat{s}^* = -\frac{(\pi_x^* - D_x^*)\pi_{xx^*}}{\pi_{xx}} > 0. \tag{20}$$

These optimal policies are the same as those shown by Walz and Wellisch (1997), except for the effect of transboundary pollution.[7] If pollution is purely local, Eq. (20) is reduced to $\hat{s}^* = -\pi_x^*\pi_{xx^*}/\pi_{xx}$, which is exactly the same as that in Walz and Wellisch. When two policy instruments are available and the government can commit to these policies before firms' decisions, there is a division of labour between the two policy instruments. That is, the emission tax is used to internalize marginal local damage and the positive export subsidy is used to shift rents from the rival firm to its domestic firm.[8]

In order to examine the home firm's optimal non-cooperative policies, it is useful to distinguish the two cases: (i) pollution is purely local; and (ii) pollution is at least partially transboundary.

3.3 Local pollution

I first consider the case in which pollution is purely local, i.e., $\alpha = 0$. In this case, the home government's FOCs (15) and (16) together with Eqs. (10) and (12) yield the optimal non-cooperative emission tax and export subsidy:

$$\hat{t} = (1-\theta)d \tag{21}$$

$$\hat{s} = -\frac{\pi_{x^*}\pi_{x^*x}^*}{\pi_{x^*x^*}^*} > 0, \tag{22}$$

respectively. Note that since $\theta \in [0,1]$, then it holds that $\hat{t} \in [0,d]$. Like the foreign policies, there is a division of labour between the two instruments. The formula of the optimal emission tax (21) is different from the foreign counterpart (19). However, it fully internalizes marginal environmental damage, as shown in the following lemma.

[7] Note that Walz and Wellisch (1997) considers local pollution only.

[8] Similar result is shown by Kennedy (1994b) in the context of emission tax and production subsidy and by Spencer and Brander (1983) in the context of R&D subsidy and export subsidy.

Lemma 1 *When $\alpha = 0$, the optimal non-cooperative emission tax in the home country is chosen so that marginal environmental damage is fully internalized.*

Proof. Substitute the optimal emission tax (21) into the home firm's FOC (7) and set $\alpha = 0$ to obtain

$$c'(a) = d. \tag{23}$$

That is, the abatement effort is chosen so that marginal abatement cost is equal to marginal environmental damage. □

This lemma implies that when the firm is somewhat environmentally conscious and is willing to engage voluntarily in higher abatement activity, the environmental policy is adjusted so that the self-regulation by the firm is taken into account. In fact, when $\theta = 1$, that is, when the home firm fully takes into account the local environmental damage, the optimal emission tax is zero.

Since the emission tax is adjusted in the manner specified in Lemma 1, I obtain the following result.

Proposition 1 *When $\alpha = 0$, the environmental consciousness of the home firm at any degree has no effect on social welfare and pollution level, compared to those in the case where the home firm is the profit maximizer.*

Proof. The home firm's abatement activity level in equilibrium, $\hat{a}$, is determined by Eq. (23), which is independent of θ. Substitute $\hat{a}$, the optimal emission tax (21), and the optimal export subsidy (22) into the home firm's another FOC (6) to yield

$$R_x(x, x^*) - C'(x) + \hat{s} - c(\hat{a})e - de(1 - \hat{a}) = 0, \tag{24}$$

which is also independent of θ. Thus, variables in equilibrium are independent of θ. □

This result shows that when pollution is purely local, the home firm's environmental consciousness only lowers the level of emission tax and has no real effect on environmental damages nor on social welfare.

