Foreign Investment and Environment in a North-South Model with Cross-border Pollution

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Abstract

We develop a North-South model with cross-border pollution. In the South, pollution is abated by both private producers and the public sector. The North suffers from cross-border pollution from the South. The policy instruments are foreign aid for the North, and funds for public abatement, emission tax rate, and a tax on foreign capital, for the South. We characterize the Nash equilibrium under two scenarios: foreign investment is (i) exogenous, and (ii) endogenous. Under (i), we examine the effect of a reform where both foreign investment and aid are changed in an income-neutral way. In the latter case, we analyze the effect of a tax-induced change in foreign investment on pollution. In both scenarios, an inflow of foreign investment unambiguously reduces the net emission of pollution.

JEL Classifications: Q28, F35, H41

Keywords: cross-border pollution, foreign investment, foreign aid, public pollution abatement, private pollution abatement

1. Introduction

The pace of globalization is almost unstoppable in today's world. More and more developed countries are extending the boundary of their investments into new, unexplored "territories", in the quest for a higher return on capital. However, many environmentalists consider such expansion of capital markets a potential threat to the environment.

The relationship between economic integration in general, and capital mobility in particular, and the environment has received a great deal of attention in the international

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economics literature.[1] One worry is that as environmental policies in some countries are being tightened, some firms in those countries would decide to relocate themselves to countries with more lax environmental restrictions, possibly creating "pollution-havens". Copeland and Taylor (1997) show that capital mobility could lower or raise pollution depending on the pattern of trade. Empirical studies by Tobey (1990), Grossman and Krueger (1991), Jaffe *et al.* (1995) and Levinson (1996) cannot find any support for this hypothesis. Another concern is that increased economic integration would result in an increase in the scale of production and thus pollution. However, Antweiler *et al.* (2001) have shown that international economic integration also creates more demand for a cleaner environment by raising the levels of income. Their empirical study on the emission of sulfur dioxide shows that the income effect just mentioned is substantial and outweighs the negative effects. In general, it is agreed that foreign investment, international trade, and policy-making play key roles in the relationship between economic integration and the environment (see, for example, Copeland, 1994, 2004; Beghin et al., 1997).

A substantial literature also relates to cross-border pollution. Merrifield (1988), in a two-country general equilibrium model with internationally mobile capital and cross-border pollution, examines the welfare effects of a number of abatement strategies. Ludema and Wooton (1994) examine the welfare effects of environmental policies *vis-à-vis* trade policies. Ludema and Wooton (1997) extend their earlier work by incorporating administrative costs and asymmetric information in pollution abatement in order to examine the welfare implications of cooperative and non-cooperative trade and environmental policies. Copeland and Taylor (1995) demonstrate, *inter alia*, that a reduction in pollution by a coalition of countries may be Pareto improving and that income transfers tied to pollution reduction can be welfare enhancing. Copeland (1996) examines the effectiveness of a "pollution content tariff", *i.e.* an import tariff whose magnitude varies with the amount of pollution generated by the production of the imported good. Hatzipanayotou *et al.* (2002) show that cross-border pollution can actually reduce the level of net pollution by inducing aid from the North to the South.

We develop a general equilibrium North-South model of capital mobility and cross-border pollution to analyze the effect of foreign investment on the environment. The two countries are small open economies in international commodity markets. The South is characterized by a production process that pollutes, and pollution moves across the border into the North. Pollution in the South is abated by both the private and the public sectors; the latter is financed by pollution tax revenue and a fraction of aid given by the North.[2, 3] At the theoretical level, the issue of public abatement has been analyzed by many researchers. Khan (1995) considers the case where abatement is done only by the public sector. Chao and Yu (1999) and Hatzipanayotou *et al.* (2002) allow for the

[1] See Copeland and Taylor (2003, 2004) for a discussion of the literature.

[2] The share of public abatement expenditure in total abatement expenditure varies quite a lot from country to country and from one type of pollution to another. According to OECD (1996), the range can be 6% to 66%.

[3] Our framework has some similarities with the upstream-downstream model of environmental pollution (see, for example, Calcott and Walls, 2000; Walls and Palmer, 2001) where people living downstream have to deal with disposing (abating) waste created by a firm upstream. In our context, the upstream firm is the South and the downstream people are the North.

coexistence of private and public abatement. We allow the two countries to employ a set of policy instruments and examine the effect of foreign investment on the environment when these instruments are employed at their non-cooperative optimal levels. We do so in two scenarios. In the first, we assume that the level of foreign investment is exogenous and consider a piecemeal reform exercise when foreign investment is accompanied by foreign aid. In the second scenario, we take foreign investment to be endogenous and consider a decrease in a tax on foreign capital to induce an increase in foreign investment. These two scenarios are taken up in sections 2 and 3. Thus our paper is different not only in relation to the model structure, but also to the specific exercises that we carry out.

