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Environmental Funds, Terms of Trade, and Welfare

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Abstract

We investigate the economic consequences of international environmental liabilities, for which environmental funds are used to provide compensation for pollution damage. We assume two large open economies that consist of a polluter and a pollutee, and the polluter country confers international transfers, which are financed by pollution tax revenue, as a means of compensation for pollution damage inflicted upon the pollutee. Within this framework, we develop the condition that an increase in the pollution tax enriches (impoverishes) the pollutee (polluter) through a change in the terms of trade, the amount of the transfers, and the amount of pollution.

Keywords: Environmental funds, Pollution taxes, Terms of trade, Welfare

JEL classification: F18; H23; Q58

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I. Introduction

Environmental funds have become a widely known environmental protection policy. One of the main purposes of environmental funds is to provide financial aid for pollution abatement activities undertaken by the private sector and/or the public sector. A notable example is Superfund in the United States, where the government imposes various pollution charges on the industries that generate pollution emissions and the revenues are used to clean up the sites being contaminated.[1] Furthermore, the environmental funds created in Central and Eastern Europe have the same purpose as the US Superfund, where governments in these transition countries use the revenues collected from pollution-related activities[2] to finance pollution abatement undertaken mainly by the public sector, known as public abatement (see OECD 1995). These uses of environmental funds have received attention in the academic literature. In particular, Chao and Yu (1999), Hatzipanayotou et al. (2002), Hatzipanayotou et al. (2003), Hatzipanayotou et al. (2005), and Haibara (2006a, b) have examined environmental funds in a general equilibrium framework. The main findings of these studies show that pollution abatement activities financed by tax revenues and/or international transfers are conducive to welfare improvement when the government increases the taxes or the transfers.

Another role of environmental funds is to compensate for pollution damage inflicted upon citizens or properties. With regard to compensation for citizens, Japan established environmental funds in 1973 under the name of the Law for the Compensation of Pollution-Related Health Injuries (which came into effect in 1974).[3] Accordingly, provision is made for compensation of victims and the compensation has been financed from a pollution levy, which is paid into a fund administered by the Pollution-Related Health Damage Compensation and Prevention Association (see OECD 1994, p. 42). Another example related to such a compensation-based environmental fund is the Black Lung Disability Trust Fund established in the US in 1954 to pay miners who become sick and unable to work because of prolonged exposure to coal dust in mines. Since 1977, the fund has been financed by excise taxes on coal from underground and surface mines (see Stavins 2000). Turning to the environmental funds aimed at compensation for property damages, it is motivated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) enacted in 1980, such that Congress authorized federal, state, and tribal trustee authorities to bring court actions to recover damages for injury caused by releases of hazardous substances to natural resources. In particular, defendants found liable for natural resource damages have to cover not only the cost of resource restoration and damage assessments, but compensation for interim losses—the lost value of

1 An excise tax on specified hazardous chemicals is used to fund (in particular) the cleanup of hazardous waste sites through the Superfund (see Stavins 2000).

2 In the case of environmental funds in Central and Eastern Europe, the revenues of most funds are largely based on the collection of pollution charges or fines. The major sources tend to be charges on air pollution emissions and waste water discharges (see OECD 1995, p. 45).

3 The compensation was designed for the victims with illnesses such as respiratory disease and chronic metal poisoning and covered medical expenses, disablement benefits, dependents' allowances, educational grants, assistance with the costs of medical treatment and funeral costs (see OECD 1981, p. 156).

injured resources pending full restoration (see Boyd 2004). These compensation-based environmental funds are targeted at domestic citizens and properties; however, there are also environmental funds aimed at compensation against pollution damage inflicted upon foreign citizens and/or properties. A notable example is the International Fund for Compensation for Oil Pollution Damage (Brussels Convention of 18th December 1971, which was renamed in 1992 as the Civil Liability Convention), which imposes a liability on tanker- or ship-owners for oil spills from their tanker or ship. The Civil Liability Convention fund was established in order to pay compensation to the victims suffering from oil pollution damage.

Turning to the academic literature, there exist few studies concerned with the economic consequences of compensation-based environmental funds from an international perspective. Although relevant studies (e.g., Chao and Yu 1999, Hatzipanayotou et al. 2002, Naito 2003, Takarada 2006) addressed international transfers and environmental protection, they ignore environmental funds aimed at compensation against pollution damage in other countries. With this deficiency in mind, we develop a simple general equilibrium model that consists of one polluter country (i.e., a pollution-generating country) and one pollutee country (i.e., a pollution-suffering country) and investigate the welfare consequences of the compensation-based environmental funds. In this framework, a polluter country confers an international transfer, which is financed by a pollution tax[4] levied on the producer of the polluter country (i.e., environmental funds), as a means of compensation against pollution damage inflicted upon the pollutee country. In this sense, the polluter country is the donor country of the compensation while the pollutee country is the recipient country of the compensation. Based on these settings, we examine the effects of a pollution tax, and thereby environmental funds, on the terms of trade, and the welfare of both countries. This analysis is along the same lines as that of Siebert (1979)[5], a pioneering study of a change in a pollution tax on terms of trade and welfare in a general equilibrium framework. This study is of great interest in the sense that environmental policy, which is thought of as harmful for export opportunities, achieves export promotion via a terms of trade improvement. However, Siebert (1979) did not address international environmental liabilities and the resulting international transfers. In this sense, this paper is a synthesis of the effects of environmental policies and international transfers in a general equilibrium framework. Beyond the academic novelty of this paper, the main findings obtained by this paper enable us to investigate the economic consequences of the international environmental liabilities, in particular, environmental funds aimed at compensation for transnational pollution damage. The relevant international policy framework is The International Fund for Atmospheric Stabilization proposed by Uzawa (2003, p. 257), where a fixed percentage of the pollution tax revenue accruing from developed countries would be transferred to developing countries via The International Fund for Atmospheric Stabilization for the

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4 Pollution tax revenue-financed environmental funds are consistent with the PPP (polluter pays principle) and therefore it must be reasonable in a moral sense.