3.4 Transboundary pollution

Now, is there any change if pollution is at least partially transboundary? When $\alpha > 0$, the home government's FOCs (15) and (16) together with Eqs. (10) and (12) yield respectively the optimal non-cooperative emission tax and export subsidy:

$$\tilde{t} = \begin{cases} (1-\theta(1+\alpha))d & \text{if } \theta \leq 1/(1+\alpha) \\ 0 & \text{if } \theta > 1/(1+\alpha) \end{cases} \tag{25}$$

$$\tilde{s} = \begin{cases} -\dfrac{(\pi_{x^*} - D_{x^*})\pi^*_{x^*x}}{\pi^*_{x^*x^*}} > 0 & \text{if } \theta \leq 1/(1+\alpha) \\ -\dfrac{(\pi_{x^*} - D_{x^*})\pi^*_{x^*x}}{\pi^*_{x^*x^*}} + e(1-a)d(\theta(1+\alpha)-1) > 0 & \text{if } \theta > 1/(1+\alpha). \end{cases} \tag{26}$$

These optimal policies are crucially based upon the assumption that the emission tax is non-negative. When $\theta \leq 1/(1+\alpha)$, the optimal emission tax is given by an interior solution and the result is qualitatively similar to that in the case of local pollution. That is, there is a clear division of labour between the two instruments and the optimal emission tax is adjusted so that marginal local damage is internalized.

When $\theta > 1/(1+\alpha)$, on the other hand, the optimal emission tax is given by a corner solution and is equal to zero. In this case, the environmentally conscious home firm *overinternalizes* the externality from the home government's point of view. This is because in the non-cooperative setting the home government only cares local damages from pollution, while the environmentally conscious home firm takes global damages into account. When the home firm overinternalizes the externality, the optimal emission policy is an *emission subsidy*, which *disinternalizes* part of overinternalized externality. However, since an emission subsidy is not feasible, the home government set $t = 0$, i.e., the lowest possible emission tax. At the same time, the home government chooses a higher export subsidy. Note that in the second line in (26) the second term is positive. This is because in addition to the rent-shifting motive, an export subsidy partially substitutes the role of disinternalizing the pollution.

These results are summarized in the following lemma.

Lemma 2 *Suppose that $\alpha > 0$. Then, (i) if $\theta \leq 1/(1+\alpha)$, the optimal non-cooperative emission tax in the home country is chosen so that marginal damage is fully internalized. (ii) If $\theta > 1/(1+\alpha)$, the optimal non-cooperative emission tax in the home country is zero. At the same time, a higher export subsidy is chosen.*

Proof. For the first part of the lemma, substitute the first line in (25) into the home firm's FOC (7) to obtain

$$c'(a) = d.$$

The second part follows directly from the second lines in (25) and (26). □

Note that when $\theta = 1/(1+\alpha)$, the externality that is internalized by the environmentally conscious home firm coincides with the local environmental damages, and hence the optimal emission tax is just equal to zero.

Unlike the case of local pollution, when pollution is at least partially transboundary, the existence of the environmentally conscious firm may have some effect on the exporting country's social welfare. In fact, the environmentally conscious home firm reduces home welfare if its environmental consciousness is sufficiently high, as shown in the following proposition.

Proposition 2 *Suppose that $\alpha > 0$. If $\theta > 1/(1+\alpha)$, home welfare is lower than that in the case where the home firm is the profit maximizer.*

Proof. Substitute $\tilde{t} = 0$ into the home firm's FOC (7) to obtain

$$c'(a) = \theta(1+\alpha)d. \tag{27}$$

Let $\tilde{a}$ be the abatement level that satisfies Eq. (27). Since $\theta > 1/(1+\alpha)$, it holds that $\theta(1+\alpha)d > d$. Then, since $c''(a) > 0$, it holds that $\tilde{a} > \hat{a}$, where $\hat{a}$ is defined by Eq. (23). Now, I have

$$dW/da = -(c'(a) - d)ex.$$

Then, evaluate dW/da at $a = \tilde{a}$ to yield

$$dW/da|_{a=\tilde{a}} = -(\theta(1+\alpha)d - d)ex < 0,$$

because $\theta(1+\alpha) > 1$. A lower abatement improves social welfare because $d^2W/da^2 = -c''(a)ex < 0$. $\square$

The welfare loss stems from the home firm's overinvestment in abatement activity. As discussed above, since the environmental policy cannot be used to disinternalize the externality, the export subsidy substitutes the role of disinternalizing the externality. However, since the export subsidy is a less-efficient policy instrument to control pollution from the production of goods, the export subsidy cannot perfectly substitute the role of emission tax. Hence, substitution of a (negative) emission tax by an export subsidy causes overinvestment in abatement effort and hence reduces home welfare.[9]

Proposition 2 implies that the corporate environmentalism may be unfavourable to its domestic welfare.

