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Increasing worldwide environmental consciousness and environmental policy adjustment

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ABSTRACT

Increasing worldwide environmental consciousness has been driving countries in the world to adjust their environmental policies. Conventional wisdom often suggests tightening environmental policy, but this paper challenges that wisdom. By using an oligopoly model, we show that, in the case of local pollution, a country that confronts increasing environmental consciousness tightens or slackens its environmental policy depending on the relative cost competitiveness to its rivals. However, in the case of global pollution, all countries in the world always tighten their environmental policies as worldwide environmental consciousness rises. These results derived from the optimal non-cooperative (Nash) equilibrium policy that maximizes own country's welfare are valid in the case of efficient policy setting in which policy is chosen to maximize global welfare. The policy gap between these two equilibria may increase or decrease as environmental consciousness changes, relying on the relative competitiveness to firm's rivals and on the initial level of environmental consciousness.

1. Introduction

Public concern about environmental degradation is growing domestically and internationally. Although tightening environmental policies to meet increasing environmental consciousness is intuitive, some instances may be purposefully designed to deviate from this wisdom. For example, although there is global awareness of the need to reduce greenhouse gas emissions, major coal exporting nations such as Australia still protect their production of coal.[1] The U.S. Supreme Court overturned the Environmental Protection Agency's (EPA) landmark air pollution rule in 2015 because of the huge cost of the regulation to power plants.[2] As a result, the following question may be raised: What factors cause governments that confront increasing environmental consciousness to slacken their environmental policies?

Most existing literature from the strategic trade policy point of view concentrates on how governments can help domestic firms gain advantages in imperfectly competitive international markets by easing their environmental policies on transboundary pollution.[3] Little attention has been paid to the effects of environmental consciousness from the economic aspect. The purpose of this paper is to investigate how governments should adjust their environmental policies when worldwide environmental consciousness increases.

Only a few exceptional studies explore this issue. Hirazawa and Yakita (2005) introduce environmental awareness to the model in Hatzipanayotou et al. (2002) to investigate the effects of becoming more conscious of cross-border pollution in a financial-aid recipient (developing country) on the welfare of the donor (developed coun-

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[1] In early 2015, Australia's prime minister backed down from his position on the issue of the production of coal in Queensland's Galilee Basin. See ABC news on September 10, 2015 (http://www.abc.net.au/environment/articles/2015/09/10/4309937.htm). Australia also became the first developed country to repeal its carbon tax (http://www.wsj.com/articles/australia-repeals-carbon-tax-1405560964).

[2] See the detailed report in the *New York Times* (June 29, 2015; http://thehill.com/policy/energy-environment/246423-supreme-court-overturns-epa-air-pollution-rule).

[3] The literature on so-called "strategic environmental policy" is large and growing. It is argued that, in the absence of trade policy to protect domestic industries, governments might seek to relax environmental policies to give their domestic producers an advantage or increase their welfare. See Barrett (1994), Kennedy (1994) and Ulph (1994, 1996).

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try). Endres (1997) considers a model of two identical countries suffering from pollution to examine the relationship between environmental consciousness and the deviation of the Nash equilibrium emissions from social optimum levels. Vogel (1999) constructs a political economy model to analyze the effects of interest group activities (such as campaigning and lobbying) on the quality of the environment. Endres (1997) and Vogel (1999) conclude that governments will tighten their environmental policies if environmental consciousness goes up. Hirazawa and Yakita (2005) find that an increase in a recipient's environmental awareness reduces the level of transboundary pollution and benefits the donor. In their results, however, the increasing environmental awareness has no effect on the developing country's emission tax rate.

This paper differs from previous literature in three key respects. First, it models the strategic interactions between two large heterogeneous firms (countries) with different cost competitiveness. Second, it explores the environmental policy adjustment after a rise in environmental awareness for both local pollution and global pollution. Baksi (2014) find that regional trade liberalization has effects on the equilibrium pollution tax in the participating countries and nonparticipating countries, but the effects are different between local pollution and global pollution; we expect that an increase in environmental consciousness of local pollution also has a different influence on a government's policy from that of global pollution. Third, instead of using pollution taxes to represent a government's policy toward environmental issues in most literature, this paper employs emission standards. Our results show that a government that faces increasing environmental consciousness may tighten or slacken its environmental policy depending on its relative cost competitiveness to its rival.

The rest of this paper is organized as follows. Section 2 presents the model. Sections 3 and 4 discuss the non-cooperative (Nash) environmental policy adjustment for local pollution and global pollution, respectively. Efficiency policy is delivered in Section 5. The effects of changes in environmental consciousness on the policy gap between non-cooperative (Nash) equilibrium and efficiency equilibrium are examined in Section 6. Some concluding remarks are contained in Section 7.