As mentioned before, according to Antweiler *et al*. (2001) economic integration increases the demand for a cleaner environment by increasing income, and this income effect can be empirically significant. In this paper we explore a few other channels via which economic integration in the form of increased mobility of capital into a country can reduce pollution emission in that country. These new channels appear because of the existence of cross-border pollution and the endogenous flow of foreign aid. For example, additional pollution in the South because of an inflow of foreign capital creates disutility in the North due to cross-border pollution. This increases the North's marginal willingness to pay for pollution abatement, which in turn induces more foreign aid from the North to the South and thus more pollution abatement in the South. As we shall show, this additional channel by which economic integration reduces pollution can be a crucial factor when policy instruments are optimally set.

2. The Case of Exogenous Foreign Investment

We develop a general equilibrium model of two small open economies, the North and the South. The North is a developed country and the South a less developed one. The latter offers private investors from the former the opportunity of a higher return on their capital. That is, foreign investment flows from the North to the South. The South has two sectors: (1) one private industrial sector that produces a set of goods (which are traded on the international market at exogenous prices) and pollution takes place as a byproduct of the production process; and (2) a public sector that takes part in pollution abatement. The government in this country imposes an emission tax, t, on the amount of pollution emitted by the private sector and, in response to it, a certain amount of private abatement takes place.

The North has only a private sector, which produces a set of goods that are also traded in the international market at exogenous prices. The private sector uses a more advanced pollution technology than that in the South, and therefore, for simplicity, we assume that the production process there is pollution-free. The North, however, suffers some disutility generated by the pollution that spills over across the borders from the South. In order to help the South fight pollution, the government in the North provides foreign aid with the hope that the South will use it for public abatement. We further assume that all the commodity and factor markets are perfectly competitive.

We represent the production side of the two countries by their respective revenue functions. Total factor endowment vector in the South has two components: internationally mobile capital, K, and the vector of internationally immobile and inelastically supplied factors, V. Denoting by F, the amount of foreign investment from the North to the South, the total endowment vector in the South is $(K + F, V)$. A part of V is employed in the private sector and the remaining part in the public sector to abate pollution. The total value of production in the private sector of the South can be represented by the "restricted" revenue function, $R(g, t, K + F)$, where g is the level of public abatement.

It may be helpful to state a few properties of, and assumptions on, the restricted revenue function defined above. First, the partial derivative of it with respect to the emission tax rate, t, gives the amount of net emission by the private sector, z, *i.e.* $z = -R_t(g, t, K + F) > 0$. Second, the partial derivative with respect to the amount of public pollution abatement, g, gives the unit cost of public pollution abatement, *i.e.* $-R_g = -\partial R / \partial g > 0$ (Copeland, 1994; Turunen-Red and Woodland, 2004). Third, $R(g, t, K + F)$ is a convex function of t, *i.e.* $R_{tt}(g, t, K + F) > 0$, meaning that a rise in the effluent tax makes the private sector reduce its emission level. Formally $R_{tt} = (\partial R_t / \partial t) = -(\partial z / \partial t) > 0$. Fourth, we assume $R_{tg} = \partial R_t / \partial g = -\partial z / \partial g > 0$ meaning that an increase in the public pollution abatement activity must reduce the amount of net pollution by the private sector. Fifth, it is assumed that an increase in the level of capital stock in the South raises the level of pollution emission by the private sector, *i.e.* $R_{tK} < 0$. Finally, we assume that $R_{gg} = R_{KK} = R_{Kg} = 0$. These last assumptions, which are made for analytical simplicity, correspond to results in the conventional Heckscher-Ohlin model where changes in factor prices are determined by changes in commodity prices but are insensitive to changes in endowment levels as long as the economy is within the cone of diversification. Abe (1992, 1995), and Hatzipanayotou and Michael (1995) use the same assumption in a different framework. Chao and Yu (1999) and Hatzipanayotou *et al*. (2002) make the same assumption in a similar context where private and public abatement coexist. We formally state the assumptions below.

