

Can Competition for Aid Reduce Pollution?

Nikos Tsakiris*, Panos Hatzipanayotou[†] and Michael S. Michael[‡]

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Abstract

In this paper we examine the optimal allocation of a pre-determined amount of international transfer between two recipient countries. The donor country suffers from cross border pollution resulting from production activities in the recipient countries. Pollution abatement in the recipient countries is undertaken by private producers and public sector. It is shown that the country with the higher fraction of the international transfer allocated in public abatement activities and with the lower emission tax, would receive a higher share of the aid when the donor country maximizes its own welfare in allocating aid. Also, we examine how competition for aid affects the optimal environmental policies of the recipient countries. It is shown that competition for aid, when it gives the right incentives, is an efficiency tool to induce the recipient countries to implement stricter environmental policies.

Keywords: Cross-border pollution, Pollution Abatement, Foreign Aid

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*Department of International and European Economic Studies, Athens University of Economics and Business; 76, Patission str., Athens 104 34, Greece.

[†]Department of International and European Economic Studies, Athens University of Economics and Business; 76, Patission str., Athens 104 34, Greece, and CESifo (Center for Economic Studies and the Ifo Institute of Economic Research)

[‡]Department of Economics, University of Cyprus; P.O. Box 20537 Nicosia, CY 1678, Cyprus, and Cesifo)

Correspondence: Panos Hatzipanayotou, Department of International and European Economic Studies, Athens University of Economics and Business; 76, Patission str., Athens 104 34, Greece. Tel. (+30-210) 8203189, Fax. (+30-210) 8214122, email: hatzip@aueb.gr

1. Introduction

In this paper, we consider the question of allocating international transfer or foreign aid¹ (financial aid) among recipient countries, which are characterized by differences either in environmental policies (i.e., emission taxes and fraction of international transfer allocated to pollution abatement) or in other factors such as the cost of pollution abatement production and the efficiency of public pollution abatement. Lahiri and Raimondos-Moller (1997, 2000) analyse the question of allocation of aid among multiple recipients. Lahiri and Raimondos-Moller (1997) examine how trade policies in the recipient countries affect the allocation of international transfer. Lahiri and Raimondos-Moller (2000) examine how lobbying by various ethnic groups in a donor country affects the allocation of international transfer to competing recipient countries.

We develop a general equilibrium trade model of three countries: one donor and two recipient countries. The environmental quality of the donor is affected by pollution created by the neighboring recipient countries. The donor distributes a fixed amount of aid between the two recipient countries. The latter countries control pollution through emission taxes and public pollution abatement which is funded by emission tax revenue and by a fraction of aid received. The donor is assumed to maximize two alternative objective functions in deciding how to allocate the international transfer: (i) its own welfare, and (ii) the global welfare. In the above framework we analyze the relationship between the relative level of environmental taxes and the proportion of aid allocated to clean-up policy (i.e., public abatement) in a country, and the amount of transfer it receives.

To the extent that the optimal allocation of aid is related to the emission tax rates and the proportion of aid allocated to public abatement activities in the recipient countries, it is likely that each recipient uses its environmental policies to divert transfer from its rival recipient.² We derive each recipient's optimal emission tax and optimal fraction of aid allocated to pollution abatement and we examine how competition for aid affects the optimal environmental policies.³

¹ Note that we will use the terms "international transfer" and "foreign aid" interchangeably.

² This may be called competition for aid. The analysis of this paper where national governments compete with each other for international transfers has some similarities with the literature on international capital taxation, where national governments compete for mobile tax bases.

³ Lahiri and Raimondos-Moller (1997) also present a similar game structure where the recipient countries take into account the donor's reaction to the tariff rates in the allocation of untied foreign aid, whilst they do not consider pollution, emission taxes, and public sector. Also, in their paper a terms of trade effect is the main mechanism which determines the allocation of foreign aid, whereas we assume small open economies i.e., commodity prices are exogenous.

Our main results are as follows. Competition for aid reduces aggregate pollution level when each recipient country uses fraction of aid allocated to pollution abatement as a policy to divert aid from its rival recipient. However, competition for aid increases aggregate pollution level when each recipient country uses emission tax to divert aid from its rival recipient.

2. Literature Review

Several studies examine the relationship between foreign aid and the environment. Copeland and Taylor (1995) consider a model of a world economy consisting of two regions –North and South- each composed of many countries. Governments control pollution by pollution permits or quotas. They demonstrate, among others, that untied income transfers may not have an impact on global pollution, and levels of national welfare. Chao and Yu (1999) in a two country model examine the welfare implications of aid tied to pollution abatement, where pollution is generated in an aid recipient country only. Hatzipanayotou et al. (2002) show that cross-border pollution may reduce the total amount of pollution emission within a non-cooperative framework. Naito (2003), in a two country model with transboundary pollution, shows the possibility of pareto-improving untied aid if the marginal propensity to consume in the donor country is sufficiently larger than in the recipient. Turunen-Red and Woodland (2004), among others, examine a variety of Pareto-improving multilateral environmental reforms when compensating international lump-sum transfers are assumed.