5 Readers can consult other relevant studies that highlight the interaction between an environmental policy and international trade in view of a large open economy, such as Asako (1979), McGuire (1982), Merrifield (1988), and Pethig (1976).

purpose they deem appropriate (e.g., compensation for pollution victims, restructuring industrial organizations and infrastructure, etc.). The model we develop in this paper considers pollution tax revenue-financed international transfers, and thus we can provide some theoretical insights regarding The International Fund for Atmospheric Stabilization, although the model we develop does not completely capture the key features of this fund.

The remainder of this paper is as follows. Section II presents the model. Section III examines the effects of a pollution tax on the terms of trade and welfare. Section IV concludes this paper.

II. The Model

We assume two large open economies exist in the world: a polluter and a pollutee, each of which produces two internationally tradable goods, good x and good y. Good x is exported by the polluter and imported by the pollutee, whereas good y is imported by the polluter and exported by the pollutee. The polluter country generates pollution as a by-product of good x, and pollution emissions harm the households' utility in both countries. The polluter country provides international transfers, which are financed by the revenue from the pollution tax levied in the polluter country, as a means of compensation against the pollution damage inflicted upon the pollutee country (i.e., environmental funds). In this sense, the polluter country is thought of as the donor of the transfers while the pollutee is thought of as the recipient of the transfers. Therefore, we hereafter define the polluter as the donor and the pollutee as the recipient.

We show the production side of the donor country using the following revenue function:

$$R(p,t,v) = \max_{x,y,z}\{px + y - tz : (x,y,z) \in T(v)\},$$

where p denotes the international relative price of good x in terms of good y, x and y are the respective outputs of goods x and y, z is the amount of pollution generated from the production of good x in the donor country, t denotes the pollution tax rate, v denotes private factors used for the production of the private goods, and $T(v)$ is the donor country's technology set. Regarding the revenue function, we assume that the amount of factor v does not vary and so we hereafter omit it from the revenue function. A standard property of revenue function is that $R_p > 0$ and $R_{pp} > 0$. From the revenue function, one obtains:

$$z = -R_t(p,t), \tag{1}$$

where we assume $R_{tp} = -\partial z/\partial p < 0$ and $R_{tt} = -\partial z/\partial t > 0$. The expression $R_{tp} = -\partial z/\partial p < 0$ implies that pollution rises via an increase in the price of good x. The expression $R_{tt} = -\partial z/\partial t > 0$ implies that an increase in the pollution tax rate reduces the amount of pollution.

Turning to the consumption side of the polluter, we characterize it as the following expenditure function:

$$E(p,z,u) = \min_{C_x,C_y}\{pC_x + C_y : u(C_x,C_y,z) \geq \overline{u}\},$$

where C_x and C_y denote the compensated demands of good x and good y, respectively, and z denotes the amount of pollution that the households of the polluter receive. A standard property of expenditure function is that $E_p = C_x, E_{pp} < 0$, and $E_u > 0$, where E_u[6] is the reciprocal of the marginal utility of income. We do not assume inferior goods, and thus we have $E_{pu} > 0$. We also assume $E_z > 0$, which is thought of as the marginal willingness to pay for a reduction in pollution in the sense that pollution harms the utility of households, and thus households should increase their expenditure so as to maintain a constant level of utility. (see Copeland 1994).

The donor country's budget constraint is expressed as follows:

$$E(p,z,u) = R(p,t) + (1-\alpha)tz . \tag{2}$$

The first term of the right-hand side of equation (2) is the revenue from production, and the second term is the net pollution tax revenue redistributed to households in the donor country. Regarding this, we assume that the donor country transfers a fixed percentage of the accrued revenues from pollution charges to the recipient country, as a means of compensation, and thus α percent of pollution charges is transferred to the recipient. In other words, α is the compensation rate of pollution damage.

Assume that the variables in the recipient country are denoted by "*". The budget constraint of the recipient country is:

$$E^*(p,z,u) = R^*(p) + \alpha tz . \tag{3}$$

The second term of the right-hand side of equation (3), αtz, denotes the amount of compensation (i.e., transfers) conferred to the recipient.

Finally, the equilibrium of the world market of good x completes the model:

$$M_p + M_p^* = 0 . \tag{4}$$

Recall the assumption that the donor exports good x, and therefore $M_p = E_p - R_p < 0$, while the recipient imports good x, and therefore $M_p^* = E_p^* - R_p^* > 0$.

There are four equations, (1), (2), (3) and (4), that examine the changes in the four endogenous variables, p, u, u^*, z, with respect to the two exogenous variables—the pollution tax rate t and the compensation rate α.

III. Comparative Statics

In this section, we investigate the effect of a change in the pollution tax, and therefore in environmental funds, on the terms of trade and welfare by using the comparative statics results (see Appendix A). Firstly, we investigate the change in the terms of trade following the change in the pollution tax:

$$dp/dt = [(E_{pz} + E_{pz}^*)R_{tt} + R_{pt}]/\Delta - E_{pu}(E_z - t)R_{tt}/\Delta + \alpha(m_x - m_x^*)(z - tR_{tt})/\Delta , \tag{5}$$

where $m_x = E_{pu}/E_u$ and $m_x^* = E_{pu}^*/E_u^*$ denote each country's marginal propensity to consume good x.