2. The model

Two firms, A and B, located in different countries, A and B, export a homogeneous good (Q^A, Q^B, respectively) to a third market with the linear inverse demand $P = \alpha - (Q^A + Q^B)$, $\alpha > 0$. Pollution emissions associated with output levels cause damage either to the local economy (denoted as local pollution) or to all countries in the world (denoted as global pollution). By considering firms' profits and environmental impacts, both governments set emission standards (E^i, $i = A, B$) as their own environmental policies.[4] Let the emission-output ratio equal one for both firms.[5] The cost of abating a level of emissions $(Q^i - E^i)$ is $(Q^i - E^i)^2/2$ which reflects the existence of the diminishing marginal returns in the abatement technology. If the pollution is local, country i suffers the environmental damage $(E^i)^2/2$ that results from its firm's emissions E^i.[6] If the pollution is global, countries in the world suffer the environmental damage $(E^A + E^B)^2/2$, which results from global emissions $(E^A + E^B)$. The model is a two-stage game, where each government chooses the level of emission standard in stage one, and each firm sets its output in stage two. The game is solved by backward induction to obtain a subgame perfect Nash equilibrium.

Firm i maximizes its profit,

$$\pi^i = (P - C^i)Q^i - (Q^i - E^i)^2/2, \quad i = A, B, \tag{1}$$

where C^i is the constant marginal cost to firm i. Solving $\frac{\partial \pi^A}{\partial Q^A} = 0$ and $\frac{\partial \pi^B}{\partial Q^B} = 0$ simultaneously, the Cournot-Nash equilibrium output levels at the second stage are

$$Q^A = \frac{1}{8}[2\alpha - 3(C^A - E^A) + (C^B - E^B)], \tag{2}$$

$$Q^B = \frac{1}{8}[2\alpha + (C^A - E^A) - 3(C^B - E^B)]. \tag{3}$$

Eqs. (3) and (4) show that stricter environmental policy (lower E^A) will cut the equilibrium output of firm A and raise the output of firm B.

While the solution to the second stage of the game as a function of environmental policies (E^A and E^B) is obtained, it can now be used to analyze the first stage, where both governments simultaneously set their emission standards (E^A and E^B) to maximize their own welfare functions. In the following two sections, we will derive the optimal emission standards and evaluate how they are affected when worldwide environmental consciousness changes for two cases: local pollution and global pollution.

3. Non-cooperative environmental policy adjustment in the case of local pollution

Let ϕ be a subjective nonnegative indicator that shows the worldwide consciousness (or concern) about environmental damage.[7] As ϕ increases, people in the world are more concerned about environmental damage, which results in more welfare reduction. Hence, we can specify country i's welfare in the local pollution case as following:

$$W^i = \pi^i - \phi(E^i)^2/2, \quad i = A, B, \tag{4}$$

which is given by the profit of its domestic firm's $\left(\pi^i\right)$ net of welfare reduction $\phi\left(E^i\right)^2/2$ from environmental damage $\left(E^i\right)^2/2$ resulting from pollution emissions $\left(E^i\right)$. Using (2) and (3), the non-cooperative (Nash) equilibrium emission standards are derived by solving $\frac{\partial W^A}{\partial E^A} = 0$ and $\frac{\partial W^B}{\partial E^B} = 0$ simultaneously:[8]

$$E_l^A = \frac{9G^B[(15 + 24\phi)G - 8(1 + \phi)]}{(32\phi + 23)(7 + 16\phi)}, \tag{5}$$

$$E_l^B = \frac{9G^B[(15 + 24\phi) - 8(1 + \phi)G]}{(32\phi + 23)(7 + 16\phi)}, \tag{6}$$

[4] Lax (weak) environmental policy represents governments that allow firms to emit more pollution.

[5] The units are chosen such that each unit of output produces a unit of pollution. Moreover, the consideration is confined to production-related pollution rather than consumption-related pollution.

[6] The quadratic environmental damage function implies that the emissions affect the environment at an increasing scale, that is, every unit of emission causes a greater damage than the previous unit.

[7] The same specification for environmental consciousness can be found in Endres (1997).

[8] The strategic nature of the governments' policies plays an important role on policy settings (Leahy and Neary, 2001). When a government's action induces the rival to take the opposite action, policies taken by both governments are strategic substitutes, otherwise they are strategic complements if same action is taken. Mathematically speaking, if $[\partial^2 W^A/\partial E^A \partial E^B] < 0$ and $[\partial^2 W^B/\partial E^B \partial E^A] < 0$, then policies of E^A and E^B are strategic substitutes. If both are positive, then both policies are strategic complements. In this paper, $[\partial^2 W^A/\partial E^A \partial E^B] = (-9/64) < 0$ and $[\partial^2 W^B/\partial E^B \partial E^A] = (-9/64) < 0$, therefore both policies are strategic substitutes. Moreover, we can show that $\{[\partial^2 W^A/\partial (E^A)^2][\partial^2 W^B/\partial (E^B)^2] - [\partial^2 W^A/\partial E^A \partial E^B][\partial^2 W^B/\partial E^B \partial E^A]\} = [(161/512) + (37\phi/32) + \phi^2] > 0$, and hence the second-order conditions of welfare maximization are satisfied.