Silva and Caplan (1997, 1999) examine the effectiveness of federal environmental policy to control transboundary pollution. In contrast with our analysis i.e., three country model, they consider a transboundary pollution problem in a federal system with two regional governments and one central government. They find that delegating authority over pollution abatement instruments to regional governments is always inefficient in a federal system with centralized leadership, but decentralized control of pollution abatement production lead to no-efficiency losses in a federal system where regional governments move first.

3. The model

In our model there are three small open economies –a donor (developed country indexed by a) and two recipients (developing countries indexed by β and γ respectively). Pollution is generated as a by-product of production in the recipient countries. For simplicity, we assume that no pollution is generated in the donor country. However, pollution created in

the recipients' countries find its way to the developed country, and the latter suffers disutility from this cross border pollution⁴. In the three countries, a number of goods, which are freely traded in the international market, are produced. The endowments of the internationally immobile factors of production are inelastically supplied and factor markets are perfectly competitive. Pollution abatement in the recipients' countries is simultaneously undertaken by private producers and the public sector. The private producers abate pollution in response to an emission tax, t^i , imposed by the government. The public sector carries out an amount of abatement g^i , which is financed with the help of emission tax revenue and part of the foreign aid received. The private and the public sectors compete in the factor market on equal terms. In the recipient countries, the total factor endowment vector, V_i ($i = \beta, \gamma$) can be decomposed into the part that is used in the private sector, V_i^p , and the part that is used in the public abatement activities, V_i^g , i.e. $V_i = V_i^p + V_i^g$. The GDP function (gross domestic product), or the restricted revenue function, $R^i(p, t, V^p)$, which is the country's maximum value of domestic production of private goods, is defined as

$$R^i(p, t^i, V_i^p) = \max_{x, z} \{ p'x^i - t^i z^i : (x, z) \in T(V_i^p) \}$$

where p is the vector of world commodity prices, $T(V_i^p)$ is the recipient's country aggregate technology set, x^i and z^i are respectively the vector of net outputs and the amount of pollution emission.⁵ The technology set includes pollution abatement technologies in the various sectors. For a given level of abatement carried out by the public sector g , the vector of factor used in the public sector V_i^g , is uniquely determined. Therefore, since the total endowments of all factors of production, V , is exogenously given, V_i^p is also uniquely determined for a given value of g^i . Moreover, since p does not vary in our analysis, for notational simplicity the revenue function can therefore be written as $R^i(t^i, g^i)$. It is well known (e.g. Abe 1992) that $-R_g^i [= -(\partial R^i / \partial g) = C_i^g(w)]$ is the unit cost of public sector abatement, where w is the vector of competitive factor returns. That is, $w = R_{V^p}^i(p, t, V^p)$. For the rest of the analysis we assume that $R_{gg}^i = 0$. The $R^i(t^i, g^i)$ function is strictly convex in

⁴ We assume that the recipient countries suffer disutility only from their own pollution.

⁵ For simplicity we consider only one type of pollutant (z), which is generated in one or more sectors.

the emission tax rate (i.e. $R_t^i > 0$), meaning that an increase in the emission tax rate lowers the amount of pollution by the private sector. It is also known (e.g. see Copeland 1994) that:

$$z^i = -R_t^i(t^i, g^i) \quad (1)$$

Therefore, taking into account both private and public sector pollution abatement, the net emission of pollution, $r^i (i = \beta, \gamma)$, is defined as:

$$r^i = z^i - g^i = -R_t^i(t^i, g^i) - g^i \quad (2)$$

The following assumption is maintained throughout the analysis. Assumption: $R_{tg}^\beta > 0$ and $R_{tg}^\gamma > 0$. In view of (1) we have $R_{tg}^i = -\partial z^i / \partial g^i$, and therefore this assumption states that an increase in the publicly provided pollution abatement reduces emission by the private sector. The justification for this assumption is an induced Rybczynski effect on private goods production due to an increase in g^i .

As for the public sector, we assume that the governments in the recipients' countries finance the cost of publicly provided pollution abatement (i.e. $g^i C_t^g = -g^i R_g^i(t^i, g^i)$) by the entire emission tax revenue (i.e. $t^i z^i = -t^i R_t^i(t^i, g^i)$) and by using a fraction $0 < b^i \leq 1$ (where $i = \beta, \gamma$) of foreign aid received (i.e. $b^\beta f(\lambda T)$ and $b^\gamma f((1-\lambda)T)$ for country β and γ respectively). The donor country allocates a fixed amount of foreign aid T (in terms of the numeraire good) to the recipient countries. The allocation parameter is denoted by λ ($0 \leq \lambda \leq 1$) and this defines the proportion of the aid that goes to country β (and thus $1-\lambda$ goes to country γ). In order to be able to derive an interior solution in the international transfer problem, i.e., a solution in which both countries receive aid, some type of friction needs to be introduced in the model. The friction introduced here is that not all aid reaches its desired destination. There may be several reasons for this (see Lahiri and Raimondos 1997). In this paper we formalize this wastage/cost by stipulating that in countries β and γ , the representative consumers receive only $f(\lambda T)$ and $f((1-\lambda)T)$ amount, respectively, of the foreign aid. The function f is assumed to be increasing and concave, i.e., $f' > 0$ and $f'' < 0$.