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6 We hereafter normalize the reciprocal of the marginal utility of income to unity, such that $E_u = 1$.

Also, $\Delta = [S_{pp} - (E_{pz} + E^*_{pz})R_{tp}] + M^*_p(m_x - m^*_x) + E_{pu}[E_z - (1-\alpha)t]R_{tp} + E^*_{pu}(E^*_z - \alpha t)R_{tp}$ denotes the determinant of the coefficient matrix of the unknown variables, where $S_{pp} = E_{pp} + E^*_{pp} - R_{pp} - R^*_{pp} < 0$. By using the stability condition shown in Appendix A, we have $\Delta < 0$. Equation (5) indicates the effect of a change in the pollution tax on the international relative price of good x. The first and second terms of the right-hand side of equation (5) are positive under the assumptions $E_{pz} < 0, E^*_{pz} < 0$ and $E_z > t$. The assumptions $E_{pz} < 0, E^*_{pz} < 0$ state that pollution and the consumption of good x are substitutes in both countries, and an increase in the pollution tax can increase the consumption of good x following a reduction in pollution. The increased consumption of good x raises its international price, leading to a terms of trade improvement (deterioration) for the donor (recipient) because good x is the exported (imported) good for the donor (recipient). Also, the second term of the right-hand side $-\Delta^{-1}E_{pu}(E_z - t)R_{tt}$ indicates the effects of the pollution tax on the international relative price of good x via the change in utility. Regarding this term, if we assume $E_z > t$, then a reduction in pollution following an increase in the pollution tax raises the utility of households and therefore the income of the donor. The increased income boosts the demand for good x because good x is a normal good, $E_{pu} > 0$, and as a result, the international relative price of good x rises. The third term of the right-hand side captures the effects of international transfers on the price of good x. Regarding this, let us suppose that $m_x < m^*_x$ and $z - tR_{tt} > 0$, then an increase in the pollution tax can increase the international relative price of good x. In this context, the assumption $m_x < m^*_x$ states that the marginal propensity to consume good x of the donor is smaller than that of the recipient. Also, the assumption $z - tR_{tt} > 0$ implies that the elasticity of pollution with respect to the pollution tax, $\varepsilon = -R_{tt} / R_t > 0$, is smaller than unity.[7] Under these assumptions, the terms of trade would turn in favor of the donor and deteriorate for the recipient. It is quite conventional that the international relative price of good x rises under the assumption $m_x < m^*_x$, because the increased consumption of good x (i.e., imported good for the recipient) by the recipient resulting from international transfers outweighs the decreased consumption of good x by the donor resulting from the transfers under the assumption. In this context, the assumption $z - tR_{tt} > 0$, which implies $\varepsilon < 1$, magnifies the increase in the international relative price of good x. For instance, if the elasticity of pollution with respect to the pollution tax is smaller than unity $\varepsilon < 1$, then a reduction in pollution achieved by increasing the pollution tax is small, so that the government of the donor country can procure a large amount of pollution tax revenue and transfer it to the recipient. In other words, the income gain of the recipient resulting from compensation is substantial. Consequently, a terms of trade deterioration arises in the recipient country because the recipient increases their consumption of good x as a result of an increase in income. However, if the elasticity of pollution with respect to the pollution tax $\varepsilon = -R_{tt} / R_t > 0$ is greater than unity, which implies $z - tR_{tt} < 0$, then a terms of trade deterioration does not arise in the recipient although we assume $m_x < m^*_x$. That is, the reduction in the

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7 The expression $z - tR_{tt}$ can be rewritten as $-R_t(1-\varepsilon)$, where $\varepsilon = -R_{tt} / R_t$ indicates the elasticity of pollution with respect to a pollution tax. Therefore, $z - tR_{tt} > 0$ implies $\varepsilon = -R_{tt} / R_t < 1$.

amount of pollution is substantial under the assumption, $\varepsilon > 1$, and thus the government of the donor country cannot procure the large amount of the pollution tax revenue transferred to the recipient. It implies that the donor country is better off whereas the recipient country is worse off[8] because a reduction in a transfer means income loss (gain) for the recipient (donor). As a result, the international relative price of good x is lowered because the decreased consumption of good x (i.e., imported good for the recipient) by the recipient dominates the increase in the consumption of good x by the donor under the assumption of $m_x < m_x^*$.

We can show the amount of pollution by differentiating equation (1) such that $dz/dt = -R_{tp}(dp/dt) - R_{tt}$. It is obvious that the change in the amount of pollution can be determined as the direct effect of the pollution tax R_{tt} and the indirect effect of the pollution tax R_{tp}. By using equation (5), we have:

$$dz/dt = -(R_{tp}^2 + R_{tt}S_{pp})/\Delta - (m_x - m_x^*)(R_{tt}M_p^* + \alpha z R_{tp})/\Delta . \qquad (6)$$

Regarding the first term of the right-hand side of equation (6), an increase in the pollution tax can lower the amount of pollution if the direct effect of the pollution tax, R_{tt}, is large enough to dominate the indirect effect of the pollution tax, R_{tp}. The indirect effect of the pollution tax attributable to a change in the international relative price of good x would be harmful for pollution abatement. That is, an increase in the international relative price of good x resulting from an increase in the pollution tax raises the amount of pollution via an increase in the output of good x. In contrast, the direct effect, which says that an increase in the pollution tax reduces the amount of pollution via a reduction in the output of good x (i.e., polluting good) is conducive to pollution abatement. The second term of the right-hand side of equation (6) states that an increase in the pollution tax lowers the amount of pollution if we assume $m_x^* > m_x$ and the direct effect of the pollution tax R_{tt} is large enough to establish $R_{tt} > -M_p^*/\alpha z R_{tp} > 0$. Regarding the assumption $R_{tt} > -M_p^*/\alpha z R_{tp} > 0$, if pollution abatement—the direct effect of the pollution tax R_{tt}—is large, then the amount of international transfers conferred to the recipient declines as a result of an increase in the pollution tax. In this context, the international relative price of good x is lowered under the assumption $m_x < m_x^*$, as we mentioned in equation (5). The decrease in the international relative price of good x lowers the amount of pollution.