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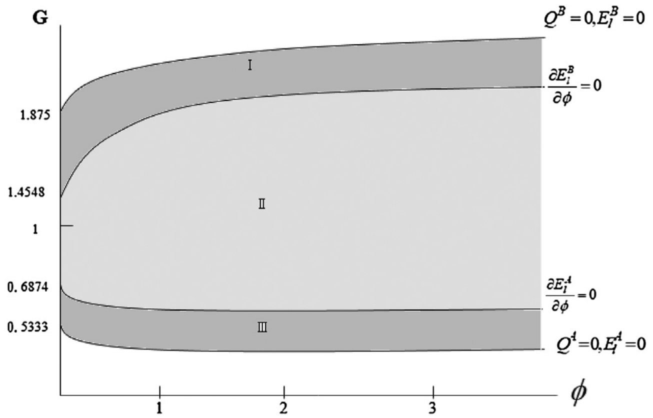

Fig. 1. Non-cooperative environmental policy adjustment in the case of local pollution.
region I: $\frac{\partial E_l^A}{\partial \phi}<0$, $\frac{\partial E_l^B}{\partial \phi}>0$,
region II: $\frac{\partial E_l^A}{\partial \phi}<0$, $\frac{\partial E_l^B}{\partial \phi}<0$,
region III: $\frac{\partial E_l^A}{\partial \phi}>0$, $\frac{\partial E_l^B}{\partial \phi}<0$.

where E_l^A and E_l^B are both countries' equilibrium emission standards under local pollution, $G^A=(\alpha-C^A)$ and $G^B=(\alpha-C^B)$ are the absolute cost competitiveness of firm A and B, respectively, and $G=\frac{G^A}{G^B}=\frac{(\alpha-C^A)}{(\alpha-C^B)}$ is firm A's relative cost competitiveness (in terms of firm B). From (5) and (6), we can evaluate the effects of change in environmental consciousness (ϕ) on the optimal emission standards:

$$\frac{\partial E_l^A}{\partial \phi}=\frac{72G^B[(431+1024\phi+512\phi^2)-(627+1920\phi+1536\phi^2)G]}{(32\phi+23)^2(7+16\phi)^2}, \quad (7)$$

$$\frac{\partial E_l^B}{\partial \phi}=\frac{72G^B[(431+1024\phi+512\phi^2)G-(627+1920\phi+1536\phi^2)]}{(32\phi+23)^2(7+16\phi)^2}. \quad (8)$$

Eqs. (7) and (8) lead to the following proposition:

Proposition 1. *In the case of local pollution, when environmental consciousness rises, country A tends to tighten, but country B tends to slacken, its own environmental policies if firm A's relative cost competitiveness is high enough. However, both countries will tighten their environmental policies if the cost competitiveness of the two firms is close.*

Proof. Six lines in Fig. 1 are drawn by setting Q^A, Q^B, E_l^A, E_l^B, $\frac{\partial E_l^A}{\partial \phi}$ and $\frac{\partial E_l^B}{\partial \phi}$ to zero.[9] Under the assumption of Q^A, Q^B, E_l^A and E_l^B being nonnegative, these lines partition the space into three regions:

region I: $\frac{\partial E_l^A}{\partial \phi}<0$, $\frac{\partial E_l^B}{\partial \phi}>0$,
region II: $\frac{\partial E_l^A}{\partial \phi}<0$, $\frac{\partial E_l^B}{\partial \phi}<0$,
region III: $\frac{\partial E_l^A}{\partial \phi}>0$, $\frac{\partial E_l^B}{\partial \phi}<0$.

Given the initial level of ϕ, if the difference of cost competitiveness between the two firms is large enough (i.e., the value of G is far enough away from one), it is likely to fall into region I or III, where one country tightens and the other slackens its own environmental policies when environmental consciousness rises. However, it will fall into region II when the cost competitiveness in both firms is close (i.e., the value of G is close to one).[10] Therefore, both countries will tighten their environmental policies.

The economic interpretation is simple. In the model of two countries competing with each other in a third market, the optimal emission standard is specified as the point at which profits shifted away from the competitor equal the marginal environmental damage. The higher firm A's relative cost competitiveness (G), the higher the A's profits that can be shifted away to firm B, and the lower the B's profits that can be shifted away to firm A.[11] Since increasing environmental consciousness (ϕ) raises the marginal environmental damage (ϕE^i), if firm A's relative cost competitiveness (G) is high, it is less likely to shift enough profit from firm B by increasing emission standards to compensate for the increase in marginal environmental damage. Therefore, country A has an incentive to tighten its environmental policy. However, with a high value of G, it is more likely that country B will shift enough profit from firm A by increasing its emission standards. Country B then tends to slacken its environmental policy.