Assumption 1: $R_{tt} > 0,\ R_{tg} > 0,\ R_{tK} < 0,\ R_{KK} = R_{gg} = R_{Kg} = 0.$

We shall now write down the equations that describe the economy in the South. The first equation defines the amount of net pollution as the total net emission by the private sector minus the amount of pollution abated by the public sector. That is,

$$r = z - g = -R_t(g, t, K + F) - g. \qquad (1)$$

The second equation describes the government budget constraint in the South, *i.e.* the cost of its abatement activity $(-gR_g(g, t, K + F))$ is financed from the emission tax revenue[4, 5] $(t \cdot z)$ and from a fraction, $\beta > 0$, of foreign aid, T, it receives from the North (βT). The rest of the transfer $(1 - \beta)T$ is distributed in a lump-sum manner to the representative household.[6] That is:

$$\beta T - tR_t(g, t, K + F) + gR_g(g, t, K + F) = 0 \tag{2}$$

The demand side in the South is represented by the expenditure function $E(P, r, u)$ which gives the minimum expenditure required to achieve a level of utility, u, at given goods-price vector, P, and a net pollution level, r. Since P does not vary in our analysis, the expenditure function is written simply as $E(r, u)$. The income side consists of factor incomes in the private sector, $R(g, t, K + F)$, plus factor income from public abatement, plus the fraction of aid given in a lump-sum manner to households, minus repatriated profits. Balancing expenditure and income, we obtain the third equation of our model:

$$E(r, u) = R(g, t, K + F) - gR_g(g, t, K + F) + (1 - \beta)T - \rho F, \tag{3}$$

where ρ is the rental rate of capital in the South, given by:

$$\rho = \frac{\partial R(g, t, K + F)}{\partial K} = R_K(g, t, K + F) \tag{4}$$

The partial derivative of the expenditure function with respect to net pollution, $E_r(r, u)$, gives the households' marginal willingness to pay for pollution abatement. Since pollution affects utility negatively, we have $E_r\,(r, u) > 0$. We assume that $E_{rr}\,(r, u) > 0$, meaning that the households are willing to pay more for marginal pollution abatement at higher levels of pollution. Third, the derivative of the expenditure function with respect to utility ($E_u(r, u) > 0$) is the reciprocal of marginal utility of income. The North does not generate any pollution and therefore it does not undertake any public abatement. It suffers from pollution generated in the South. Apart from this, the structure of the economy in the North is the same as that in the South. The expenditure function and the revenue function here are given respectively by $E^*\,(r, u^*)$ and $R^*\,(K^* - F)$ where F is the level of foreign investment that flows out of the North. Note that variables with an asterisk describe the North.

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[4] There is some evidence that emission taxes are often earmarked for pollution abatement activities. For example, Brett and Keen (2000) note that, in the U.S., it is quite common for environmental taxes to be earmarked for specific expenditure programs. In particular such tax proceeds are commonly paid into trust funds that finance various clean-up activities.

[5] If the North could impose a strict conditionality on foreign aid so that all aid is spent on public abatement, β would cease to be a policy instrument for the South and one would have $\beta = 1$. However, several studies have shown that it is very difficult for donor countries to enforce such conditionalities, and foreign aid is, to all intents and purposes, highly fungible (see Pack and Pack, 1994; Khilji and Zampelli, 1994; Boone, 1996; and Feyzioglu *et al.*, 1998). Following this literature, here we assume that aid is fully fungible and β is a policy instrument for the South.

[6] The instrument β can be interpreted as a lump-sum way of financing public abatement: foreign aid is given in a lump-sum manner to the consumers who are then taxed in a lump-sum way to pay for public abatement. See footnote 8 for consequences of this interpretation.

The income-expenditure identity for the North is:

$$E^* (r, u^*) = R^* (K^* - F) + \rho F - T, \quad (5)$$

where $E_r^*(r, u^*) > 0$, $E_{rr}^* (r, u^*) > 0$, and $E_u^* (r, u^*) > 0$.

As noted before, the level of foreign investment is exogenous in this section. The source of exogeniety can be either in the South or in the North. That is, we assume either the government of the South restricts inflow of foreign investment or that the government in the North puts a cap on the outflow of capital from the country. We justify the presence of foreign investment by assuming $R_K (g, t, K) - R_K^* > 0$, meaning that the return on capital is higher in the South than in the North, both of which are endogenous in the model. Formally,

Assumption 2: $R_K > R_K^*$.

The model has a system of five equations, (1) to (5), and five endogenous variables: r (the net level of net pollution), g (the level of public abatement), u and u^* (the utility in each of the two countries), and ρ (the rent of capital in the South). The North's policy instrument is the amount of aid, T, and the South's instruments are the fraction of aid directed to public pollution abatement, β, and the rate of emission tax, t.

2.1 Comparative Statics

In this section we shall examine how some of the exogenous variables and policy instruments affect the level of net emission. To this end, we totally differentiate (1) and (2) to get:

$$dr = -(1 + R_{tg})\, dg - R_{tt}\, dt - R_{tK}\, dF, \quad (6)$$

$$Q\, dg = \beta\, dT + T\, d\beta - [tR_{tt} - (gR_{gt} - R_t)]\, dt - tR_{tK}\, dF, \quad (7)$$

where $Q + tR_{tg} - R_g > 0$, where $-R_g$ is the unit cost of public abatement and is positive, and R_{tg} is assumed to be positive (see assumption 1).

