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

By

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ABSTRACT

We develop a North-South model with cross-border. In the South, pollution is abated by both private producers and the public sector. The North suffers from cross-border from the South. The policy instruments are the foreign aid for the North, and the fraction of aid allocated to public abatement and emission tax rate for the South. We characterize the Nash optimal level of policy instruments and analyze the effect of foreign investment on environment when the instruments are adjusted optimally. We also look at the case where the North changes both the amount of aid and the level of foreign investment in an income neutral fashion.

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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 quest for higher return on capital. However, many environmentalists consider the expansion of capital markets as a potential threat to environment.

The relationship between capital mobility and environment has received a great deal of attention in the international economics literature. Grossman and Krueger (1991) show that international economic integration may create more demand for a cleaner environment in less developed countries by raising the levels of income in those countries. Copeland and Taylor (1997) also show that capital mobility could lower or raise pollution depending on the pattern of trade. In general, it is agreed that in the debate over economic integration and environment, foreign direct investment, international trade, and policy making process play key roles (see, for example, Copeland 1994; Beghin, Roland-Holst, and Van der Mensbrugghe 1997).

There is also a substantial literature on 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 previous theoretical framework by incorporating administrative costs and asymmetric information in pollution abatement in order to examine the welfare implications of co-operative and non-co-operative trade and environmental policies. Copeland and Taylor (1995) demonstrate, *inter alia*, that 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 effects of foreign investment on environment. The two countries are small open economies in the 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 sector; the latter is financed by pollution tax revenue and a fraction of aid given by the North.[1] We allow the two countries to employ a set of policy instruments and examine the effect of foreign investment on environment when these instruments are employed at their non-cooperative optimal levels. We also consider a piece-meal reform exercise when foreign investment is accompanied by foreign aid.

2. THE MODEL.

We develop a general equilibrium model of two small open economies – called the North and the South. The North is a developed country and the South a less developed one. The latter offers the investors from the former the opportunity of a higher return on their

[1] 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%. 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 coexistence of private and public abatement.

capital. That is, there is a flow of foreign investment 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, some amount of private abatement takes place.

The North only has the 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 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, we can write the total endowment vector in the South as $(K+F, V)$. A part of V is, Vp, employed in the private sector and the remaining part, Vg, in the public sector to abate the pollution.[2] Thus, $V=Vp+Vg$.

[2] We make the simplifying assumption that internationally mobile capital K is not used in the public sector.

We can define the revenue function which gives the country's maximum production of private goods evaluated at the internationally given prices:

$$R(P,t,K,V^P) = \max_{Y,\, z} \left\{ P'Y - t \cdot z \;\middle|\; (Y,z) \in T(K+F, V^P) \right\},$$

where P is the vector of commodity prices determined in the international market, Y represents the vector of outputs, t is the emission tax rate, z is the level of net pollution emission by the private sector, and $T(K+F,V^P)$ represents technology which includes both *production* and *abatement* technologies. We make also the simplifying assumption that there is only one type of pollution.

It is well known that the factor prices for immobile factors are given by:[3]

$$w = R_{V^P}(P,t,V^P,K+F) \;,$$

and that for the internationally mobile factor by:

$$r = R_K(P,t,V^P,K+F) \;.$$

Turning to the public sector, we assume that it is price taker in the factor market and compete with the private sector for inputs. Assuming constant returns to scale, the cost-minimizing problem in the public sector gives the unit cost of public abatement, $C^g(w)$ as a function of w. It is known (Abe, 1992, Hatzipanayotou *et al* (2002)) that the demand for immobile factors per unit of public abatement is given by $C_w{}^g(w)$. Therefore, the total demand for factors from the public sector is $C_w{}^g(w) \cdot g$, where g is the level of public abatement. Thus, $V^P = V - C_w{}^g(w) \cdot g = V - C_w{}^g(R_{V^P}(P,t,V^P,K+F)) \cdot g$. Solving this equation for V^P we obtain the amount of immobile factors employed in the private sector

[3] For any function *f(x, y, …)*, we denote by f_x, for example, the partial derivative of *f* with respect to *x*.