Regarding the change in the donor country's welfare resulting from the pollution tax, we have:

$$du/dt = \alpha R_{tp}\{tR_{tp} + S_{pp}R_{tp}^{-1}(tR_{tt} - z) + z(E_{pz} + E_{pz}^*) - zE_{pu^*}^*[(E_z - t)R_{tt} + E_z^*]\}/\Delta$$

$$+ M_p\{E_{pu^*}^*[(E_z - t)R_{tt} + E_z^*R_{tt}] - [(E_{pz} + E_{pz}^*)R_{tt} + R_{pt}]\}/\Delta + (E_z - t)(R_{tp}^2 + R_{tt}S_{pp})/\Delta . \qquad (7)$$

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8 This can be confirmed by examining the coefficients of dt of equations (2) and (3) (see Appendix A). The coefficient of dt in equation (2) is $[(E_z - t)R_{tt} + \alpha R_t(1-\varepsilon)]$ while in equation (3) it is $[E_z^* - \alpha R_t(1-\varepsilon)]$. Therefore, $\varepsilon > 1$ implies a welfare gain (loss) for the donor (recipient) as a result of an increase in a pollution tax.

The first term of the right-hand side of equation (7) indicates the change in the donor country's welfare via the change in the amount of transfers. If we assume that the donor country's marginal willingness to pay for pollution abatement is greater than the pollution tax, such that $E_z > t$, the consumption of good x is a substitute for pollution, such that $E_{pz} < 0$ and $E^*_{pz} < 0$, and pollution abatement by the pollution tax is not so large, such that $tR_{tt} - z < 0$ (i.e., $\varepsilon < 1$), then the welfare effects of international transfers are negative for the donor country. The main reason for this is that the amount of transfers conferred to the recipient rises following an increase in the pollution tax under these assumptions. For instance, an increase in the pollution tax reduces pollution via the direct effect of the pollution tax, and therefore raises the international relative price of good x. That is, household utility and therefore the consumption of good x in the donor country rise under the assumption $E_z > t$. Also, the assumptions $E_{pz} < 0$ and $E^*_{pz} < 0$, which say that the consumption of good x is a substitute for pollution, are conducive to an increase in the international relative price of good x following an increase in the pollution tax because the consumption of good x rises as a result of a reduction in the amount of pollution. These effects of an increase in the international relative price of good x increase the amount of pollution and therefore the international transfer. The assumption $tR_{tt} - z < 0$ implies that the amount of direct transfers is large because pollution abatement is not substantial or the initial amount of pollution z is large. The second term of the right-hand side of equation (7) captures the terms of trade effects of the donor country. If we assume $E_z > t$, $E_{pz} < 0$ and $E^*_{pz} < 0$, then the terms of trade can favor the donor country, and thus the donor country's welfare rises. That is, the international relative price of good x rises under the assumptions $E_z > t$, $E_{pz} < 0$ and $E^*_{pz} < 0$, as we explained for the first term of the right-hand side. The last term of the right-hand side of equation (7) shows the welfare effects of the donor country via the change in the amount of pollution. As we explained above, the change in pollution is directly or indirectly affected by the pollution tax. If the direct effect of a pollution tax R_{tt} dominates the indirect effect of the pollution tax R_{tp}, then an increase in the pollution tax can reduce the amount of pollution, although the price of good x (i.e., polluting good) rises. A decrease in the amount of pollution increases the welfare of the donor country under the assumption $E_z > t$. If, however, the assumption $E_z = t$ prevails, the change in the amount of pollution has a neutral effect on the welfare of the donor country because pollution is internalized in the donor country. In summary, the net effect of transfers on the donor country's welfare can be determined as follows:[9]

$$du/dt < 0 \qquad \text{if } \alpha > \alpha_d \tag{8}$$

$$\alpha_d = \frac{-M_p\{E^*_{pu^*}R_{tt}[(E_z - t) + E^*_z] - (E_{pz} + E^*_{pz})R_{tt} - R_{pt}\} - (E_z - t)(R^2_{tp} + R_{tt}S_{pp})}{R_{tp}\{tR^{-1}_{tp}(R^2_{tp} + S_{pp}R_{tt}) - zS_{pp}R^{-1}_{tp} - zE^*_{pu^*}[(E_z - t) + E^*_z] + z(E_{pz} + E^*_{pz})\}},$$

where $\alpha > \alpha_d$ implies that the transfer effect dominates the terms of trade effect and the pollution change effect in the donor country. A sufficient condition to guarantee $\alpha > \alpha_d$ is that (i) R_{tt} is sufficiently small to

9 This method follows the same line as Chao and Yu (1999).

ensure $z - R_{tt} > 0$ [10], which implies ε is small, (ii) pollution and the consumption of good x are substitutes $E_{pz} < 0, E^*_{pz} < 0$, and (iii) the marginal willingness to pay for pollution abatement in the donor country is equal to or greater than the pollution tax $E_z \geq t$.