Thus each government's budget constraint can be written as:

$$b^\beta f(\lambda T) + t^\beta z^\beta = -g^\beta R_g^\beta(g^\beta, t^\beta) \quad (3)$$

$$b^\gamma f((1-\lambda)T) + t^\gamma z^\gamma = -g^\gamma R_g^\gamma(g^\gamma, t^\gamma) \quad (4)$$

Turning to the demand side in the recipient countries, the expenditure function $E^i(r^i, u^i)$ denotes the minimum expenditure required to achieve a level of utility u at the prevailing fixed world commodity prices, when the level of net pollution is r^i . The partial derivative of the expenditure function with respect to u (E_u^i) denotes the reciprocal of marginal utility of income. Since pollution adversely affects household utility, the partial derivative of the expenditure function with respect to r^i (E_r^i), is positive and denotes the households marginal willingness to pay for the reduction in pollution (e.g. see Chao and Yu 1999). That is: a higher level of pollution requires a higher level of spending on private goods to mitigate its detrimental effects in order to maintain a constant level of utility. The expenditure function is assumed to be strictly convex in r^i , $E_{rr}^i > 0$. That is: a higher level of net pollution raises the households marginal willingness to pay for pollution abatement.

The description of the aid-receiving pollution emitting countries is completed by writing the income-expenditure identities. The budget constraint of each recipient country requires that private spending $E^i(r^i, u^i)$ must equal income from production of private goods ($R^i(g^i, t^i)$), from publicly provided pollution abatement ($-g^i R_g^i(g^i, t^i)$) plus the fraction of aid distributed to domestic households in each recipient's country households in a lump-sum manner ($((1-b^i)T)$). Using equations (3), (4), the budget constraints of the recipient countries can be written as:

$$E^\beta(u^\beta, r^\beta) = R^\beta(g^\beta, t^\beta) - g^\beta R_g^\beta(g^\beta, t^\beta) + (1-b^\beta)f(\lambda T) \quad (5)$$

$$E^\gamma(u^\gamma, r^\gamma) = R^\gamma(g^\gamma, t^\gamma) - g^\gamma R_g^\gamma(g^\gamma, t^\gamma) + (1-b^\gamma)f((1-\lambda)T) \quad (6)$$

Turning to the donor country, as noted before, it allocates a fixed amount of aid T between the two recipient countries and it does not generate any pollution. The utility of this country, however, is affected adversely by cross-border pollution originated in the recipient countries. Aggregate (total) pollution level equals to:

$$\rho = \theta^\beta r^\beta + \theta^\gamma r^\gamma \quad (7)$$

where θ^i denotes the spill-over parameter from each recipient country. Therefore the donor country's income-expenditure identity requires that private spending, denoted by the

expenditure function $E^\alpha(\rho, u^\alpha)$, must equal revenue from production of the private goods, R^α , minus the amount of foreign aid transferred to the recipient countries. That is,

$$E^\alpha(\rho, u^\alpha) = R^\alpha - T \quad (8)$$

The properties of $E^\alpha(\rho, u^\alpha)$ function follow those of the recipient countries. Since commodity prices are exogenous, and factors of production are inelastically supplied, and since there is no pollution or pollution abatement –private or public- in the donor country, R^α is exogenous to our analysis.

3. Comparative statics

In this section we examine how the policy instruments affect the level of net pollution. Totally differentiating equations (2), (3) and (4) we get:

$$dr^\beta = \Delta_\beta^{-1} \left\{ -(1+R_{tg}^\beta)b^\beta f'(\lambda T)Td\lambda - (1+R_{tg}^\beta)f(\lambda T)db^\beta + \left[R_{tt}^\beta(t^\beta + R_g^\beta) - (1+R_{tg}^\beta)(z^\beta + g^\beta R_{gt}^\beta) \right] dt^\beta \right\}, \quad (9)$$

$$dr^\gamma = \Delta_\gamma^{-1} \left\{ (1+R_{tg}^\gamma)b^\gamma f'((1-\lambda)T)Td\lambda - (1+R_{tg}^\gamma)f((1-\lambda)T)db^\gamma + \left[R_{tt}^\gamma(t^\gamma + R_g^\gamma) - (1+R_{tg}^\gamma)(z^\gamma + g^\gamma R_{gt}^\gamma) \right] dt^\gamma \right\}, \quad (10)$$

where $\Delta_i = (t^i R_{tg}^i - R_g^i) > 0$, $i = \beta, \gamma$. These changes in gross pollution affecting the donor country are given by: $d\rho = \theta^\beta dr^\beta + \theta^\gamma dr^\gamma \Leftrightarrow$