as: $V^P = V^P(P, t, g, V, K+F)$. Since V and P do not vary in our analysis, V^P can be, equivalently, expressed as: $V^P = V^P(t, g, K+F)$, and so we define the restricted revenue function as:

$$R(g, t, K+F) = \overline{R}(P, t, V^P(P, t, g, V, K+F), K+F).$$

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: $z = -R_t(g, t, K+F) > 0$. Second, the partial derivative with respect to the amount of public pollution abatement, g, gives the unit cost of public pollution abatement: $-R_g = -\partial R / \partial g > 0$ (Copeland 1994, Turunen-Red and Woodland 2004). Third, $R(g, t, K+F)$ is a convex function in t, i.e., $R_{tt}(g, t, K+F) > 0$, meaning that the rise in the affluent 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 $R_{gg} = 0$ and $R_{KK} = 0$. These assumptions 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. Abe (1992), and Hatzipanayoutou and Michael (1995) use the same assumption in a different framework. Chao and Yu (1999) and Hatzipanayotou *et al* (2001) use the same assumption in a similar context where private and public abatement coexist.

Having done the groundwork, we shall now write down the equations that describes 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,

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

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

(2) $$b \cdot T - t \cdot R_t(g,t,K+F) + g \cdot R_g(g,t,K+F) = 0$$

The demand side in the South is represented by the expenditure function *E(P,r,u)* which gives the minimum expenditure required to achieve the level of utility, u at the given market prices vector, P, and a net pollution level, *r*. Since P does not vary in our analysis, the expenditure function can be 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 the households, minus repatriated profits due to foreign investment. Balancing expenditure and income, we obtain the third equation of our model:

(3) $$E(r,u) = R(g,t,K+F) - g \cdot R_g(g,t,K+F) + (1-b) \cdot T - r \cdot F,$$

[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 US, 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, or are spend on road and public transport networks.

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

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

It is to be noted that 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 negatively affects utility, 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 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.

In the North pollution is not generated and therefore there is no public abatement, but it suffers from pollution generated in the South. Apart from this, the structure of the economy in the North is exactly 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, as noted before, is the level of foreign investment that flows out of the North.

The income-expenditure identity for the North takes the following form:

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

where $E^*{}_r(r, u^*) > 0$, $E^*{}_{rr}(r, u^*) > 0$, and $E^*{}_u(r, u^*) > 0$.

We justify foreign investment by assuming $[R_K(g, t, K) - R_K{}^*(g, t, K)] > 0$, meaning that the return on capital is higher in the South – the country that receives foreign investment -- than in the North -- the source of foreign investment.

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 ? 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, ß and the rate of emission tax, t.

3. 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 equations (1) and (2) to get:

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

(7) $$dg = (t \cdot R_{tg} - R_g)^{-1} \cdot \{ b \cdot dT \quad + T \cdot db \quad -[t \cdot R_{tt} - (g \cdot R_{gt} - R_t)] \cdot dt \quad - t \cdot R_{tK} \cdot dF \} \,.$$

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

(8) $$\begin{aligned} Q \cdot dr = &- b \cdot (1+R_{tg}) \cdot dT - T \cdot (1+R_{tg}) \cdot db \\ &-[(1+R_{tg}) \cdot (g \cdot R_{gt} - R_t) - (t+R_g) \cdot R_{tt}] \cdot dt - (t + R_g) \cdot R_{tK} \cdot dF \end{aligned}$$

where $Q = (t \cdot R_{tg} - R_g)$.

An increase in either the amount of aid *(T)* or share of foreign aid allocated for public abatement activities *(ß)* unambiguously reduces the level of pollution. This is because an increase in either of the two variables raises the amount of funds used by the government in the South for public abatement activities.

A change in the level of foreign investment *(F)* 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 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 negative if and only if $(t + R_g) < 0$, i.e., the cost of abatement exceeds the tax rate.