4. Non-cooperative environmental policy adjustment in the case of global pollution

If the pollution is global, the emissions generated by one firm can damage not only the country where the firm is located but also other countries as well. Therefore, we can define country i's welfare as follows:

$$W^i=\pi^i-\phi(E^A+E^B)^2/2, \quad i=A,B \quad (9)$$

where $\phi(E^A+E^B)^2/2$ is the welfare reduction from environmental damage resulting from global emissions (E^A+E^B). As discussed in Section 3, the non-cooperative (Nash) equilibrium emission standards can be derived as[12]

$$E_g^A=\frac{9G^B[(15+32\phi)G-8(1+4\phi)]}{7(23+64\phi)}, \quad (10)$$

$$E_g^B=\frac{9G^B[(15+32\phi)-8(1+4\phi)G]}{7(23+64\phi)}. \quad (11)$$

From (10) and (11), we have

$$\frac{\partial E_g^A}{\partial \phi}=-\frac{288G^B(G+1)}{(23+64\phi)^2}, \quad (12)$$

$$\frac{\partial E_g^B}{\partial \phi}=-\frac{288G^B(G+1)}{(23+64\phi)^2}, \quad (13)$$

where $\frac{\partial E_g^A}{\partial \phi}=\frac{\partial E_g^B}{\partial \phi}<0$. This leads to the following proposition:

Proposition 2. *In the case of global pollution, both countries will tighten their environmental policies as environmental consciousness rises.*

The economic intuition is similar to that in Proposition 1. However, global pollution enlarges the marginal environmental

[9] The lines of $Q^A=0$ and $Q^B=0$ are drawn based on the values of Q^A and Q^B derived from substituting (5) and (6) into (2) and (3), respectively. It is noted that both lines of $Q^A=0$ and $E_l^A=0$ are identical, and both lines of $Q^B=0$ and $E_l^B=0$ are the same in Fig.1.

[10] We show that $\lim_{G\to 1}(\partial E_l^A/\partial\phi)=\lim_{G\to 1}(\partial E_l^B/\partial\phi]=-288G^B/(32\phi+23)^2<0$, which implies that it falls into region II if the value of G is nearly 1.

[11] The profit levels for both firms and the difference are $\pi^A=\frac{3(G^B)^2(37+128\phi+64\phi^2)[(15G-8)+8\phi(3G-1)]^2}{2(23+32\phi)^2(7+16\phi)^2}$, $\pi^B=\frac{3(G^B)^2(37+128\phi+64\phi^2)[(15-8G)+8\phi(3-G)]^2}{2(23+32\phi)^2(7+16\phi)^2}$ and $\pi^A-\pi^B=\frac{3(G^B)^2(37+128\phi+64\phi^2)(G^2-1)}{2(23+32\phi)(7+16\phi)}$. Hence, $\pi^A>\pi^B$ if $G>1$.

[12] The second-order conditions of welfare maximization are satisfied as follows: $[\partial^2W^A/\partial E^A\partial E^B]=-[(9/64)+\phi]<0$, $[\partial^2W^B/\partial E^B\partial E^A]=-[(9/64)+\phi]<0$ and $\{[\partial^2W^A/\partial(E^A)^2][\partial^2W^B/\partial(E^B)^2]-[\partial^2W^A/\partial E^A\partial E^B][\partial^2W^B/\partial E^B\partial E^A]\}=[(161/512)+(7\phi/8)]>0$.

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damage ($\phi(E_g^A + E_g^B)$), which increases the cost of allowing slackened environmental policies. Hence, both countries will tighten their environmental policies.

5. Efficient environmental policy adjustment

Literature on strategic trade policy under imperfect competition markets shows that the optimal non-cooperative (Nash) equilibrium policy that maximizes one country's welfare as discussed in Sections 2 and 3 deviates from the efficient equilibrium policy that maximizes global welfare. Kennedy (1994) decomposes the deviation into three effects. The rent capture effect (RCE) illustrates that a government has the incentive to unilaterally adopt slackened policy to shift profit from foreign rivals. The pollution shifting effect (PSE) demonstrates that government tends to tighten its policy to reduce domestic output (and hence domestic pollution) and increase foreign output (and hence foreign pollution). The transboundary externality effect (TEE) implies that a country that neglects the effects of pollution generated inside its boundary on foreign countries is inclined to slacken its policies. If the sum of RCE and TEE is greater than PSE, the Nash equilibrium policy is laxer than the efficient equilibrium policy. In the other case, the Nash equilibrium policy is tighter than the efficient equilibrium policy. This section attempts to examine how government adjusts policy if the efficient policy is adopted.