Substituting (7) in (6), we obtain the effect of the four key variables on net pollution:

$$\begin{aligned} Q\, dr = & -\beta(1 + R_{tg})\, dT - T(1 + R_{tg})\, d\beta \\ & - [(1 + R_{tg})(gR_{gt} - R_t) - (t + R_g)\, R_{tt}]\, dt + (t + R_g)\, R_{tK}\, dF. \end{aligned} \quad (8)$$

The above equation is similar to the corresponding equation in Hatzipanayotou *et al*. (2002) except the effect of foreign investment, dF. We shall therefore only explain the last term here. A change in the level of foreign investment F, for given levels of the policy instruments, has an ambiguous effect on net pollution. First, an increase in F scales up production activities in the South raising pollution. Second, an extended private sector will increase the pollution tax base and thus the amount of funds used for public sector abatement, reducing pollution. The net effect of foreign investment on net emission is non-positive if and only if $t + R_g \geq 0$, *i.e*. the emission tax rate exceeds the unit cost of abatement.[7]

Turning to welfare levels, differentiating (3) and substituting dr from (8), we obtain:

$$QE_U\, du = A_T\, dT + A_\beta\, d\beta + A_t\, dt + A_F\, dF \tag{9}$$

where

$$A_T = \beta(1 + R_{tg})\, E_r + (1 - \beta)(t \cdot R_{tg} - R_g),\ A_\beta = T\,[(1 + R_{tg})\, E_r - (tR_{tg} - R_g)],$$
$$A_t = (gR_{gt} - R_t)\,[(1 + R_{tg})\, E_r - (tR_{tg} - R_g)] - (t + R_g)\, E_r\, R_{tt} - (tR_{tg} - R_g)\, FR_{Kt},$$
$$A_F = -(t + R_g)\, E_r\, T_{tK}.$$

Once again, we shall only explain the expression A_F. A change in F has an ambiguous effect on welfare for the same reasons as its effect on net emission level is ambiguous.

Turning to the North, differentiating (4) and substituting dr from (8) in it, we get:

$$QE_u^*\, du^* = C_T\, dT + C_\beta\, d\beta + C_t\, dt + C_F\, dF,$$

where

$$C_T = \beta(1 + R_{tg})\, E_r^* - (tR_{tg} - R_g),\ C_\beta = T(1 + R_{tg})\, E_r^*,$$
$$C_t = E_r^*\,[(1 + R_{tg})(gR_{gt} - R_t) - (t + R_g)\, R_{tt}] + (tR_{tg} - R_g)\, FR_{Kt},$$
$$C_F = -(t + R_g)\, E_r^*\, R_{tK} + (tR_{tg} - R_g)[R_K - R_K^*].$$

We shall only explain C_F once. A change in F has an ambiguous effect on the North's level of welfare. A part of this ambiguity comes from the already discussed ambiguous effects these variables have on pollution. A change in F has an additional positive effect by increasing repatriated income from foreign investment.

We now characterize a Nash equilibrium in which the South optimally chooses the levels of emission tax rate, t, and the fraction, β, of aid that it uses for public pollution abatement while the North optimally chooses the amount of transfer, T. We shall, *pro tempore*, take the initial level of foreign investment to be zero, *i.e*. $F = 0$. In this case, the first order conditions that give the optimal level of policy variable are:

$$A_t\,(T, \beta, t, F) = 0,\ \ A_\beta\,(T, \beta, t, F) = 0,\ \ C_T\,(T, \beta, t, F) = 0, \tag{10}$$

where the coefficients have been defined before. From the above three equations, the optimality conditions can be simplified as:

[7] As we shall show later, when policy instruments are optimally chosen, $t + R_g = 0$, so that foreign investment has no direct effect on pollution level.

$$E_r = -R_g, E_r = t, \beta E_r^* = t. \tag{11}$$

Equation (11) combines the Samuelsonian rule for the optimal provision for public goods in the South, namely that the marginal willingness to pay for a public good is equal to the marginal cost of producing it, with the Pigouvian rule for environmental taxation in the South, namely that the marginal willingness to pay for pollution abatement is equal to emission tax rate.[8] It also gives a modified Pigouvian rule for optimal aid decided by the North. The results of this subsection are exactly the same as in Hatzipanayotou *et al*. (2002).