$$\begin{aligned} d\rho = & -\theta^\beta \Delta_\beta^{-1} (1+R_{tg}^\beta) f(\lambda T) db^\beta + \theta^\beta \Delta_\beta^{-1} \left[R_{tt}^\beta (t^\beta + R_g^\beta) - (1+R_{tg}^\beta)(z^\beta + g^\beta R_{gt}^\beta) \right] dt^\beta \\ & - \theta^\gamma \Delta_\gamma^{-1} (1+R_{tg}^\gamma) f((1-\lambda)T) db^\gamma + \theta^\gamma \Delta_\gamma^{-1} \left[R_{tt}^\gamma (t^\gamma + R_g^\gamma) - (1+R_{tg}^\gamma)(z^\gamma + g^\gamma R_{gt}^\gamma) \right] dt^\gamma \\ & - \left[\theta^\beta \Delta_\beta^{-1} (1+R_{tg}^\beta) b^\beta f'(\lambda T) T - \theta^\gamma \Delta_\gamma^{-1} (1+R_{tg}^\gamma) b^\gamma f'((1-\lambda)T) T \right] d\lambda. \end{aligned} \quad (11)$$

Equation (11) indicates that an increase in the fraction of aid allocated for public abatement activities unambiguously reduce the aggregate level of pollution. This is because an increase in b^i raises the amount of funds used by the recipient countries for public abatement activities. The effect of a higher t^i on aggregate pollution level is ambiguous. An increase in t^i , *ceteris paribus*, reduces pollution emission by the private sector and therefore the tax base for public sector abatement. The net effect of an increase in t^i on aggregate level of pollution is therefore ambiguous. A higher emission tax reduces aggregate pollution level if the

emission tax rate (t^i) is lower than the unit cost of public abatement ($-R_g^i$). That is, if $t^i + R_g^i < 0$. The effect of a higher λ on aggregate pollution level is ambiguous. Starting with equal share, a reallocation of the aid to country β decreases the aggregate level of pollution if

$$\left[\theta^\beta \Delta_\beta^{-1} (1 + R_{tg}^\beta) b^\beta f'(\lambda T) T - \theta^\gamma \Delta_\gamma^{-1} (1 + R_{tg}^\gamma) b^\gamma f'((1-\lambda)T) T \right]_{\lambda=\frac{1}{2}} > 0 \quad (12)$$

Proof: After some manipulations in equation (12) we obtain:

$$\left\{ f'((1-\lambda)T) \theta^\beta \Delta_\beta^{-1} (1 + R_{tg}^\beta) b^\beta T \left(\frac{f'(\lambda T)}{f'((1-\lambda)T)} - \frac{\theta^\gamma \Delta_\gamma^{-1} (1 + R_{tg}^\gamma) b^\gamma T}{\theta^\beta \Delta_\beta^{-1} (1 + R_{tg}^\beta) b^\beta T} \right) \right\}_{\lambda=\frac{1}{2}} > 0, \quad (13)$$

Equation (13) is positive if and only if:

$$\frac{\theta^\gamma (t^\beta R_{tg}^\beta - R_g^\beta) (1 + R_{tg}^\gamma) b^\gamma T}{\theta^\beta (t^\gamma R_{tg}^\gamma - R_g^\gamma) (1 + R_{tg}^\beta) b^\beta T} < 1. \quad (14)$$

Proposition 1. *When the donor country maximizes its own welfare in allocating a given amount of foreign aid, country β gets a higher share of the aid⁶ if*

$$\theta^\gamma \Delta_\gamma^{-1} (1 + R_{tg}^\gamma) b^\gamma T < \theta^\beta \Delta_\beta^{-1} (1 + R_{tg}^\beta) b^\beta T.$$

From the above proposition the following corollary is derived straightforwardly.

Corollary: Suppose the two recipient countries are symmetric in the following ways:

1. *If $t^\beta = t^\gamma$, $\theta^\beta = \theta^\gamma$, $R_{tg}^\beta = R_{tg}^\gamma$ and $-R_{g^\beta}^\beta = -R_{g^\gamma}^\gamma$ then the country with the higher fraction of foreign aid allocated to pollution abatement (i.e., b^i) gets a higher share of the foreign aid when the donor minimizes the aggregate pollution level.*
2. *If $\theta^\beta = \theta^\gamma$, $R_{tg}^\beta = R_{tg}^\gamma$ and $-R_{g^\beta}^\beta = -R_{g^\gamma}^\gamma$, $b^\beta = b^\gamma$ then the country with the lower emission tax rate (i.e., t^i) gets a higher share of the foreign aid when the donor minimizes the aggregate pollution level.*
3. *If $t^\beta = t^\gamma$, $R_{tg}^\beta = R_{tg}^\gamma$ and $-R_{g^\beta}^\beta = -R_{g^\gamma}^\gamma$, $b^\beta = b^\gamma$ then the country exerting the higher degree of cross border pollution (i.e., θ^i) gets a higher share of the foreign aid when the donor minimizes the aggregate pollution level.*

⁶ If the function f was linear, the country with the higher fraction or lower emission tax receives the entire aid, and the country with the lower fraction or higher emission tax none.