To investigate the efficient policy under the local pollution case, we have global welfare (W) as the sum of both countries' welfare ($W^A + W^B$), where W^A and W^B are evaluated in Eq. (4). The efficient emission standards are derived by solving $\frac{\partial W}{\partial E^A} = 0$ and $\frac{\partial W}{\partial E^B} = 0$ simultaneously:

$$\overline{E}_l^A = \frac{3G^B[(7+10\phi)G - 6(1+\phi)]}{(1+4\phi)(13+16\phi)}, \tag{14}$$

$$\overline{E}_l^B = \frac{3G^B[(7+10\phi) - 6(1+\phi)G]}{(1+4\phi)(13+16\phi)}, \tag{15}$$

where $\overline{E}_l^A$ and $\overline{E}_l^B$ are both countries' equilibrium emission standards under local pollution.[13] Compared to the results in (5) and (6), we can show that the efficient emission standards in (14) and (15), respectively, are less than those in Nash equilibrium emission standards (i.e., $E_l^A > \overline{E}_l^A$ and $E_l^B > \overline{E}_l^B$) when both $\overline{E}_l^A$ and $\overline{E}_l^B$ are positive.[14] These results echo the wisdom of strategic trade literature (Brander and Spencer, 1985; Barrett, 1994) that both governments, due to rent capture effect under non-cooperative game, have incentive to deviate the efficient policy and set a laxer emission standard policy.

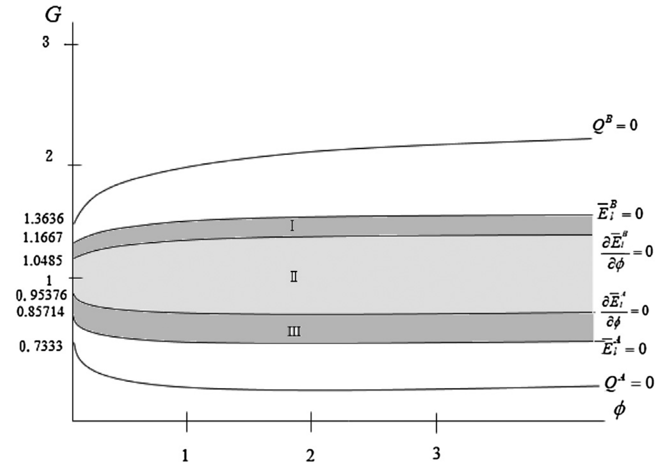

Fig. 2. Efficient environmental policy adjustment in the case of local pollution.

region I: $\frac{\partial \overline{E}_l^A}{\partial \phi} < 0$, $\frac{\partial \overline{E}_l^B}{\partial \phi} > 0$,

region II: $\frac{\partial \overline{E}_l^A}{\partial \phi} < 0$, $\frac{\partial \overline{E}_l^B}{\partial \phi} < 0$,

region III: $\frac{\partial \overline{E}_l^A}{\partial \phi} > 0$, $\frac{\partial \overline{E}_l^B}{\partial \phi} < 0$.

The effects of change in environmental consciousness (φ) on the efficient emission standards are as follows:

$$\frac{\partial \overline{E}_l^A}{\partial \phi} = \frac{6G^B[(165+384\phi+192\phi^2) - (173+448\phi+320\phi^2)G]}{(1+4\phi)^2(13+16\phi)^2}, \tag{16}$$

$$\frac{\partial \overline{E}_l^B}{\partial \phi} = \frac{6G^B[(165+384\phi+192\phi^2)G - (173+448\phi+320\phi^2)]}{(1+4\phi)^2(13+16\phi)^2}. \tag{17}$$

Under the assumption of Q^A, Q^B, $\overline{E}_l^A$, and $\overline{E}_l^B$ being nonnegative, as shown in Fig. 2, we also can partition the space into three regions as in Fig. 1 under a Nash equilibrium regime. The results and economic implications are similar to Proposition 1, in which relative cost competitiveness plays an important role for policy adjustment under an efficient policy regime.

In the global pollution case, W^A and W^B are evaluated in Eq. (9) in global welfare ($W = W^A + W^B$). The efficient emission standards are derived by solving $\frac{\partial W}{\partial E^A} = 0$ and $\frac{\partial W}{\partial E^B} = 0$ simultaneously:[15]

$$\overline{E}_g^A = \frac{3G^B[(7+32\phi)G - (6+32\phi)]}{(13+64\phi)}, \tag{18}$$

$$\overline{E}_g^B = \frac{3G^B[(7+32\phi) - (6+32\phi)G]}{(13+64\phi)}. \tag{19}$$

Compared to the results in (10) and (11), we find that the efficient emission standards in (18) and (19), respectively, are less than those in Nash equilibrium emission standards (i.e., $E_g^A > \overline{E}_g^A$ and $E_g^B > \overline{E}_g^B$) when both $\overline{E}_g^A$ and $\overline{E}_g^B$ are positive.[16] Similar to the local

[13] The second-order conditions of welfare maximization are satisfied as follows: $[\partial^2 W^A/\partial(E^A)^2] = -(9/32) < 0$, $[\partial^2 W^B/\partial(E^B)^2] = -(9/32) < 0$ and $\{[\partial^2 W^A/\partial(E^A)^2][\partial^2 W^B/\partial(E^B)^2] - [\partial^2 W^A/\partial E^A \partial E^B][\partial^2 W^B/\partial E^B \partial E^A]\} = [(13/64) + (17\phi/16) + \phi^2] > 0$.