The effect of a change in the tax rate (*t)* on the level of net pollution is also ambiguous. A change in *t* reduces pollution emission by the private sector. But it also reduces the tax base for public sector abatement which increases net emission levels. Finally, it reduces factor prices by reducing the demand for factors in the private sector, and thus reduces the unit cost of public abatement which in turn reduces net emission levels. A sufficient condition for net emission level to decrease is that $(t + R_g) \leq 0$.

4. WELFARE EFFECTS

In this section we shall examine the effect on changes on four key variables on the levels of welfare in the two countries. First, for the South, differentiating equation (3) substituting *dr* from equation (8), we obtain:

(9) $$E_u \cdot du = Q \cdot \left\{ A_T \cdot dT \quad + A_b \cdot db \quad + A_t \cdot dt \quad + A_F \cdot dF \right\} \;,$$

where:

$A_T = b \cdot (1 + R_{tg}) \cdot E_r + (1 - b) \cdot (t \cdot R_{tg} - R_g)$, $\qquad A_b = T \cdot [(1 + R_{tg}) \cdot E_r - (t \cdot R_{tg} - R_g)]$,

$A_t = (g \cdot R_{gt} - R_t) \cdot [(1 + R_{tg}) \cdot E_r - (t \cdot R_{tg} - R_g)] - (t + R_g) \cdot E_r \cdot R_{tt} - (t \cdot R_{tg} - R_g) \cdot F \cdot R_{Kt}$,

$A_F = -(t + R_g) \cdot E_r \cdot R_{tK}$.

An increase in T unambiguously improves welfare in the South if $b \leq 1$ (i.e., there is no matching aid). As pointed out before, aid unambiguously reduces net emission level and it also increases income of the households if $b \leq 1$.

A change in either F or t has an ambiguous effect on welfare for the same reasons why its effect on net emission level is ambiguous. As for the effect of t, there is an additional effect here via changes in the rate of return on capital: an increase in t reduces the demand for capital from the private sector and thus the return on it which in turn increases welfare by reducing the amount of repatriated income.

An increase in *ß* has an ambiguous effect on welfare in the South. On one hand, a higher *ß* unambiguously reduces net emission, as mentioned before, which increases welfare. On the other hand, a higher *ß* reduces lump-sum transfer to the households which reduces welfare.

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

(10) $$E_u^* \cdot du^* = Q \cdot \left\{ C_T \cdot dT \quad + C_b \cdot db \quad + C_t \cdot dt \quad + C_F \cdot dF \right\}$$

Where:

$$C_T = b \cdot (1 + R_{tg}) \cdot E_r^* \ - (g \cdot R_{gt} - R_t), \quad C_b = T \cdot (1 + R_{tg}) \cdot E_r^* \ ,$$

$$C_t = E_r^* \cdot [(1 + R_{tg}) \cdot (g \cdot R_{gt} - R_t) \ - (t + R_g) \cdot R_{tt}] \quad - (t \cdot R_{tg} - R_g) \cdot F \cdot R_{Kt}$$

$$C_F = \ - (t + R_g) \cdot E_r \cdot R_{tK} \ + (t \cdot R_{tg} \ - R_g) \cdot [R_K \ - R_K^*].$$

An increase in *ß* will unambiguously increase welfare in the North by reducing net emission in the South and thus the level of cross-border pollution into the North.

Changes in F and t have an ambiguous effect on 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.

As for the effect of T, on one hand, it reduces income and thus welfare in the North. On the other hand, it decreases the level of pollution in the South and disutility from cross-border pollution in the North.

4.1 NASH EQUILIBRIUM

In this section we characterize a Nash equilibrium in which the North optimally chooses the levels of emission tax, t and the fraction, *ß*, 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. $F = 0$, and examine how the optimal values change when F increases from this initial value. In this case, the first order conditions that give the optimal level of policy variable are:[5]

(11) $$Q^{-1} \cdot \frac{E_u \cdot du}{dt} = A_t(T, b, t, F) = 0,$$

(12) $$Q^{-1} \cdot \frac{E_u \cdot du}{d\,b} = A_b(T, b, t, F) = 0,$$

(13) $$Q^{-1} \cdot \frac{E_u^{*} \cdot du^{*}}{dT} = C_T(T, b, t, F) = 0,$$

where the coefficients have been defined before.