2.2 Income-neutral Policy Reform

We now examine the pollution implication of a piecemeal reform where, starting from the Nash equilibrium given by (16), both F and T are changed in a way that the extra amount of repatriated profits equals the extra amount of aid transferred to the South. It is possibly best to interpret reform as a multilateral one in which the North and the South cooperatively decide that the South would allow more foreign investment and in return the North will give more foreign aid. We call this reform an income-neutral change in F and T, and it is formalized by:

$$[R_K - R^*_{K^*}]\, dF = dT. \tag{12}$$

Further, we assume that, in response to the North's reform, the South adjusts both policy instruments (*i.e*. t and β).

Totally differentiating the first two equations in (10) and using (12), we get[9]:

$$\frac{dt}{dF} = -\frac{R_{Kt}}{R_{tt}} > 0 \tag{13}$$

$$D_1 \frac{d\beta}{dF} = TQ(1 + R_{tg})\left\{(gR_{gt} - R_t)\, \mu_r R_{Kt} + \left[\mu_u - \beta\mu_r\right] R_{tt} \left[R_K - R_K^*\right]\right\} \tag{14}$$

where

$$D_1 = T^2(1+R_{tg})\, Q\mu_r R_{tt} > 0,\ \ \mu_u = \frac{E_{ru}}{E_u} > 0,\ \ \mu_r = \frac{E_{rr}}{Er} > 0$$

$$\mu_u^* = \frac{E_{ru}^*}{E_u^*} > 0,\ \ \mu_r^* = \frac{E_{rr}^*}{Er^*} > 0$$

[8] Here, the two rules are satisfied simultaneously because the instrument β functions, to some degree, as a lump-sum tax for financing the public abatement. See footnote 6 for a discussion on the relationship between β and lump-sum taxation.

[9] See Appendix for details.

It follows from the above that while an increase in F has an ambiguous effect on β, its effect on t is unambiguously positive. Turning to the effect on emission level, substituting (12), (13) and (14) into (8), and using assumption 2, we get:

$$\frac{dr}{dF} = -\frac{\mu_u}{\mu_r Q}(1+R_{tg})[R_K - R^*_K] < 0.$$

That is, an increase in F and an associated increase in T satisfying (12) unambiguously reduce pollution emission. Formally,

Proposition 1 *Suppose initial values of the policy instruments are at the Nash optimal levels. Then a piecemeal increase in the level of foreign investment and an associated increase in foreign aid satisfying (12) unambiguously reduce net pollution emission.*

In order to understand the above result, note that the effect of a change in r can be decomposed into three components since at the Nash equilibrium, equation (8) can be rewritten as:

$$Q\, dr = -\beta\,(1 + R_{tg})\, dT - T(1 + R_{tg})\, d\beta - (1 + R_{tg})(gR_{gt} - R_t)\, dt.$$

The first and the last effects are pollution reducing since $dT > 0$ and t increases with the reform. The middle term is ambiguous since the reform's effect on β is ambiguous. However, the net effect is pollution reducing.

As for the effects on welfare, for the South it can be shown from (9), and from the fact $A_\beta = A_t = A_F = 0$ at the Nash equilibrium, that $E_u du = dT > 0$. For the foreign country, substituting (11), (12) and (13) into (10), we get

$$E^*_u \cdot \frac{du^*}{dF} = R_K \left[\frac{\mu_u}{\beta\mu_r}\left\{1 - \frac{R^*_K}{R_K}\right\} - \frac{F}{K+F}\cdot\frac{\varepsilon_{Kt}\varepsilon_{tK}}{\varepsilon_{tt}}\right] \tag{15}$$

where

$$\varepsilon_{Kt} = -\frac{\partial R_K}{\partial t}\cdot\frac{t}{R_K} > 0,\ \ \varepsilon = \frac{\partial(-R_t)}{\partial(K+F)}\cdot\frac{K+F}{(-R_t)} > 0,\ \ \varepsilon_{tt} = -\frac{\partial(-R_t)}{\partial t}\cdot\frac{t}{(-R_t)} > 0.$$

From (15) it is clear that the reform considered in the section will increase the welfare of the North if $R_K > R^*_K$ and/or $F\,/\,(K + F) \simeq 0$. The ambiguity comes from that in the effect of the reform on β.

3. The Case of Endogenous Foreign Investment

In the preceding section we treated foreign investment in an exogenous manner. In contrast, foreign investment is an endogenous variable in this section, and its level is determined by equating the rates of return to capital in the two countries. In order to consider the effect of a change in foreign investment on the level of pollution, we shall introduce another policy instrument in the South that is directly related to the level of foreign investment, namely, a tax on foreign capital. We then examine the effect of a change in this instrument (and therefore of an induced change in the level of foreign investment) on the level of pollution.