4. If $t^\beta = t^\gamma$, $\theta^\beta = \theta^\gamma$ and $-R_{g^\beta}^\beta = -R_{g^\gamma}^\gamma$, $b^\beta = b^\gamma$, then the country with the higher efficiency of public pollution abatement (i.e., R_{ig}^i) gets a higher share of the foreign aid when the donor minimizes the aggregate pollution level if and only if the emission tax rate in each recipient country is lower than the unit cost of public abatement i.e., $t^i + R_{g^i}^i < 0$.

5. If $t^\beta = t^\gamma$, $\theta^\beta = \theta^\gamma$ and $R_{t^\beta g^\beta}^\beta = R_{t^\gamma g^\gamma}^\gamma$, $b^\beta = b^\gamma$, then the country with the lower unit cost of public sector abatement (i.e., $R_{g^i}^i$) gets a higher share of the foreign aid when the donor minimizes the aggregate pollution level.

4. Welfare Effects

In this section we shall examine the effect on changes on policy instruments on the levels of welfare in the three countries, and also we characterize the Nash optimal levels of the policy instruments. Totally differentiating equations (5), (6) and (8) we obtain the welfare effects in the donor and the recipient countries as follows

$$\Delta_\beta E_u^\beta du^\beta = B_\lambda d\lambda + B_{b^\beta} db^\beta + B_{t^\beta} dt^\beta, \quad (12)$$

$$\Delta_\gamma E_u^\gamma du^\gamma = \Gamma_\lambda d\lambda + \Gamma_{b^\gamma} db^\gamma + \Gamma_{t^\gamma} dt^\gamma, \quad (13)$$

$$E_u^\alpha du^\alpha = A_\lambda d\lambda + A_{t^\beta} dt^\beta + A_{t^\gamma} dt^\gamma + A_{b^\beta} db^\beta + A_{b^\gamma} db^\gamma + A_{\theta^\beta} d\theta^\beta + A_{\theta^\gamma} d\theta^\gamma \quad (14)$$

where $B_\lambda = f'(\lambda T)T \left[(1 + R_{ig}^\beta)E_{r^\beta}^\beta b^\beta + (1 - b^\beta)(t^\beta R_{ig}^\beta - R_g^\beta) \right]$,

$B_{b^\beta} = f(\lambda T) \left[(1 + R_{ig}^\beta)E_{r^\beta}^\beta - (t^\beta R_{ig}^\beta - R_g^\beta) \right]$,

$B_{t^\beta} = (z^\beta + g^\beta R_{gt}^\beta) \left[E_r^\beta (1 + R_{ig}^\beta) + R_g^\beta - t^\beta R_{ig}^\beta \right] - E_r^\beta R_{tt}^\beta (t^\beta + R_g^\beta)$,

$\Gamma_\lambda = f'((1 - \lambda)T)T \left[-(1 + R_{ig}^\gamma)E_{r^\gamma}^\gamma b^\gamma - (1 - b^\gamma)(t^\gamma R_{ig}^\gamma - R_g^\gamma) \right]$,

$\Gamma_{b^\gamma} = f((1 - \lambda)T) \left[(1 + R_{ig}^\gamma)E_{r^\gamma}^\gamma - (t^\gamma R_{ig}^\gamma - R_g^\gamma) \right]$,

$\Gamma_{t^\gamma} = (z^\gamma + g^\gamma R_{gt}^\gamma) \left[E_r^\gamma (1 + R_{ig}^\gamma) + R_g^\gamma - t^\gamma R_{ig}^\gamma \right] - E_r^\gamma R_{tt}^\gamma (t^\gamma + R_g^\gamma)$.

$A_\lambda = E_\rho^\alpha \theta^\beta \Delta_\beta^{-1} \left[(1 + R_{ig}^\beta) b^\beta f'(\lambda T)T \right] - E_\rho^\alpha \theta^\gamma \Delta_\gamma^{-1} \left[(1 + R_{ig}^\gamma) b^\gamma f'((1 - \lambda)T)T \right]$

$A_{t^\beta} = -E_\rho^\alpha \theta^\beta \Delta_\beta^{-1} \left[R_{tt}^\beta (t^\beta + R_g^\beta) - (1 + R_{ig}^\beta)(z^\beta + g^\beta R_{gt}^\beta) \right]$

$A_{t^\gamma} = -E_\rho^\alpha \theta^\gamma \Delta_\gamma^{-1} \left[R_{tt}^\gamma (t^\gamma + R_g^\gamma) - (1 + R_{ig}^\gamma)(z^\gamma + g^\gamma R_{gt}^\gamma) \right]$, $A_{\theta^\beta} = -E_u^\alpha r^\beta$, $A_{\theta^\gamma} = -E_u^\alpha r^\gamma$,

$A_{b^\beta} = E_\rho^\alpha \theta^\beta \Delta_\beta^{-1} (1 + R_{ig}^\beta) f(\lambda T)$, $A_{b^\gamma} = E_\rho^\alpha \theta^\gamma \Delta_\gamma^{-1} (1 + R_{ig}^\gamma) f((1 - \lambda)T)$.