4 Welfare Effects of Trade Liberalization in the Presence of Corporate Environmentalism

Walz and Wellisch (1997) have shown that trade liberalization in the form of a symmetric reduction in export subsidies improves the exporting countries' welfare, while it reduces world welfare. In this section, I examine whether their result still holds in an environmental mixed duopoly.

In order to address this issue in a tractable manner, it is useful to use specific functional forms, as Walz and Wellisch (1997) have done in their analysis. I assume that the inverse demand function in the third market is given by

$$p(X) = h - bX, \tag{28}$$

where $X = x + x^*$. I also assume the cost function is given by $C(x) = cx$.

[9] Petrakis and Xepapadeas (1999) also show that self-regulation causes overinvestment in abatement activity and reduces social welfare in the framework of monopoly in a closed economy. In their model, the crucial factor to induce the overinvestment is the government's inability to precommit to a specific emission tax.

Consider now a symmetric reduction in export subsidies. As was shown by Walz and Wellisch (1997), in response to an decrease in the export subsidy, each government has an incentive to *reduce* its emission tax, i.e., $dt/ds > 0$ and $dt^*/ds^* > 0$.[10] However, the decrease in the emission tax does not fully compensate the firm for the lower export subsidy, i.e., $e(1-a)dt/ds < 1$ and $e(1-a^*)dt^*/ds^* < 1$.[11] Although the reduced emission taxes worsen the environmental damages, the exporting countries' monopoly power in the third market is increased and the exporting countries move towards the direction of joint profit maximization.[12]

The above argument is still true for the foreign country in my model. On the other hand, if the pollution is at least partially transboundary and if the home firm's environmental consciousness is sufficiently strong, then the home government cannot lower its emission tax after a symmetric reduction in export subsidies. This is because the home emission tax is already at the lowest possible level before the trade liberalization. Thus, the reduction in the home export subsidy is not offset by the adjustment in the home emission tax, while the reduction in the foreign export subsidy is partially offset by the reduction in the foreign emission tax. This widens the cost difference between the two firms and hence the symmetric reduction in export subsidies may have asymmetric welfare effects on the two countries.

Proposition 3 *Whenever pollution is local or global, a symmetric reduction in export subsidies improves foreign welfare. The home welfare, on the other hand, may be reduced by the symmetric reduction in export subsidies, if* $\alpha > 0$ *and* $\theta > 1/(1+\alpha)$.

Proof. See Appendix. □

As shown in Appendix, the home welfare is reduced by the symmetric reduction in export subsidies if the decrease in the foreign emission tax in response to the symmetric reduction in export subsidies is sufficiently large. This is because a

[10] See Appendix 1 in Walz and Wellisch (1997) for the proof.

[11] See Appendix 1 in Walz and Wellisch (1997) for the proof.

[12] This result is in line with that in Copeland (1990). He shows that trade negotiations causes distortion in other policy instruments while still leading to welfare improvement in the negotiating countries.

stronger response is more beneficial to the foreign firm and hence more detrimental to the home firm.

The welfare loss in the home country is explained by the rent-shifting caused by the symmetric reduction in export subsidies. The rent-shifting may occur because the symmetric reduction in export subsidies affects asymmetrically the two firms' production costs. This result implies that the home government may not sign the trade agreement which liberalizes trade. In other words, the existence of the environmentally conscious firm may be an obstacle to trade liberalization.

5 Conclusions

(To be concluded.)