[14] From (5), (6), (14) and (15), we can derive the gap between the two equilibria as $(E_l^A - \overline{E}_l^A) = [6G^B(1+\phi)][(768\phi^2 + 960\phi + 327) - (256\phi^2 + 608\phi + 271)G]/[(7+16\phi)(23+32\phi)(13+16\phi)(1+4\phi)]$ and $(E_l^B - \overline{E}_l^B) = [6G^B(1+\phi)][-(256\phi^2 + 608\phi + 271) + (768\phi^2 + 960\phi + 327)G]/[(7+16\phi)(23+32\phi)(13+16\phi)(1+4\phi)]$. We know that $\overline{E}_l^A > 0$ if $G > [6(1+\phi)/(7+10\phi)]$ and $\overline{E}_l^B > 0$ if $G < [(7+10\phi)/6(1+\phi)]$. Let $G = [(7+10\phi)/6(1+\phi)]$ and $G = [6(1+\phi)/(7+10\phi)]$, and plug them into $(E_l^B - \overline{E}_l^B)$ and $(E_l^A - \overline{E}_l^A)$, respectively, we can show that, under the conditions of $\overline{E}_l^A > 0$ and $\overline{E}_l^B > 0$, $(E_l^A - \overline{E}_l^A) = [G^B(32\phi+5)]/[(7+16\phi)(23+32\phi)] > 0$ and $(E_l^B - \overline{E}_l^B) = [6G^B(1+\phi)(5+32\phi)]/[(7+16\phi)(23+32\phi)(7+10\phi)] > 0$. Therefore, $E_l^A > \overline{E}_l^A$ and $E_l^B > \overline{E}_l^B$ hold.

[15] The second-order conditions of welfare maximization are satisfied as follows: $[\partial^2 W^A/\partial E^A \partial E^B] = -[(9/32) + 2\phi] < 0$, $[\partial^2 W^B/\partial E^B \partial E^A] = -[(9/32) + 2\phi] < 0$ and $\{[\partial^2 W^A/\partial(E^A)^2][\partial^2 W^B/\partial(E^B)^2] - [\partial^2 W^A/\partial E^A \partial E^B][\partial^2 W^B/\partial E^B \partial E^A]\} = [(13/64) + \phi] > 0$.

[16] From (10), (11), (18) and (19), we can derive the gap between the two equilibria as $(E_g^A - \overline{E}_g^A) = 6G^B[(4096\phi^2 + 2528\phi + 327) - (4096\phi^2 + 2080\phi + 271)G]/[7(23+64\phi)(13+64\phi)]$ and $(E_g^B - \overline{E}_g^B) = 6G^B[(4096\phi^2 + 2528\phi + 327)G - (4096\phi^2 + 2080\phi + 271)]/[7(23+64\phi)(13+64\phi)]$. We know that $\overline{E}_g^A > 0$ if $G > [(6+32\phi)/(7+32\phi)]$ and $\overline{E}_g^B > 0$ if $G < [(7+32\phi)/(6+32\phi)]$. Let $G = [(6+32\phi)/(7+32\phi)]$ and $G = [(7+32\phi)/(6+32\phi)]$, and plug them into $(E_g^B - \overline{E}_g^B)$ and

pollution case, the rent capture effect still plays the leading role for both governments to slacken their own policies.

The effects of change in environmental consciousness (ϕ) on the efficient emission standards under the global pollution case are as follows:

$$\frac{\partial \overline{E}_g^A}{\partial \phi} = \frac{-96G^B(G+1)}{(13+64\phi)^2} < 0, \tag{20}$$

$$\frac{\partial \overline{E}_g^B}{\partial \phi} = \frac{-96G^B(G+1)}{(13+64\phi)^2} < 0. \tag{21}$$

Eqs. (20) and (21) suggest that both countries need to tighten environmental policy in an efficient policy regime under the global pollution case.[17]

Analysis in this section brings us the following proposition:

Proposition 3. *Whatever the pollution type is local or global, the efficient equilibrium policy is tighter than the non-cooperative equilibrium policy. Nevertheless, how government adjust her efficient equilibrium policy when environmental consciousness rises depends on the pollution type and her cost competitiveness relative to her rival.*

6. The effects of changes in environmental consciousness on the policy gap

Although we have shown that the optimal non-cooperative (Nash) equilibrium policy deviates from the efficient equilibrium policy, we follow Endres (1997) in wanting to know if changes in environmental consciousness can increase or decrease the policy deviation (gap). Since we have proved in Proposition 3 that the efficient equilibrium policy is tighter than the non-cooperative equilibrium policy, our following analysis in this section is hence discussed under the conditions of $E_l^A > \overline{E}_l^A$ and $E_g^A > \overline{E}_g^A$.