Turning to the effects of the pollution tax on the recipient country's welfare, we have:

$$du^*/dt = -\alpha R_{tp}\{tR_{tp} + S_{pp}R_{tp}^{-1}(tR_{tt} - z) + z(E_{pz} + E^*_{pz}) - zE_{pu}[(E_z - t)R_{tt} + E^*_z]\}/\Delta$$
$$+ M^*_p\{E_{pu}[(E_z - t)R_{tt} + E^*_z R_{tt}] - [(E_{pz} + E^*_{pz})R_{tt} + R_{pt}]\}/\Delta + E^*_z(R_{tp}^2 + R_{tt}S_{pp})/\Delta. \quad (9)$$

The first term of the right-hand side of equation (9) shows the transfer effect on the recipient's welfare. Regarding this, if we assume $E_z > t$, $E_{pz} < 0$ and $E^*_{pz} < 0$, and pollution abatement by the pollution tax is not so large, such that $z - tR_{tt} > 0$, which implies $\varepsilon < 1$, then international transfers have a positive impact on the recipient country's welfare. Under these assumptions, the amount of transfers rises, as we explained in equation (7) and therefore has a positive impact on the recipient country's welfare. The second term of the right-hand side of equation (9) captures the terms of trade effects on the recipient country's welfare. Regarding this, if we assume $E_z > t$, $E_{pz} < 0$ and $E^*_{pz} < 0$, then the terms of trade disfavor the recipient country, as we explained in the second term of the right-hand side of equation (7). The third term of the right-hand side of equation (9) shows the indirect effect of the pollution tax. An increase in the pollution tax may increase the international relative price of good x following a reduction in the output of good x. The increase in the price of good x raises the amount of pollution, which damages the utility of the households in the recipient country. Therefore, the indirect effect of the pollution tax lowers the recipient country's welfare.

The net effect of the transfers on the recipient country's welfare can be determined as follows:

$$du^*/dt > 0 \qquad \text{if } \alpha > \alpha_r \quad (10)$$

$$\alpha_r = \frac{M^*_p\{E_{pu^*}R_{tt}[(E_z - t) + E^*_z] - (E_{pz} + E^*_{pz})R_{tt} - R_{pt}\} + E^*_z(R_{tp}^2 + R_{tt}S_{pp})}{R_{tp}\{tR_{tp}^{-1}(R_{tp}^2 + S_{pp}R_{tt}) - zS_{pp}R_{tp}^{-1} - zE_{pu}[(E_z - t) + E^*_z] + z(E_{pz} + E^*_{pz})\}},$$

where $\alpha > \alpha_r$ implies that the transfer effect dominates the terms of trade effect and the pollution change effect in the recipient country. A sufficient condition to guarantee $\alpha > \alpha_r > 0$ is that (i) R_{tt} is small—$z - R_{tt} > 0$ (i.e., $\varepsilon < 1$), (ii) $E_{pz} < 0, E^*_{pz} < 0$, and (iii) $E_z > t, E^*_z < t$. By using the conditions shown in equations (8) and (10), we obtain the following proposition.

Proposition 1. *If we assume: (i) the direct effect of the pollution tax* R_{tt} *is small enough to ensure that the elasticity of pollution with respect to the pollution tax* ε *is sufficiently small; (ii) pollution and the consumption of good x are substitutes* $E_{pz} < 0$ *and* $E^*_{pz} < 0$*; (iii) the marginal willingness to pay for pollution abatement in the recipient (the donor)country is smaller(greater or equal to) than the pollution*

10 The assumption that R_{tt} is small, implies that the numerator of α_d, and thereby α_d itself would not be so large as to ensure $\alpha > \alpha_d$.

tax $E_z^* < t$ *(* $E_z \geq t$ *); and (iv) the marginal propensity to consume good x of the recipient country is greater than that of the donor country* $m_x < m_x^*$ *, then the transfer effect dominates the terms of trade effect and the pollution change effect in the recipient country* $\alpha > \alpha_r$ *, and international transfers enrich the recipient whereas they impoverish the donor.*

Proof

See Appendix B.

The result shown in proposition 1 is a synthesis of the studies of environmental policies and international transfers in a large open economy in the sense that the environmental policy represented by the pollution tax affects the terms of trade and international transfers. For instance, it is a well-known result that the government of a large open economy will tend to impose a strict environmental regulation on the production of the exported good generating pollution in order to achieve increased welfare via a terms of trade improvement.[11] However, the result shown in proposition 1 does not support this view if the government of the polluter confers international transfers, which are financed by pollution tax revenue, to the recipient. This is because the amount of transfers rises as the terms of trade improve in the polluter country. Also one invokes the conventional literature of international transfers such as Bhagwati et al. (1983), where international transfers conferred to the recipient country impoverish the recipient and enrich the donor, then if the marginal propensity to consume good x of the recipient is higher than it is of the donor, then there exist certain distortions[12]. This is thought of as a “transfer paradox”. However, a transfer paradox does not arise according to proposition 1 even though we assume environmental pollution exists as a distortion and the marginal propensity to consume good x of the recipient is higher than that of the donor[13]. The main reason behind this is that an increase in the international relative price of good x (i.e., terms of trade deterioration for the recipient) resulting from an increase in the pollution tax increases the amount of transfers conferred to the recipient, and the increased international transfers dominate other effects. This can occur if the pollution damage of the recipient is not large— $E_z^* < t$.

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11 See, for instance, Siebert (1979), Krutilla (1991), and Rauscher (1991).

12 There are many studies of international transfers in the presence of distortions, including Beladi (1990), Bhagwati et al. (1983), Kemp and Wong (1993), and Oyama (1974).

13 There are many studies of international transfers in the presence of distortions, including Beladi (1990), Bhagwati et al. (1985), Kemp and Wong (1993), and Oyama (1974).