For the recipient countries an increase in foreign aid improve welfare, if $b^i \leq 1$ (i.e., there is no matching aid). Aid unambiguously reduces net emission level and it also increases income of the households. An increase in b^i have an ambiguous effect on the welfare of the recipient countries. On the one hand a higher b^i unambiguously reduces net emission which increases welfare. On the other hand, a higher b^i reduces lump-sum transfer to the households which reduces welfare. An increase in t^i has ambiguous effect on welfare. On the one hand a higher t^i reduce pollution, but on the other hand takes resources away from the private sector to the public sector, reducing private income.

Turning to the donor country, an increase in b^i will unambiguously increase welfare in the donor country by reducing emission in the recipient countries and thus the level of cross-border pollution into the donor country. An increase in t^i has an ambiguous effect on the welfare of the donor country. This is because an increase in t^i has an ambiguous effect on the level of net emission. As for the welfare effects of λ , since we assume that the total amount is fixed, the allocation of aid among the recipient countries has only one effect on the donor and that is via changes in the level of pollution in the recipient countries.

5. The Nash Equilibrium (One-shot game)

Having explained the welfare equations, we can now characterize the non-cooperative Nash optimal levels of the policy instruments. That is, when the two recipient countries choose respectively the levels of (b^i, t^i) simultaneously by maximizing their respective welfare while the donor maximizes its own welfare in deciding the optimal value of λ . The first order conditions are given by:

$$\Delta_\beta E_u^\beta du^\beta / db^\beta = B_{b^\beta} = 0, \quad (15)$$

$$\Delta_\beta E_u^\beta du^\beta / dt^\beta = B_{t^\beta} = 0, \quad (16)$$

$$\Delta_\gamma E_u^\gamma du^\gamma / db^\gamma = \Gamma_{b^\gamma} = 0, \quad (17)$$

$$\Delta_\gamma E_u^\gamma du^\gamma / dt^\gamma = \Gamma_{t^\gamma} = 0, \quad (18)$$

$$E_u^\alpha du^\alpha / d\lambda = A_\lambda = 0. \quad (19)$$

From the above five equations, we obtain the following optimality conditions:

$$t^\beta = E_r^\beta = -R_g^\beta \quad (20)$$

$$t^\gamma = E_r^\gamma = -R_g^\gamma \quad (21)$$

$$\frac{f'(\lambda^* T)}{f'((1 - \lambda^*) T)} = \frac{b^\gamma t^\beta \theta^\gamma}{b^\beta t^\gamma \theta^\beta} \cdot \quad (22)$$

It is interesting to note that the optimality conditions (20), (21) combine the Samuelson rule for the optimal provision for public goods with the Pigouvian rule for environmental taxation. The first equality in the optimality conditions (20) and (21) gives the Pigouvian rule, *viz.* that the marginal willingness to pay for pollution abatement is equal to emission tax rate. The second equality gives the Samuelsonian rule, *viz.* that the marginal willingness to pay for a public good is equal to the marginal cost of producing it. Nash equilibrium pollution taxes (t_N^i) and fraction of aid allocated to pollution abatement (b_N^i) in the recipient country are not Pareto efficient (optimal), because recipients countries are not taking into account the spillover effects on damage to donor. As a result the Nash equilibrium rates of the recipients' countries policy instruments are very low from the efficiency point of view.

Equation (22) gives the optimal allocation of aid under the assumption of self-interested donor.

Proposition 2. *When the donor country maximizes its own welfare in allocating a given amount of aid, country β gets a higher proportion of the aid if and only if*

$$\frac{f'(\lambda^* T)}{f'((1 - \lambda^*) T)} = \frac{b^\gamma t^\beta \theta^\gamma}{b^\beta t^\gamma \theta^\beta} < 1. \quad (23)$$

Consequently, it follows that $\lambda^* > \frac{1}{2}$ if the right-hand side of equation (23) is less than unity.

From the above proposition the following corollary is derived straightforwardly:

Corollary: Suppose the two recipient countries are symmetric in the following ways:

1. *If $t^\beta = t^\gamma$ and $\theta^\beta = \theta^\gamma$, then the country with the higher fraction of foreign aid allocated to pollution abatement(*i.e.*, b^i) gets a higher share of the foreign aid when the donor selfishly maximizes its own welfare.*
2. *If $\theta^\beta = \theta^\gamma$ and $b^\beta = b^\gamma$ then the country with the lower emission tax rate (*i.e.*, t^i) gets a higher share of the foreign aid when the donor maximizes its own welfare.*
3. *If $t^\beta = t^\gamma$ and $b^\beta = b^\gamma$ then the country exerting the higher degree of cross border pollution (*i.e.*, θ^i) gets a higher share of the foreign aid when the donor maximizes its own welfare.*

The economic intuition behind the above results can be explained as follows. As the donor country's welfare is affected only via changes in cross-border pollution, that country prefers an allocation of aid that has a more negative effect on aggregate pollution level. Also, note that Proposition 2 will hold if the donor maximizes global welfare i.e, the sum of the welfares of the three countries.⁷ The difference between the case of self-interested donor and that of altruistic donor is that in the latter case the country with the higher marginal willingness to pay for a reduction of pollution gets a higher proportion of the aid, whereas in the former case the result is just the opposite.