[5] The expressions for A_t, A_b, and C_T are given in Appendix A.

From the above three equations, the optimality conditions can be simplified as:

(14) $$E_r + R_g = 0,$$

(15) $$E_r = t,$$

and

(16) $$b \cdot E_r^{*} = t.$$

It is to be noted that the optimality conditions (14) and (15) combine the Samuelson rule for the optimal provision for public goods with the Pigouvian rule for environmental taxation. Equation (14) gives the Pigouvian rule, *viz*. that the marginal willingness to pay for pollution abatement is equal to emission tax rate. Equation (15) gives the Samuelsonial rule, *viz*. that the marginal willingness to pay for a public good is equal to the marginal cost of producing it. Equation (16) gives a modified Pigouvian rule for optimal aid.

Having characterized the Nash optimal values of the policy instruments, we shall now examine how these values change when the level of foreign investment is increased.[6] By totally differentiating (11) - (13), and using equations (8), (9) and (10), we get: [7]

(17) $$D \cdot \frac{dT}{dF} = -t \cdot T \cdot (1+R_{tg})^3 \cdot m_r \cdot \left\{ b \cdot T \cdot m_u^{*} \cdot [R_K - R_K^{*}] \cdot R_{tt} + (g \cdot R_{gt} - R_t) \cdot E_r^{*} \cdot R_{Kt} \right\}$$

(18) $$D \cdot \frac{db}{dF} = t \cdot T \cdot (1+R_{tg})^3 \cdot m_u^{*} \cdot [b \cdot m_r - m_u] \cdot \left\{ b \cdot [R_K - R_K^{*}] \cdot R_{tt} - (g \cdot R_{gt} - R_t) \cdot R_{Kt} \right\} - t \cdot T \cdot (1+R_{tg})^3 \cdot (g \cdot R_{gt} - R_t) \cdot m_u \cdot m_r^{*} \cdot R_{Kt}$$

(19) $$D \cdot \frac{dt}{dF} = t \cdot T \cdot (1+R_{tg})^3 \cdot R_{Kt} \left\{ (b \cdot m_r - m_u) \cdot \left(E_r^{*} + T \cdot m_u^{*} \right) + (T \cdot m_u \cdot m_r^{*}) \right\}$$

where $D < 0$ for the stability of the Nash equilibrium.

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[6] In view of equations (14) and (15) it follows from equation (8) that if the two countries do not adjust their policy instruments as a response to an increase in F, such an increase will have no effect of pollution.

[7] See Appendix B for details.

Finally, substituting (17), (18), and (19) in equation (8) we get:

(20) $$m_r \cdot \frac{dr}{dF} = -t \cdot (1+R_{tg})^2 \cdot m_u \cdot \frac{dT}{dF},$$

where m_r and m_u are given in Appendix B.

The effects of an in increase in F on the optimal levels of t and b are in general ambiguous. However, noting that $D < 0$, a sufficient condition for F to increase t and decrease b is that $b \cdot m_r - m_u > 0$. This condition states that, in the South, the marginal propensity to pay for public abatement (m_u) is sufficiently lower than the elasticity of the marginal willingness to pay for pollution abatement with respect to the aggregate level of net pollution (m_r). What is more interesting is the result that an increase in F reduces pollution if and only if it also increases the level of optimal level of foreign aid. The latter effect is however ambiguous. There are two effects of an increase in F on the optimal level of aid. First, an increase in F increases repatriated income for a given level of the rental rates. This increase in income in the North increases marginal willingness to pay for pollution abatement and thus the amount of transfer made to the South. An increase in F, also has an induced (via changes in t and b) negative effect on aid via changes in the rental rate. If the difference in the rental rates in the two countries is sufficiently high the former effect will dominate the latter and an increase in foreign aid will reduce pollution.