13 This result contrasts with Naito (2003), who shows that a decrease in the international relative price of polluting good as a result of transfers leads to a Pareto improvement.

14 This result contrasts with Naito (2003), who shows that a decrease in the international relative price of good x as a result of transfers leads to a Pareto improvement.

However, we cannot exclude the case of a transfer paradox. To see this, one should consider the case in which the amount of compensation is insufficient and the pollution damage is large; then it is likely that $\alpha_d < \alpha < \alpha_r$, which says that the transfer effect does not dominate the terms of trade effect and the pollution change effect in the recipient. In these circumstances, we can obtain a paradoxical case—a strong transfer paradox case, $du/dt < 0$ and $du^*/dt < 0$. Or we can obtain an ordinary transfer paradox case such that an increase in the pollution tax raises the welfare of the donor and decreases that of the recipient—$du/dt > 0$ [14]and $du^*/dt < 0$. This is possible under the conditions shown in the following proposition.

Proposition 2. *If we assume: (i) the initial amount of pollution z is small* $z - R_{tt} < 0$*; (ii) the indirect direct effect of the pollution tax* R_{tp} *dominates the direct effect of the pollution tax* R_{tt}*; (iii) pollution and the consumption of good x are substitutes* $E_{pz} < 0$ *and* $E^*_{pz} < 0$*; (iv) the marginal willingness to pay for pollution abatement in the recipient(the donor) country is greater (equal to) than the pollution tax* $E^*_z > t$ *(* $E_z = t$ *); and (v) if the marginal propensity to consume good x of the recipient country is equal to that of the donor country* $m_x = m^*_x$*, then the transfer effect does not dominate the terms of trade effect and the pollution change effect in the recipient country* $\alpha < \alpha_r$*, and international transfers enrich the donor and impoverish the recipient.*

Proof

See Appendix C.

If the marginal propensities to consume a polluting good are identical between the countries, then, as equation (5) states, an increase in the pollution tax increases the international relative price of the polluting good insofar as $E_{pz} < 0, E^*_{pz} < 0$, and $E_z = t$. It implies that the terms of trade improves (deteriorates) in the donor (recipient) country. Also, the assumption, which says that the indirect effect of the pollution tax R_{tp} is large, increases the international relative price of good x following a reduction in the output of good x. It magnifies the terms of trade improvement (deterioration) of the donor (recipient) country. However, an increase in the international relative price of good x raises the amount of pollution, which reduces the recipient country's welfare insofar as $E^*_z > t$, however it does not affect the donor country's welfare insofar as $E_z = t$. In these circumstances, if the amount of transfers is small, which is ensured by a small initial amount of pollution z, then the transfer effect does not dominate the terms of trade effect and the pollution change effect, and therefore the welfare of the recipient (donor) is lowered (increased) as a result of an increase in the pollution tax.

Turning to global welfare, we can show this by using equation (7) with equation (9):

$$du/dt + du^*/dt = -(E_z + E_z^* - t)(dz/dt) \tag{11}$$

Regarding this, if we assume $E_z = t$, $m_x^* > m_x$, and the direct effect of the pollution tax R_{tt} is large enough to dominate the other effect—the indirect effect of the pollution tax R_{tp}, then global welfare rises by increasing the pollution tax. This makes reasonable sense according to equation (6). Equation (6) states that an increase in the pollution tax lowers the amount of pollution if the direct effect of the pollution tax is sufficiently large and the marginal propensity to consume good x in the recipient country is greater than that of in the donor country. A decrease in the amount of pollution would increase the welfare of both countries insofar as $E_z + E_z^* > t$. We summarize the result shown in equation (11) as the following proposition.

Proposition 3. *An increase in the pollution tax as a means of transfers increases (decreases) global welfare if we assume: (i) the direct effect of the pollution tax is sufficiently large (small); (ii) the marginal propensity to consume good x in the recipient country is higher than it is in the donor country; and (iii) the marginal willingness to pay for pollution abatement is greater than the pollution tax in both countries.*

IV. Concluding Remarks

We have investigated the economic consequences of environmental funds aimed at compensating for transnational pollution damage by means of the traditional framework of international transfers. We have shown that whether international transfers as a means of compensation enrich the recipient depends, *inter alia*, on the magnitude of the direct pollution abatement, the relationship between pollution and the consumption of the polluting good, the marginal propensity to consume the polluting good, and the magnitude of pollution damage. In particular, the international transfers would enrich the recipient (i.e., the pollutee) and impoverish the donor (i.e., the polluter) under the conditions such that: (i) the direct effect of the pollution tax is small enough to ensure that the elasticity of pollution with respect to the pollution tax is sufficiently small; (ii) pollution and the consumption of the polluting good are substitutes; (iii) the marginal willingness to pay for pollution abatement in the recipient country is smaller than the pollution tax, and in the donor country it is equal to or greater than the pollution tax; and (iv) the marginal propensity to consume good x of the recipient country is greater than that of the donor country. In these circumstances, the welfare gain resulting from an increase in the amount of transfers would dominate the welfare loss arising from the terms of trade deterioration and the increase in pollution damage in the recipient country. This is contrary to the conventional wisdom of the large open economy model that international transfers impoverish (enrich) the recipient (donor) country in the presence of distortions. Also, it is contrary to a conventional result of environmental policy in a large open economy that a tightening of environmental regulations (e.g., an increase in the pollution tax) on the production of the polluting exported good leads to welfare increases via a terms of trade improvement. Nevertheless, we cannot deny the fact that an enrichment (immiserization) of the donor (recipient) country arises if the amount of transfers is insufficient. It can reproduce the well-known result that welfare increases arise through a terms of trade improvement following a tightening of environmental regulations, and as a result, the donor country is better off whereas the recipient country is worse off. These results provide us with the economic consequences of the international environmental liabilities, which environmental funds are used to compensate for. They also provide useful information for the policy makers about international transfers, which are financed by the revenues from pollution charges, such as The International Fund for Atmospheric Stabilization.