In order to avoid unnecessary duplication, we shall straightaway write down the formal structure of the model explaining only the points of departure. The model structure is:

$$r = z - g = -R_t(g, t, K + F) - g, \tag{16}$$

$$0 = \beta T - tR_t(g, t, K + F) + gR_g(g, t, K + F) + \tau F, \tag{17}$$

$$E(r, u) = R(g, t, K + F) - gR_g(g, t, K + F) + (1 - \beta)T - R_K(g, t, K + F)F, \tag{18}$$

$$\rho = R_K(g, t, K + F) - \tau = R_K^*(K^* - F), \tag{19}$$

$$E^*(r, u^*) = R^*(K^* - F) + \rho F - T, \tag{20}$$

where τ is the specific tax rate on foreign capital and all other notations are as in the last section. The only difference is that F is an additional endogenous variable here and it is determined by equating the net-of-tax rates of return on capital in the two countries (see (19)).

As in the previous section, we assume the model in the South to be of the Heckscher-Ohlin type so that $R_{KK} = R_{gg} = R_{Kg} = 0$ (see assumption 1). With these assumptions, taking derivatives of (16)-(20), we obtain:

$$dF = \frac{1}{R_{KK}^*} \cdot d\tau - \frac{R_{Kt}}{R_{KK}^*} \cdot dt \tag{21}$$

$$\begin{aligned} Q\,dr = &-\beta(1 + R_{tg})\,dT - T(1 + R_{tg})d\beta - [(1 + R_{tg})(gR_{gt} - R_t) \\ &-(t + R_g)R_{tt}]\,dt + [(t + R_g)R_{tK} - \tau(1 + R_{tg})]\,dF - (1 + R_{tg})F\,d\tau, \end{aligned} \tag{22}$$

$$QE_u\,du = A_T\,dT + A_\beta\,d\beta + \bar{A}_t\,dt + A_\tau\,d\tau \tag{23}$$

$$QE_u^*\,du^* = C_T\,dT + C_\beta\,d\beta + \bar{C}_t\,dt + C_\tau\,d\tau \tag{24}$$

where

$$A_\tau = \frac{-(t + R_g)E_r R_{tK} + \tau(1 + R_{tg})E_r + (1 + R_{tg})E_r F R_{KK}^*}{R_{KK}^*}$$

$$\begin{aligned} \bar{A}_t = &(gR_{gt} - R_t)((1 + R_{tg})E_r - (tR_{tg} - R_g)) - (t + R_g)E_r R_{tt} \\ &+ ((t + R_g)E_r R_{tK} - \tau(1 + R_{tg})E_r - F(tR_{tg} - R_g)R_{KK}^*) \cdot \frac{R_{Kt}}{R_{KK}^*}, \end{aligned}$$

$$C_\tau = -\frac{[(t+R_g)R_{tK} - \tau(1+R_{tg})]E_r^*}{R_{KK}^*} + (1+R_{tg})E_r^*F - (tR_{tg} - R_g)F,$$

$$\bar{C}_t = E_r^*((1+R_{tg})(gR_{gt} - R_t) - (t+R_g)R_{tt}) + (tR_{tg} - R_g)FR_{tK} + \frac{[(t+R_g)R_{tK} - \tau(1+R_{tg})]R_{tK}E_r^*}{R_{KK}^*}$$

and the expressions for Q, A_T, A_β, C_T and C_β are the same as defined after (9) and (10).

Equations (22) - (24) can be explained in a similar way as in the last section. Equation (21) is new, and it indicates that an increase in either τ or t reduces the inflow of foreign capital in the South. An increase in either τ or t reduces the rental rate of capital in the South and thus the inflow of foreign capital: τ reduces the net-of-tax rate of return, and t increases the unit cost of production in the private sector and thus the rate of return to capital. The expressions $\bar{A}_t$ and $\bar{C}_t$ are somewhat different from those of A_T and C_T respectively for the case of exogenous F. An increase in t reduces F (see (21)) and thus revenue from taxation of capital at a given level of τ. This is an extra term that appears in $\bar{A}_t$. This reduction in tax revenue reduces public abatement (as this tax revenue finances public abatement) and increases cross-border pollution, reducing welfare in the North. This is an extra effect that appears in the expression of $\bar{C}_t$. The two new coefficients in (23) and (24) – A_τ and C_τ respectively – can be explained as follows. An increase in τ decreases F and thus reduces pollution. This reduces the base for emission taxation and therefore the level of public abatement. This effect is captured by the first term in A_τ. An induced reduction in F also reduces the base for foreign-investment taxation and this also reduces public abatement. This is captured by the second term in A_τ. Finally an increase in τ increases revenue from taxing foreign investment, for a given level of F. This increases public abatement. This is the third term in A_τ. The above three effects in A_τ also affect welfare in the North (C_τ) via changes in cross-border pollution. In addition an increase in τ reduces repatriated profits to North and therefore its welfare. This is the last term in C_τ.