The gap between these two emission standards in the local pollution case can be derived as follows:

$$\frac{\partial(E_l^A - \overline{E}_l^A)}{\partial \phi} = \frac{6G^B[(8388608\varphi^6 + 56623104\phi^5 + 134578176\phi^4 + 153788416\phi^3 + 91685376\phi^2 + 27394368\phi + 3212777)G - (25165824\varphi^6 + 113246208\phi^5 + 208207872\phi^4 + 201363256\phi^3 + 107920512\phi^2 + 30185856\phi + 3402897)]}{(16\phi+7)^2(32\phi+23)^2(16\phi+13)^2(4\phi+1)^2} \tag{22}$$

$$\frac{\partial(E_l^B - \overline{E}_l^B)}{\partial \varphi} = \frac{6G^B[(8388608\varphi^6 + 56623104\phi^5 + 134578176\phi^4 + 153788416\phi^3 + 91685376\phi^2 + 27394368\phi + 3212777) - (25165824\varphi^6 + 113246208\phi^5 + 208207872\phi^4 + 201363256\phi^3 + 107920512\phi^2 + 30185856\phi + 3402897)G]}{(16\varphi+7)^2(32\phi+23)^2(16\phi+13)^2(4\phi+1)^2} \tag{23}$$

Equations (22) and (23) direct to the following proposition:

Proposition 4. *In the case of local pollution, an increase in environmental consciousness may increase or decrease the policy gap between the non-cooperative equilibrium and the efficient equilibrium, depending on the relative competitiveness to the firm's rivals and on the initial level of environmental consciousness. However, the policy gap, regardless of the initial level of environmental consciousness, will decrease if the cost competitiveness of the two firms is similar.*

Proof. To evaluate the signs of (22) and (23), it is required that firms' outputs (Q^A and Q^B) and emission standards (E^A and E^B) in both non-cooperative and efficient equilibria be nonnegative. It is under these requirements that Fig. 3 is drawn.[18] The three regions display how the policy gap is affected if the environmental consciousness changes as follows:

region I: $\frac{\partial(E_l^A - \overline{E}_l^A)}{\partial\phi} > 0$, $\frac{\partial(E_l^B - \overline{E}_l^B)}{\partial\phi} < 0$

region II: $\frac{\partial(E_l^A - \overline{E}_l^A)}{\partial\phi} < 0$, $\frac{\partial(E_l^B - \overline{E}_l^B)}{\partial\phi} < 0$

region III: $\frac{\partial(E_l^A - \overline{E}_l^A)}{\partial\phi} < 0$, $\frac{\partial(E_l^B - \overline{E}_l^B)}{\partial\phi} > 0$

If the initial level of ϕ is small, and the difference in the cost competitiveness between the two firms is large enough (i.e., the value of G is far enough away from one), the equilibrium is likely to fall into region I or III, where the policy gap increases in one country and decreases in the other country if environmental consciousness

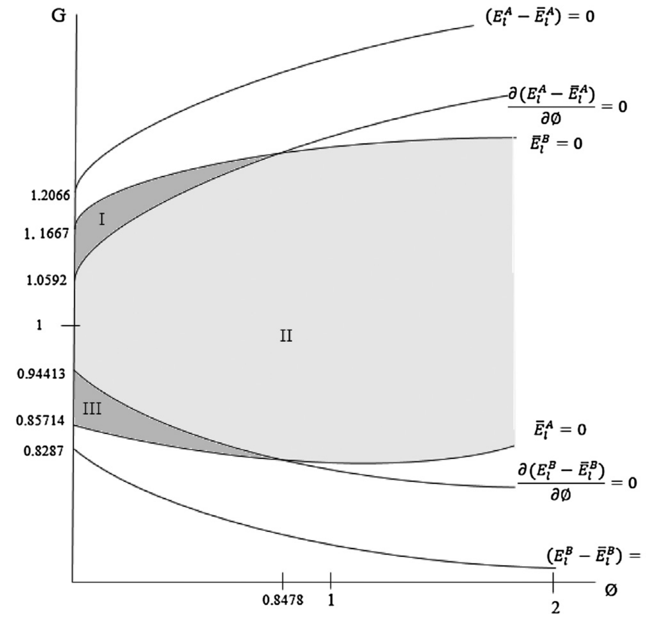

Fig. 3. The effects of changes in environmental consciousness on the policy gap.

region I: $\frac{\partial(E_l^A - \overline{E}_l^A)}{\partial\phi} > 0$, $\frac{\partial(E_l^B - \overline{E}_l^B)}{\partial\phi} < 0$

region II: $\frac{\partial(E_l^A - \overline{E}_l^A)}{\partial\phi} < 0$, $\frac{\partial(E_l^B - \overline{E}_l^B)}{\partial\phi} < 0$

region III: $\frac{\partial(E_l^A - \overline{E}_l^A)}{\partial\phi} < 0$, $\frac{\partial(E_l^B - \overline{E}_l^B)}{\partial\phi} > 0$

$(E_g^A - \overline{E}_g^A)$, respectively, we can show that, under the conditions of $\overline{E}_g^A > 0$ and $\overline{E}_g^B > 0$, $(E_g^A - \overline{E}_g^A) = [15G^B(1+32\phi)]/[7(23+64\phi)(3+16\phi)] > 0$ and $(E_g^B - \overline{E}_g^B) = [30G^B(1+32\phi)]/[7(23+64\phi)(7+32\phi)] > 0$. Therefore, $E_g^A > \overline{E}_g^A$ and $E_g^B > \overline{E}_g^B$ hold.