A Appendix: Proof of Proposition 3

The welfare improvement in the foreign country directly follows from Proposition 3 in Walz and Wellisch (1997). With regard to the welfare effect of the symmetric reduction in export subsidies on the home country for $\alpha > 0$ and $\theta > 1/(1+\alpha)$ is shown in the following way. Totally differentiate Eq. (14) to yield

$$\begin{aligned}\frac{dW}{ds} &= (\pi_{x^*} - d\alpha e(1-a^*))\left(\frac{dx^*}{ds} + \frac{dx^*}{dt}\frac{dt}{ds} + \frac{dx^*}{ds^*} + \frac{dx^*}{dt^*}\frac{dt^*}{ds}\right) - s\left(\frac{dx}{ds} + \frac{dx}{dt}\frac{dt}{ds} + \frac{dx}{ds^*}\right.\\ &\quad \left. + \frac{dx}{dt^*}\frac{dt^*}{ds}\right) + e(1-a)\left\{t - d\left(1-\theta(1+\alpha)\right)\right\}\left(\frac{dx}{ds} + \frac{dx}{dt}\frac{dt}{ds} + \frac{dx}{ds^*} + \frac{dx}{dt^*}\frac{dt^*}{ds}\right)\\ &\quad -ex(t-d)\left(\frac{da}{dt}\frac{dt}{ds}\right). \qquad \text{(A.1)}\end{aligned}$$

Noting that in equilibrium $dt/ds = 0$ and $\tilde{t} = 0$, evaluate (A.1) at the non-cooperative equilibrium to obtain

$$\begin{aligned}\left.\frac{dW}{ds}\right|_{\{\tilde{t}_N, \tilde{s}_N, \hat{t}^*_N, \hat{s}^*_N\}} &= (\pi_{x^*} - d\alpha e(1-\hat{a}^*))\left(\frac{dx^*}{ds} + \frac{dx^*}{ds^*} + \frac{dx^*}{dt^*}\frac{dt^*}{ds}\right)\\ &\quad + \frac{(\pi_{x^*} - D_{x^*})\pi^*_{x^*x}}{\pi^*_{x^*x^*}}\left(\frac{dx}{ds} + \frac{dx}{ds^*} + \frac{dx}{dt^*}\frac{dt^*}{ds}\right).\end{aligned}$$

$$
\begin{aligned}
&= \frac{1}{\Omega}\left[\frac{(\pi_{x^*}-D_{x^*})\pi^*_{x^*x}\pi_{xx^*}}{\pi^*_{x^*x^*}} - d\alpha e(1-\hat{a}^*)\pi^*_{x^*x} - \pi_{xx}\left(\pi_{x^*}-d\alpha e(1-\hat{a}^*)\right)\right.\\
&\quad \left. + e(1-\hat{a}^*)\frac{dt^*}{ds}\left(\pi_{xx}\left(\pi_{x^*}-d\alpha e(1-\hat{a}^*)\right) - \frac{(\pi_{x^*}-D_{x^*})\pi^*_{x^*x}\pi_{xx^*}}{\pi^*_{x^*x^*}}\right)\right]\\
&= \frac{1}{\Omega}\left[-d\alpha e(1-\hat{a}^*)b - \frac{3b^2x_N}{2} + e(1-\hat{a}^*)\frac{dt^*}{ds}\left(2d\alpha e(1-\hat{a}^*)b\right.\right.\\
&\quad \left.\left. + \frac{3b^2x_N}{2}\right)\right], \qquad \text{(A.2)}
\end{aligned}
$$

where the last equality follows from the assumptions of the specific functional forms. Thus, $dW/ds|_{\{\tilde{t}_N,\tilde{s}_N,\hat{t}^*_N,\hat{s}^*_N\}} > 0$ holds if and only if

$$
e(1-\hat{a}^*)\frac{dt^*}{ds} > \frac{2d\alpha e(1-\hat{a}^*)+3bx_N}{4d\alpha e(1-\hat{a}^*)+3bx_N}. \qquad \text{(A.3)}
$$

Note that the right hand side of (A.3) is less than one and greater than a half. □

References

[1] Barrett, Scott. 1994. "Strategic environmental policy and international trade." *Journal of Public Economics* 54: 325-338.