6. Competition for Aid Equilibrium (Two-stage game)

The donor's allocation of aid depends on the relative magnitude of the emission tax rates and the rates of fraction of foreign aid allocated to pollution abatement in the two recipient countries. From this result it follows that the recipient countries may want to use environmental policy instruments in competing with each other for international transfers. In this section we analyze how competition for aid affects the optimal emission tax and optimal fraction of aid allocated to pollution abatement, when the donor maximizes its own welfare. That is we consider the case where each country maximize its own welfare by using the policy instruments at its disposal, i.e., recipient countries their environmental policy instruments and the donor country uses its aid allocation instrument λ .⁸ We compare the competition for aid equilibrium with the one where the countries act simultaneously.

Case 1: The recipient countries set optimally the emission tax rate t^i .

We consider a two-stage game. In the first stage the recipient countries set their emission taxes in a Nash way. The donor country then decides on the allocation of aid in the second stage. The model works by backward induction: the recipient countries take into account the donor country's reaction in deciding on the Nash optimal levels of the emission taxes. The reactions functions for the donor and the two recipient countries can be derived respectively from equation (12), (13) and (14). The recipient countries take into account the donor country's reaction when they determine their optimal Nash (non-cooperative) emission taxes. Thus, starting backwards from the donor's behavior we know that the donor maximizes its welfare by choosing λ and taking the emission taxes rates as given, i.e. $A_\lambda = 0$.

⁷ Under the altruistic donor scenario, international transfer might be given by an international agencies or institutions instead of a donor country (e.g., the Global Environment Facility).

⁸ We assume that all countries know the other countries' objective functions.

$$\frac{f'(\lambda^* T)}{f'((1-\lambda^*) T)} = \frac{(1+R_{tg}^\gamma) b^\gamma (t^\beta R_{tg}^\beta - R_g^\beta) \theta^\gamma}{(1+R_{tg}^\beta) b^\beta (t^\gamma R_{tg}^\gamma - R_g^\gamma) \theta^\beta} \quad (24)$$

We denote the donor's reaction function by:

$$R_u : \lambda^* = \lambda^*(t^\beta, t^\gamma)$$

which is a solution for λ from equation (24). Differentiating equation (24) and setting $dt^\gamma = d\theta^\beta = d\theta^\gamma = 0$, we obtain:

$$\left(\frac{\partial \lambda^*}{\partial t^\beta} \right)_{reaction} = -\frac{A_{\lambda t^\beta}}{A_{\lambda \lambda}} < 0,$$

Differentiating (24) and setting $dt^\beta = d\theta^\beta = d\theta^\gamma = 0$, we obtain:

$$\left(\frac{\partial \lambda^*}{\partial t^\gamma} \right)_{reaction} = -\frac{A_{\lambda t^\gamma}}{A_{\lambda \lambda}} > 0,$$

where $A_{\lambda t^\beta} = -E_\rho^\alpha \theta^\gamma R_{tg}^\beta \left[(1+R_{tg}^\gamma) b^\gamma f'((1-\lambda)T) \right] < 0$,

$A_{\lambda t^\gamma} = E_\rho^\alpha \theta^\beta R_{tg}^\gamma \left[(1+R_{tg}^\beta) b^\beta f'(\lambda T) \right] > 0$, and $A_{\lambda \lambda} < 0$.

Notice that $A_{\lambda \lambda} < 0$ for the Nash equilibrium allocation parameter rate to maximize welfare of the donor country.⁹ That is, a reduction in the emission tax rate in a country increases the proportion of aid going to it.

Turning to the reaction functions of the recipient countries, assuming that $b^i = 1$, $i = \beta, \gamma$ (i.e., that the whole aid is allocated for pollution abatement in each recipient country), and setting $A_\lambda = 0$ we get,

$$R^\beta : \frac{\partial u^\beta}{\partial t^\beta} = 0 \Leftrightarrow B_{t^\beta} + B_\lambda (\partial \lambda^* / \partial t^\beta) = 0, \quad (25)$$

$$R^\gamma : \frac{\partial u^\gamma}{\partial t^\gamma} = 0 \Leftrightarrow \Gamma_{t^\gamma} dt^\gamma + \Gamma_\lambda (\partial \lambda^* / \partial t^\beta) = 0. \quad (26)$$