[17] Two more models were extended: The first is the case where environmental consciousness rises in one country but not in the other. The second is the case where domestic consumption is taken into account and environmental policy is set to maximize global welfare. The results obtained in these two cases are consistent with those in sections 3 ~ 5. The results are available from the authors upon request.

[18] To make Figure 3 easy to read, six lines are not drawn, including line $Q^A = 0$, line $Q^B = 0$, line $E_l^A = 0$, and $E_l^B = 0$ under the non-cooperative equilibrium case, as displayed in Figure 1, and line $Q^A = 0$ and line $Q^B = 0$ under the efficient equilibrium case, as displayed in Figure 2.

rises. However, if the cost competitiveness in both firms is close (i.e., the value of G is close to one), it will fall into region II, where the policy gap decreases in both countries.[19]

In the global pollution case, the policy gap between the two emissions standards can be derived as follows:

$$\frac{\partial(E_g^A - \overline{E}_g^A)}{\partial\phi} = \frac{-192G^B(G+1)(4096\phi^2+1024\phi-11)}{(64\phi+23)^2(64\phi+13)^2} \tag{24}$$

$$\frac{\partial(E_g^B - \overline{E}_g^B)}{\partial\phi} = \frac{-192G^B(G+1)(4096\phi^2+1024\phi-11)}{(64\phi+23)^2(64\phi+13)^2} \tag{25}$$

Eqs. (24) and (25) yield the following proposition:[20]

Proposition 5. *In the case of global pollution, an increase in environmental consciousness may increase or decrease the policy gap between the non-cooperative equilibrium and the efficient equilibrium, depending on the initial level of environmental consciousness. If the initial value is greater (less) than* 1.03×10^{-2}*, the policy gap in both countries decreases (increases).*

Although our model settings are dissimilar to those of Endres (1997), the results in Proposition 4 are consistent with Endres (1997). By assuming homogeneous firms and transboundary pollution,[21] Endres (1997) illustrates that the deviation comes from international resource misallocation and is subject to the tragedy of the commons.[22] An increase in environmental consciousness may cause the extent of deviation to be increased or decreased. The extent of deviation increases if the initial level of environmental consciousness is low enough, compared to the slope of the marginal abatement cost. Otherwise, the extent of deviation decreases.

7. Conclusion

This paper attempts to examine how exporting countries should adjust their environmental policies when worldwide environmental consciousness increases. In the basic model without consideration of domestic consumption, we set up an oligopoly game where two large heterogeneous firms (countries) sell all their output in a third market. Governments move first by choosing environmental policies (emission standards). Firms take these standards as given and compete with each other by choosing output levels. Pollution emissions associated with output levels are either local pollution or global pollution.

Under non-cooperative (Nash) equilibrium, this paper shows that if it is a local type pollution, a country with high enough cost advantage over its rival has incentives to tighten its environmental policies as worldwide environmental consciousness increases, while the rival country has incentive to slacken its policies. However, both countries will tighten their environmental policies if firms' cost competitiveness in the two countries is close. In the global pollution case, regardless of relative cost competitiveness, both countries always tighten their environmental policies.

Although the efficient equilibrium policy is always tighter than the non-cooperative equilibrium policy no matter the pollution type is local or global, the policy adjustments acquired in non-cooperative (Nash) equilibrium are still suitable in efficient equilibrium. However, the policy gap between these two equilibria may widen or narrow as environmental consciousness changes, depending on firm's relative competitiveness and on the initial level of environmental consciousness.

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[19] $\lim_{G\to 1}[\partial(E_l^A - \overline{E}_l^A)/\partial\phi] = \lim_{G\to 1}[\partial(E_l^B - \overline{E}_l^B)/\partial\phi] = -[48G^B(512\phi^2 + 1024\phi + 485)]/[(16\phi+13)^2(32\phi+23)^2] < 0$ shows that it falls into region II if the value of G is nearly 1.

[20] The signs of both $[\partial(E_g^A - \overline{E}_g^A)/\partial\phi]$ and $[\partial(E_g^B - \overline{E}_g^B)/\partial\phi]$ are determined by $(4096\phi^2 + 1024\phi - 11)$. If ϕ is greater (less) than 1.03×10^{-2}, $(4096\phi^2 + 1024\phi - 11)$ is greater (less) than zero, and hence $[\partial(E_g^A - \overline{E}_g^A)/\partial\phi]$ and $[\partial(E_g^B - \overline{E}_g^B)/\partial\phi]$ are negative (positive).

[21] Firms are homogeneous if we set $G = 1$ in our paper.

[22] We thank the referee for the suggestion to point out Endres' (1997) interpretation.

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