Appendix A

Totally differentiating equations (1), (2), (3), and (4) yields:

$$dz = -R_{tp}dp - R_{tt}dt\ , \tag{A.1}$$

$$E_u du + [E_z - (1-\alpha)t]dz + M_p dp = -\alpha z dt - tz d\alpha\ , \tag{A.2}$$

$$E^*_{u^*}du + (E^*_z - \alpha t)dz + M^*_p dp = \alpha z dt + tz d\alpha\ , \tag{A.3}$$

$$E_{pu}du + E^*_{pu^*}du^* + S_{pp}dp + (E_{pz} + E^*_{pz})dz = R_{pt}dt\ , \tag{A.4}$$

where $M_p = E_p - R_p < 0$, $M^*_p = E^*_p - R^*_p > 0$, and $S_{pp} = E_{pp} + E^*_{pp} - R_{pp} - R^*_{pp} < 0$. Substituting equation (A.1) into equations (A.2), (A.3), and (A.4) yields the following matrix:

$$\begin{bmatrix} 1 & 0 & \{M_p - [E_z - (1-\alpha)t]R_{tp} \\ 0 & 1 & [M^*_p - (E^*_z - \alpha t)R_{tp}] \\ E_{pu} & E^*_{pu^*} & [S_{pp} - (E_{pz} + E^*_{pz})R_{tp}] \end{bmatrix} \begin{bmatrix} du \\ du^* \\ dp \end{bmatrix} = \begin{bmatrix} \{[E_z - (1-\alpha)t]R_{tt} - \alpha z\} \\ [(E^*_z - \alpha t)R_{tt} + \alpha z] \\ [(E_{pz} + E^*_{pz})R_{tt} + R_{pt}] \end{bmatrix} dt + \begin{bmatrix} -tz \\ tz \\ 0 \end{bmatrix} d\alpha\ . \tag{A.5}$$

By solving the system shown in (A.5), one obtains:

$$dp/dt = [(E_{pz} + E^*_{pz})R_{tt} + R_{pt}]/\Delta - E_{pu}(E_z - t)R_{tt}/\Delta + \alpha(m_x - m^*_x)(z - tR_{tt})/\Delta \tag{A.6}$$

$$du/dt = \{[E_z - (1-\alpha)R_{tt} - \alpha z\}[S_{pp} - (E_{pz} + E^*_{pz})R_{tp}]/\Delta + E^*_{pu^*}[(E^*_z - \alpha t)R_{tt} + \alpha z]\{M_p - [E_z - (1-\alpha)t]R_{tp}\}/\Delta$$

$$- \{M_p - [E_z - (1-\alpha)t]R_{tp}\}[(E_{pz} + E^*_{pz})R_{tt} + R_{pt}]/\Delta - E^*_{pu^*}[M^*_p - (E^*_z - \alpha t)R_{tp}]\{[E_z - (1-\alpha)t]R_{tt} - \alpha z\}/\Delta$$

$$= M_p[E^*_{pu}(E_z - t)R_{tt} + E^*_z E^*_{pu^*}R_{tt} - (E_{pz} + E^*_{pz})R_{tt} - R_{pt}]/\Delta + [E_z - (1-\alpha)t](R^2_{tp} + S_{pp}R_{tt})/\Delta$$

$$+ \alpha z\{E^*_{pu^*}R_{tp}[(E_z - t) + E^*_z] - S_{pp} + (E_{pz} + E^*_{pz})R_{tp}\}/\Delta$$

$$= \alpha R_{tp}\{tR_{tp} + S_{pp}R_{tp}^{-1}(tR_{tt} - z) + z(E_{pz} + E_{pz}^*) - zE_{pu^*}^*[(E_z - t)R_{tt} + E_z^*]\}/\Delta$$

$$+ M_p\{E_{pu^*}^*[(E_z - t)R_{tt} + E_z^* R_{tt}] - [(E_{pz} + E_{pz}^*)R_{tt} + R_{pt}]\}/\Delta + (E_z - t)(R_{tp}^2 + R_{tt}S_{pp})/\Delta\,, \quad \text{(A.7)}$$

$$du^*/dt = \{(E_z^* - \alpha t)R_{tt} + \alpha z\}[S_{pp} - (E_{pz} + E_{pz}^*)R_{tp}]/\Delta + E_{pu}\{[E_z - (1-\alpha t)]R_{tt} - \alpha z\}[M_p^* - (E_z^* - \alpha t)R_{tp}]/\Delta$$

$$-[M_p^* - (E_z^* - \alpha t)R_{tp}][(E_{pz} + E_{pz}^*)R_{tt} + R_{pt}]/\Delta - E_{pu}\{M_p - [E_z - (1-\alpha)t]R_{tp}\}[(E_z^* - \alpha t)R_{tt} + \alpha z]/\Delta$$

$$= M_p^*\{E_{pu}[(E_z - t)R_{tt} + E_z^*]R_{tt} - (E_{pz} + E_{pz}^*)R_{tt} - R_{pt}]/\Delta + (E_z^* - \alpha t)(R_{tp}^2 + S_{pp}R_{tt})/\Delta$$

$$+ \alpha z\{E_{pu}R_{tp}[(E_z - t) + E_z^*] + S_{pp} + (E_{pz} + E_{pz}^*)R_{tp}\}/\Delta$$