The second term in the above equations is the *competition for aid effect* (second stage effect) on the reaction functions. This effect is negative for both equations. Thus competition for aid gives wrong incentives to recipient countries and induce them to choose an even lower emission tax rate than the inefficiently low emission tax rate in the Nash (simultaneous)

⁹ Rearranging equation (18) we get that $du^\alpha / d\lambda = A_\lambda / E_u^\alpha$. Since $\frac{d^2 u^\alpha}{d\lambda^2} = (A_{\lambda \lambda} / E_u^\alpha) < 0$ at the Nash equilibrium for maximizing welfare, we get $A_{\lambda \lambda} < 0$ since $E_u^\alpha > 0$.

equilibrium, i.e., $t_N^i > t_C^i$, where t_N^i and t_C^i denote equilibrium tax rates under Nash (simultaneous) and competition for aid, respectively.

Proposition 3. *When the donor maximizes its own welfare in allocating foreign aid, competition for aid reduces the optimal emission tax rates in the recipient countries, i.e., $t_N^i > t_C^i$ and thus aggregate pollution increases.*

Competition for international transfers has been shown to have a positive effect to the level of aggregate pollution since it reduces emission taxes in both recipient countries and results in “a race to the bottom”.

Case 2: *The recipient countries set optimally the fraction b^i of foreign aid allocated to pollution abatement.*

We consider a two-stage game. In the first stage the recipient countries set their fractions of foreign aid allocated to pollution abatement in a Nash game. The donor country then decides on the allocation at the second stage. The model works by backward induction: the recipient countries take into account the donor country’s reaction in deciding on the Nash optimal levels of the fraction of the aid allocated to pollution abatement. The reactions functions for the donor and the two recipient countries can be derived respectively from equation (12), (13) and (14). The recipient countries take into account the donor country’s reaction when they determine their optimal Nash (non-cooperative) fractions. Thus, starting backwards from the donor’s behavior we know that the donor maximizes its welfare by choosing λ and taking the emission taxes rates as given, i.e. $A_\lambda = 0$. We denote the donor’s reaction function by:

$$R_a : \lambda^* = \lambda^*(b^\beta, b^\gamma).$$

which is a solution for λ from equation (24). Differentiating equation (24) and setting $db^\gamma = d\theta^\beta = d\theta^\gamma = 0$, we obtain:

$$\left(\frac{\partial \lambda^*}{\partial b^\beta} \right)_{reaction} = -\frac{A_{\lambda b^\beta}}{A_{\lambda \lambda}} > 0,$$

Differentiating equation (15) and setting $db^\beta = d\theta^\beta = d\theta^\gamma = 0$, we obtain:

$$\left(\frac{\partial \lambda^*}{\partial b^\gamma} \right)_{reaction} = -\frac{A_{\lambda b^\gamma}}{A_{\lambda \lambda}} < 0.$$

That is, an increase in the fraction of aid allocated in pollution abatement reduce in the emission tax rate in a country increases the proportion of aid going to it.

Turning to the reaction functions of the recipient countries and setting $A_\lambda = 0$ we get,

$$R^\beta : \frac{du^\beta}{db^\beta} = 0 \Leftrightarrow B_{b^\beta} + B_\lambda (\partial \lambda^* / \partial b^\beta) = 0 \quad (27)$$

$$R^\gamma : \frac{du^\gamma}{db^\gamma} = 0 \Leftrightarrow \Gamma_{b^\gamma} + \Gamma_\lambda (\partial \lambda^* / \partial b^\gamma) = 0 \quad (28)$$

The second term in the above equations is the *competition for aid effect* on the reaction functions. This effect is positive for both equations. Thus competition for aid gives right incentives to recipient countries and induce them to choose higher proportion of aid allocated to public abatement than the inefficiently low level in the Nash (simultaneous) equilibrium, i.e., $b_C^i > b_N^i$.

Proposition 4. *When the donor maximizes its own welfare in allocating foreign aid, competition for aid increases the levels of optimal fractions of aid allocated to pollution abatement in the recipient countries, i.e., $b_C^i > b_N^i$ and thus aggregate pollution is reduced.*

Competition for international transfers has been shown to have a negative effect to the level of aggregate pollution since it increases the fraction of aid allocated to public pollution abatement in both recipient countries and results in “a race to the top”.

8. Conclusion

This paper considers the optimal allocation of a pre-determined amount of international transfer between two recipient countries. The donor country suffers from cross border pollution resulting from production activities in the recipient countries. Pollution abatement in the recipient countries is undertaken by private producers and public sector. It is shown that the country with the higher fraction of the international transfer allocated in public abatement activities and with the lower emission tax, would receive a higher share of the aid either when the donor country maximizes its own welfare in allocating aid or when it maximizes global welfare. We derive the optimal environmental policies in the case where countries decide simultaneously and also in the case where the recipient countries compete with each other for aid. We compare the competition for aid equilibrium with the one where the countries act

simultaneously and we demonstrate that competition for aid, when it gives the right incentives to the recipient countries, can induce them to take stricter environmental policies.

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