When the South responds to changes in F by adjusting the policy instruments, but the North does not alter the level of aid, we get:

(21) $$D\frac{dr}{dF} = t^2 T(1+R_{tg})^5 [m_u - b \cdot m_r]\left\{b \cdot T \cdot m_u^* [R_K - R_K^*] \cdot R_{tt} + (gR_{tg} - R_t) \cdot E_r^* \cdot R_{Kt}\right\}$$

Comparing the above equation with (17) and (20), it follows that the qualitative effect of an increase in F on pollution will be the same as when aid is adjusted if and only if $b \cdot m_r - m_u > 0$.

4.2 INCOME- NEUTRAL POLICY CHANGES IN THE NORTH

We now examine the case where the North changes both F and T in a way that the extra amount of repatriated profits equals the extra amount of aid transferred to the South.[8] We assume that the South adjusts both policy instruments (i.e., t and *ß)* in response to the above actions by the North. The actions by the North – which can be called income-neutral changes in policy instruments- can be formalized by:

(22) $$[R_K - R^*_{K^*}] \cdot dF = dT \, .$$

Totally differentiating equations (11) and (12) and using (22), we get:[9]

(23) $$\frac{dt}{dF} = -\frac{R_{Kt}}{R_{tt}} > 0,$$

(24) $$D_1 \cdot \frac{db}{dF} = T \cdot (1+R_{tg}) \cdot \{m_r \cdot R_{Kt} \cdot \left[E_r (1+R_{tg}) \cdot (g \cdot R_{gt} - R_t) \; - (tR_{tg} - R_g) \cdot F \cdot R_{Kt}\right] + (tR_{tg} - R_g) \cdot R_{tt} \cdot [m_u - m_u^*] \cdot R_{tK} - [R_K - R_K^*] \cdot \left[m_u - b \cdot m_r\right]\}$$

where $D_1 = T^2 \cdot (1 + R_{tg}) \cdot (t \cdot R_{tg} - R_g) \cdot m_r \cdot R_{tt} \quad > 0$.

[8] For this exercise we do not assume that the initial level of foreign investment is zero.
[9] See Appendix C for details.

It follows from the above that while an increase in F has an ambiguous effect on b, its effect on t is unambiguously positive. Turning to the effect on emission level, substituting equations (22), (23) and (24) into equation (8), we get:

$$\text{(25)} \qquad \frac{dr}{dF} = (t \cdot R_{tg} - R_g)^{-1} \cdot \frac{m_u}{m_r} \cdot \{ (t + R_g) \cdot R_{tK} - T^2 \cdot (1 + R_{tg}) \cdot [R_K - R_K^{*}] \},$$

where from (11) and (12) we have:

$$E_r \cdot (t + R_g) \cdot R_{tt} = -(tR_{tg} - R_g) \cdot F \cdot R_{Kt}.$$

Since $R_{tt} > 0$ and $R_{Kt} = R_{tK} < 0$, it follows that $(t + R_g) > 0$ and thus dr/dF is unambiguously negative. In other words, an increase in F and an associated increase in T satisfying (22) unambiguously reduce pollution emission.

5 CONCLUSIONS.

One of the most challenging problems for the today's world 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 environment.

The literature thus far, however, has some deficiencies. First, the interaction between developing and developed countries needs to be more carefully considered. On one hand, the developing countries tend to have weak environmental regulations in order to develop a comparative advantage in promoting pollution intensive industries, and on the other hand, developed countries tend to use "sticks" (such as trade sanctions) against developing countries as a way to promote and/or enforce better environmental policies in the latter. Second, the literature consider only one or two policy instruments while the issue may be better addressed by a flexible policy mixes. Third, people do not consider the fact that the private sector and the public sector can have synergic advantages if they complement each other in abating pollution.

In order to address some of the above mentioned deficiencies, we develop a general equilibrium North-South model with cross-border pollution. We examine the effect of foreign investment on environment when the two countries are allowed to employ a set of policy instruments: the North chooses the level of aid and the South decides on the fraction of aid to be allocated to public abatement and on the level of affluent tax rate.