$$= -\alpha R_{tp}\{tR_{tp} + S_{pp}R_{tp}^{-1}(tR_{tt} - z) + z(E_{pz} + E_{pz}^*) - zE_{pu}[(E_z - t)R_{tt} + E_z^*]\}/\Delta$$

$$+ M_p^*\{E_{pu}[(E_z - t)R_{tt} + E_z^* R_{tt}] - [(E_{pz} + E_{pz}^*)R_{tt} + R_{pt}]\}/\Delta + E_z^*(R_{tp}^2 + R_{tt}S_{pp})/\Delta\,, \quad \text{(A.8)}$$

where $\Delta = [S_{pp} - (E_{pz} + E_{pz}^*)R_{tp}] + M_p^*(m_x - m_x^*) + E_{pu}[E_z - (1-\alpha)t]R_{tp} + E_{pu}^*(E_z^* - \alpha t)R_{tp}$ is the determinant of the unknown variables, and $\Delta < 0$ by the following Walrasian adjustment process:

$$\dot{p} = aS(p)\,, \quad \text{(A.9)}$$

where $S(p)$ denotes the excess demand of good x and thus $S(p) = E_p + E_p^* - R_p - R_p^*$. The adjustment process is stable if and only if $ds(p)/dp < 0$. By using equations (A. 5), one obtains:

$$dS(p)/dp = \Delta\,. \quad \text{(A.10)}$$

Therefore we obtain $\Delta < 0$ under stability.

Appendix B

To prove $du/dt < 0$ and $du^*/dt > 0$, it is sufficient to show $\alpha > \alpha_r > \alpha_d$. In terms of $\alpha > \alpha_r$, if we assume R_{tt} is sufficiently small to guarantee $z - R_{tt} > 0$, pollution and the consumption of good x are substitutes $E_{pz} < 0, E_{pz}^* < 0$, and the marginal damage of pollution is small such that $E_z^* < t$, then the numerator of α_r becomes small enough to be $\alpha > \alpha_r > 0$. Secondly, we show $\alpha_r > \alpha_d$ by comparing the denominators and the numerators of α_d and α_r. In terms of the denominators, we have $A - B = zR_{tp}[(E_z - t) + E_z^*](m_x^* - m_x)$, where A and B denote the denominators of α_r and α_d, respectively. If we assume $E_z \geq t$ and $m_x^* > m_x$, then we obtain $A < B$, which implies that the denominator of α_d is greater than that of α_r. In terms of the numerators of α_r and α_d, we have $A^* - B^* = M_p^* R_{tt}(m_x - m_x^*) + E_z^* R_{tp}^2$, where A^* and B^* denote the numerators of α_r and α_d, respectively. If we assume the direct effect of the pollution tax R_{tt} is small, then the indirect effect of the pollution tax R_{tp} dominates, so that we obtain $A^* > B^*$, even though we assume $m_x^* > m_x$. Therefore, we have $\alpha > \alpha_r > \alpha_d$, which implies $du/dt < 0$ and $du^*/dt > 0$.

Appendix C

We can show $du/dt > 0$ and $du^*/dt < 0$ by showing $\alpha_r > \alpha_d > \alpha$. In terms of $\alpha_d > \alpha$, if we assume that the initial amount of pollution z is sufficiently small to ensure $z - R_{tt} > 0$, then the indirect effect of the pollution tax is large enough to ensure $R_{tp}^2 + S_{pp}R_{tt} > 0$, and if the marginal damage of pollution is equal to the pollution tax $E_z = t$, then we obtain $\alpha_d > 0$ and the denominator of α_d is small. It implies that α_d

becomes large enough to be $\alpha_d > \alpha$. Regarding $\alpha_r > \alpha_d$, as in Appendix B, we compare the denominators of α_d and α_r. If we assume that the marginal propensity to consume good x between the countries is identical, $m_x = m_x^*$, then the denominators of both α_d and α_r are identical. Turning to the numerators of α_d and α_r, the numerator of α_r is greater than that of α_d under the assumption $m_x = m_x^*$ (see Appendix A). Therefore, we have $\alpha_r > \alpha_d$, and thus we can obtain $\alpha_r > \alpha_d > \alpha$.

Appendix D

We can obtain the optimal pollution tax rate for the donor by setting $du/dt = 0$ in equation (7):

$$t^{opt} = \Theta^{-1}\{E_z[E_{pu}^*(\alpha z R_{tp} - M_p R_{tt}) - (R_{tp}^2 + R_{tt}S_{pp})] - M_p[E_z^* E_{pu^*}^* R_{tt} - (E_{pz} + E_{pz}^*)R_{tt} - R_{pt}]\}$$

$$-\Theta^{-1}\alpha R_{tp}[z(E_{pz} + E_{pz}^*) - zS_{pp}R_{tp}^{-1} - zE_{pu^*}^* E_z^*], \qquad \text{(D.1)}$$

where $\Theta = [E_{pu^*}^*(\alpha z R_{tp} - M_p R_{tt}) - (R_{tp}^2 + R_{tt}S_{pp})(1-\alpha)]$.

The sign of the optimal pollution tax rate is ambiguous in general. However, one obtains:

$$du/dt = (t - t^{opt})[E_{pu^*}^*(\alpha z R_{tp} - M_p R_{tt}) - (R_{tp}^2 + R_{tt}S_{pp})(1-\alpha)]/\Delta. \qquad \text{(D.2)}$$

Equation (D.2) implies that the government of the donor country increases the pollution tax toward the optimal rate, leading to a welfare improvement (decreasing) insofar as the indirect effect of the pollution tax R_{tp} is small (large), and the terms of trade effect M_p is large (small).

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