[2] Brander, James A. and Spencer, Barbara J. 1985. "Export subsidies and international market share rivalry." *Journal of International Economics* 18: 83-100.

[3] Burguet, Roberto and Sempere, Jaume. 2003. "Trade liberalization, environmental policy, and welfare." *Journal of Environmental Economics and Management* 46: 25-37.

[4] Conrad, Klaus. 1993. "Taxes and subsidies for pollution-intensive industries as trade policy." *Journal of Environmental Economics and Management* 25: 121-135.

[5] Conrad, Klaus. 2001. "Voluntary environmental agreements vs. emission taxes in strategic trade models." *Environmental and Resource Economics* 19: 361-381.

[6] Copeland, Brian R. 1990. "Strategic interaction among nations: Negotiable and non-negotiable trade barriers." *Canadian Journal of Economics* 23: 84-108.

[7] Cremer, Helmuth, Marchand, Maurice, and Thisse, Jacques-François. 1989. "The public firm as an instrument for regulating an oligopolistic market." *Oxford Economic Papers* 41: 283-301.

[8] De Fraja, Giovanni and Delbono, Flavio. 1989. "Alternative strategies of a public enterprise in oligopoly." *Oxford Economic Papers* 41: 302-311.

[9] Kennedy, Peter W. 1994a. "Equilibrium pollution taxes in open economies with imperfect competition." *Journal of Environmental Economics and Management* 27: 49-63.

[10] Kennedy, Peter W. 1994b. "Environmental policy and trade liberalization under imperfect competition." In: van Ierland, E.C. ed. *International Environmental Economics*. Amsterdam: Elsevier. pp. 195-212.

[11] Lyon, Thomas P. and Maxwell, John W. 2001. " 'Voluntary' approaches to environmental regulation: A survey." In: Franzini, M. and Nicita, A. eds. *Economic Institutions and Environmental Policy*. Aldershot, Hampshir: Ashgate Publishing, forthcoming.

[12] Lutz, Stefan, Lyon, Thomas P., and Maxwell, John W. 2000. "Quality leadership when regulatory standards are forthcoming." *Journal of Industrial Economics* 48: 331-348.

[13] Matsumura, Toshihiro. 1998. "Partial privatization in mixed duopoly." *Journal of Public Economics* 70: 473-483.

[14] Matsumura, Toshihiro and Matsushima, Noriaki. 2003a. "Mixed oligopoly and spatial agglomeration." *Canadian Journal of Economics* 36: 62-87.

[15] Matsumura, Toshihiro and Matsushima, Noriaki. 2003b. "Mixed duopoly with product differentiation: Sequential choice of location." *Australian Economic Papers* 42: 18-34.

[16] Maxwell, John W., Lyon, Thomas P., and Hackett, Steven C. 2000. "Self-regulation and social welfare: The political economy of corporate environmentalism." *Journal of Law and Economics* 43: 583-617.

[17] Petrakis, Emmanuel and Xepapadeas, Anastasios. 1999. "Does governmental precommitment promote environmental innovation?" In: Petrakis, E., Sartzetakis, E.S., and Xepapadeas, A. eds. *Environmental Regulation and Market Power: Competition, Time Consistency and International Trade*. Cheltenham, U.K. and Northampton, Mass.: Edward Elgar. pp. 145-61.

[18] Poyago-Theotoky, Joanna. 2000. "Voluntary approaches and the organisation of environmental R&D." Fondazione Eni Enrico Mattei. Nota Di Lavaro 74.2000.

[19] Spencer, Barbara J. and Brander, James A. 1983. "International R&D rivalry and industrial strategy." *Review of Economic Studies* 50: 707-722.

[20] Tanguay, Georges A. 2001. "Strategic environmental policies under international duopolistic competition." *International Tax and Public Finance* 8: 793-811

[21] Walz, Uwe and Wellisch, Dietmar. 1997. "Is free trade in the interest of exporting countries when there is ecological dumping?" *Journal of Public Economics* 66: 275-291.