3.1 The Nash Equilibrium

We now characterize the optimal values of the policy parameters: t, β and τ for the South and T for the North. Assuming that the two countries decide on the optimal levels simultaneously, the first order conditions for the Nash equilibrium are given by $\bar{A}_t = A_\tau = A_\beta = C_T = 0$.

It can easily be shown that the optimal levels satisfy:

$$E_r = t,\ t = -R_g,\ \beta E_r{}^* = t, \tag{25}$$

as before (see (16)). In addition, here, the optimal value of τ satisfies:

$$\tau = -FR^*_{KK} > 0. \tag{26}$$

That is, it is optimal for the South to tax foreign investment. The intuition for the above result is as follows. An increase in foreign investment increases pollution and therefore also emission tax revenue. These two opposite effects cancel each other out because the other instruments (t, β and T) are optimally set. However, an increase in τ raises revenue from the taxation of foreign investment for a given level of F. This, in turn, increases public abatement and therefore welfare. It also reduces foreign investment and thus tax revenue on foreign capital, for a given level of τ, and therefore public abatement and welfare. Therefore, the optimal tax on foreign capital is positive. These last two effects can be seen better by writing:

$$E_u \cdot \frac{\partial u}{\partial \tau} = F + \tau \cdot \frac{\partial F}{\partial \tau}$$

It is interesting to note that the endogeneity of foreign investment does not affect the qualitative nature of the optimal values of t, β and T. This is because foreign capital, being optimally chosen via the instrument τ, does not introduce any additional distortion.

Having characterized the Nash optimal values of the policy parameters, we shall now examine the effect of a decrease in τ (and thus of an induced increase in the value of foreign investment, F) on the level of pollution. This exercise is taken up in the following subsection.

3.2 Foreign Investment and Pollution

In this section we analyze the effect on pollution of a policy reform in which, starting from the Nash optimal levels of the policy instruments described in subsection 3.1, the South reduces only the value of τ, leaving t and β unchanged, and the North responds by adjusting the optimal level of foreign aid, T.[10]

Since the initial values of the policy instruments are at their Nash equilibrium levels, from (22) and using (25) and (26) it can be shown that

$$Q \frac{dr}{d\tau} = -\beta(1 + R_{tg}) \frac{dT}{d\tau} \tag{27}$$

That is, a decrease in τ will reduce pollution r if and only if it increases the level of foreign aid. To find the effect on foreign aid, we differentiate the first order condition $C_T = 0$ and use (25) and (26) to get

[10] It can be verified from (23) and (24) that the optimal first-best value of τ is zero when other policy instruments are at their optimal second-best levels. That is, from the global welfare point of view, there should be no tax on foreign capital. We shall also show a little later that a reduction in τ by the South is reciprocated by the North by an increase in the level of foreign aid, T. Thus, the present exercise can be seen as a multilateral move toward the first best.

$$\frac{dT}{d\tau} = -\frac{F\mu_u^*}{\mu_r^*} < 0,$$

where μ_u^* and μ_r^* are defined after (14).

Thus, a decrease in τ increases the optimal level of foreign aid, which in view of (27) in turn implies that a decrease in τ unambiguously reduces the level of pollution. Intuitively, a reduction in τ increases the inflow of foreign capital, which initially increases pollution. This increase in pollution and thus the increase in cross-border pollution increases the marginal willingness to pay for pollution abatement in the North. This induces an increased flow of foreign aid and thus an increased level of public abatement of pollution in the South, reducing the level of net pollution.

Turning to the effects of a reduction in τ on welfare levels in the two countries, from (23) and (24), we get

$$(QE_u) \cdot \frac{du}{d\tau} = A_T \cdot \frac{dT}{d\tau} = -\frac{[\beta(1+R_{tg})E_r + (1-\beta)Q]\,F\mu_u^*}{\mu_r^*} < 0,$$

$$(QE_u^*) \cdot \frac{du^*}{d\tau} = C_\tau = -QF < 0,$$

since at the initial Nash equilibrium $A_\tau = C_T = t + R_g = 0$ and t and β are not changed.

That is, a reduction in τ and a consequent increase in T increases the welfare of both countries. Formally,

Proposition 2 *Suppose initial values of the policy instruments are at the Nash optimal levels. A reduction in the rate of taxation on foreign capital by the South unambiguously reduces the level of net emission, and increases the welfare levels of both countries, when the North adjusts its optimal level of foreign aid.*

As mentioned in the introduction, there are many studies that examine the effect of globalization in general, and foreign investment in particular, on pollution and welfare levels. None of these studies, however, considers a mechanism that works via an endogenous determination of foreign aid and its effect on the level of public abatement, which the present study does.