We characterize the non-cooperative, optimal level of policy instruments and analyze the effect of foreign investment on environment when the instruments are adjusted optimally. We find that, if the difference in the rental rates in the two countries is sufficiently high, an increase in foreign investment will reduce pollution emission.

Finally, we look at the case where the North changes both the amount of aid and the level of foreign investment in an income neutral fashion and the South adjusts both its policy instruments. Here we find that foreign investment unambiguously reduces the net level of pollution.

The paper's main conclusion is that, with the right policies in place, foreign investment need not be bad for environment.

Appendix A: The explicit form of expressions in (11)-(13):

$$A_t = (-R_t + g\,R_{gt})\left[E_r(1+R_{tg}) - (tR_{tg} - R_g)\right] - E_r\,(t+R_g)R_{tt} - (tR_{tg} - R_g)F\,R_{Kt}$$

$$A_b = \quad T\left[E_r(1+R_{tg}) - (tR_{tg} - R_g)\right]$$

$$A_T = \quad b\,E_r^{\,*}(1+R_{tg}) - (tR_{tg} - R_g)$$

Appendix B: The derivation of equations (17), (18), and (19):

By totally differentiating (11) - (13), using $\frac{dr}{dT}$, $\frac{dr}{dF}$, $\frac{dr}{dt}$, $\frac{dr}{db}$ given by (8), and $\frac{du^*}{dT}$, $\frac{du^*}{dF}$, $\frac{du}{dt}$, and $\frac{du}{db}$ given by (9) and (10), we get the following system of conditions:

$$\begin{bmatrix} C_{TT} & C_{Tb} & C_{Tt} \\ A_{bT} & A_{bb} & A_{bt} \\ A_{tT} & A_{tb} & A_{tt} \end{bmatrix} \cdot \begin{bmatrix} \frac{dT}{dF} \\ \frac{db}{dF} \\ \frac{dt}{dF} \end{bmatrix} = \begin{bmatrix} -C_{TF} \\ 0 \\ -A_{tF} \end{bmatrix}$$

where:

$$A_{tT} = (1+R_{tg})\cdot(g\cdot R_{gt} - R_t)\cdot[m_u - b\cdot m_r]\,,$$

$$A_{tb} = -T\cdot(1+R_{tg})\cdot(g\cdot R_{gt} - R_t)\cdot m_r\,,$$

$$A_{tt} = -(1+R_{tg})\cdot\left[(g\cdot R_{gt} - R_t)^2\cdot m_r - t\cdot R_{tt}\right],$$

$$A_{tF} = -(1+R_{tg})\cdot E_r\cdot R_{Kt}\,,$$

$$A_{bT} = T\cdot(1+R_{tg})\cdot\left[m_u - b\cdot m_r\right]\,,$$

$$A_{bb} = -T^2\cdot(1+R_{tg})\cdot m_r\,,$$

$$A_{bt} = -T\cdot(1+R_{tg})\cdot(g\cdot R_{gt} - R_t)\cdot m_r\,,$$

$$A_{bF} = 0,$$

$$C_{TT} = -b\cdot(1+R_{tg})\cdot m_r^{\,*},$$

$$C_{Tb} = (1+R_{tg})\cdot\left\{E_r^{\,*} + T\cdot\left[m_u^{\,*} - m_r^{\,*}\right]\right\},$$

$$C_{Tt} = (1+R_{tg})\cdot(g\cdot R_{gt} - R_t)\cdot\left[m_u^{\,*} - m_r^{\,*}\right],$$

$$C_{TF} = b\cdot(1+R_{tg})\cdot m_u^{\,*}\cdot[R_K - R_K^{\,*}]\,,$$

$$m_u = r\cdot\frac{E_{ru}}{E_u} > 0, \qquad m_r = r\cdot\frac{E_{rr}}{Er} > 0\,, \qquad m_u^{\,*} = r\cdot\frac{E_{ru}^{\,*}}{E_u^{\,*}} > 0, \qquad m_r^{\,*} = r\cdot\frac{E_{rr}^{\,*}}{Er^{*}} > 0\,,$$

and $D = \det\begin{vmatrix} C_{TT} & C_{Tb} & C_{Tt} \\ A_{bT} & A_{bb} & A_{bt} \\ A_{tT} & A_{tb} & A_{tt} \end{vmatrix} < 0$

Solving for dT/dF, db/dF and dt/dF, we get (17), (18), and (19).

Replacing dT/dF, db/dF and dt/dF in (8), we get (20).

Replacing $dT = 0$, db/dF and dt/dF in (8), we get (21).

Appendix C: The derivation of equations (23) and (24):

Totally differentiating (11) and (12), we get:

$$\begin{bmatrix} A_{bb} & A_{bt} \\ A_{tb} & A_{tt} \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial b}{\partial F} \\ \frac{\partial t}{\partial F} \end{bmatrix} = \begin{bmatrix} -A_{bF} \\ -A_{tF} \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} A_{bb} & A_{bt} \\ A_{tb} & A_{tt} \end{bmatrix} \cdot \begin{bmatrix} \frac{\partial b}{\partial T} \\ \frac{\partial t}{\partial T} \end{bmatrix} = \begin{bmatrix} -A_{bT} \\ -A_{tT} \end{bmatrix}$$

where:

$$A_{tT} = \left\{(1+R_{tg}) \cdot (g \cdot R_{gt} - R_t) - (t + R_g) \cdot R_{tt}\right\} \cdot (m_u - b \cdot m_r)$$

$$A_{tb} = -T \cdot (1+R_{tg}) \cdot (g \cdot R_{gt} - R_t) \cdot m_r$$

$$A_{tt} = -Q^{-1} \cdot (1+R_{tg})^2 \cdot (g \cdot R_{gt} - R_t)^2 \cdot E_r \cdot m_r - Q \cdot R_{tt}$$

$$A_{tF} = -(t+R_g) \cdot Q^{-1} \cdot (1+R_{tg}) \cdot (g \cdot R_{gt} - R_t) \cdot E_r \, [m_u - m_r] \cdot R_{tK} - (1+R_{tg}) \cdot E_r \cdot R_{Kt}$$

$$A_{bT} = T \cdot (1+R_{tg}) \cdot m_u - b \cdot T \cdot (1+R_{tg}) \cdot m_r \qquad A_{bb} = -T^2 \cdot (1+R_{tg}) \cdot m_r$$

$$A_{bt} = -T \cdot (1+R_{tg}) \cdot (g \cdot R_{gt} - R_t) \cdot m_r \qquad A_{bF} = -T \cdot (t+R_g) \cdot [m_u - m_u] \cdot R_{tK}$$

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

(26) $$D_1 \cdot \left[\frac{\partial b}{\partial F}\right] = (T \cdot M \cdot Q \cdot m_r \cdot R_{Kt}) - (T \cdot A_2 \cdot Q \cdot \Delta_{ur} \cdot R_{tt} \cdot R_{tK}),$$

(27) $$D_1 \cdot \left[\frac{\partial t}{\partial F}\right] = -(T^2 \cdot A_1 \cdot Q \cdot m_r \cdot R_{Kt}),$$

(28) $$D_1 \cdot \left[\frac{\partial b}{\partial T}\right] = (T \cdot A_1 \cdot Q \cdot m_u \cdot R_{tt}) - (b \cdot T \cdot A_1 \cdot Q \cdot m_r \cdot R_{tt}), \text{ and}$$

(29) $$D_1 \cdot \left[\frac{\partial t}{\partial T}\right] = 0$$

where: $$D_1 = \det \begin{vmatrix} A_{bb} & A_{bt} \\ A_{tb} & A_{tt} \end{vmatrix} = (T^2 \cdot A_1 \cdot Q \cdot m_r \cdot R_{tt}) > 0$$

Substituting (22), (27), and (29) in $dt = \frac{\partial t}{\partial F} \cdot dF + \frac{\partial t}{\partial T} \cdot dT$, we get (23).

Substituting (22), (26), and (28) in $db = \frac{\partial b}{\partial F} \cdot dF + \frac{\partial b}{\partial T} \cdot dT$, we get (24).

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