4. Conclusion

One of the most challenging problems for the world today is to assure rapid economic growth while protecting the environment. As the international mobility of capital increases, the international community gets more concerned about the possible negative effects of globalization on the environment.

The literature has identified a number of channels through which foreign capital inflow in particular and economic integration in general can affect pollution levels.

Some of the channels work in opposite directions. On the one hand, for example, foreign capital inflow or increased economic integration can change the composition of production in favor of pollution-intensive industries and raise overall pollution levels. On the other hand, increased prosperity from economic integration makes society more willing to impose stricter pollution-reduction policies and thus reduces overall pollution. Whether the net effect is positive or negative is a matter of empirical investigation, and so far most studies find that "free trade is good for the environment" (e.g. Antweiler *et al.*, 2001). In this paper we have identified another channel for pollution reduction, namely that pollution often knows no geographic boundaries and thus the willingness of parties affected by cross-border pollution to provide financial assistance to combat pollution at the source. We have shown that this new channel works in favor of the hypothesis that globalization is good for the environment.

We have carried out our analysis by developing a general equilibrium North-South model with cross-border pollution. We examine the effects of an exogenous and an endogenous increase in foreign capital flow from the North to the South on the environment when the two countries are allowed to optimally employ a set of policy instruments: the North chooses the level of aid and the South decides on the fraction of aid allocated to public abatement, on the level of affluent tax rate, and on a tax/subsidy on foreign capital, the last instrument applied only to the case when foreign investment is endogenous.

The paper's main conclusion is that, with the right policies in place, foreign investment is good for the environment.

Appendix: The Derivation of Equations (13) and (14)

Totally differentiating (11) and (12), and then evaluating the expressions at the Nash equilibrium described by (11), we get:

$$\begin{bmatrix} A_{\beta\beta} & A_{\beta t} \\ A_{t\beta} & A_{tt} \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial \beta}{\partial F} \\ \frac{\partial t}{\partial F} \end{bmatrix} = \begin{bmatrix} -A_{\beta F} \\ -A_{tF} \end{bmatrix}, \text{ and}$$

$$\begin{bmatrix} A_{\beta\beta} & A_{\beta t} \\ A_{t\beta} & A_{tt} \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial \beta}{\partial T} \\ \frac{\partial t}{\partial T} \end{bmatrix} = \begin{bmatrix} -A_{\beta T} \\ -A_{tT} \end{bmatrix}, \text{ where}$$

$$A_{tT} = (1+R_{tg})(g \cdot R_{gt} - R_t)(\mu_u - \beta\mu_r),\ A_{t\beta} = -T(1+R_{tg})(gR_{gt} - R_t)\mu_r,$$
$$A_{tt} = -Q^{-1}(1+R_{tg})^2(gR_{gt} - R_t)^2 E_r\mu_r - QR_{tt},\ A_{tF} = -QR_{Kt},$$
$$A_{\beta T} = T(1+R_{tg})[\mu_u - \beta\mu_r],\ A_{\beta\beta} = -T^2(1+R_{tg})\mu_r,$$
$$A_{\beta t} = -T(1+R_{tg})(gR_{gt} - R_t)\mu_r,\ A_{\beta F} = 0.$$

Solving $\partial\beta / \partial F$, $\partial t / \partial F$, $\partial\beta / \partial T$, and $\partial t / \partial T$, we get:

$$D_1 \frac{\partial \beta}{\partial F} = TQ(1+R_{tg})(gR_{tg} - R_t)\mu_r R_{Kt}, \tag{A.1}$$

$$D_1 \frac{\partial t}{\partial F} = -T^2(1+R_{tg})Q\mu_r R_{Kt}, \tag{A.2}$$

$$D_1 \frac{\partial \beta}{\partial T} = T(1+R_{tg})Q[\mu_u - \beta\mu_r]R_{tt}, \tag{A.3}$$

$$D_1 \frac{\partial t}{\partial T} = 0, \tag{A.4}$$

where

$$D_1 = det \begin{vmatrix} A_{\beta\beta} & A_{\beta t} \\ A_{t\beta} & A_{tt} \end{vmatrix} = T^2(1+R_{tg})Q\mu_r R_{tt} > 0.$$

Substituting (12), (A.2), and (A.4) in

$$dt = \frac{\partial t}{\partial F} \cdot dF + \frac{\partial t}{\partial T} \cdot dT,$$

we get (13), and substituting (12), (A.1), and (A.3) in

$$d\beta = \frac{\partial \beta}{\partial F} \cdot dF + \frac{\partial \beta}{\partial T} \cdot dT,$$

we get (14).

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