ECONOMIC POLICY FOR THE ENVIRONMENT: THE ROLE OF INTERNATIONAL COOPERATION

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Resumo

Em uma abordagem normativa, este artigo estuda a utilização de políticas econômicas quando externalidades negativas de produção/consumo sobre o meio-ambiente atravessa as fronteiras entre países. Em um modelo com dois países, um dos países produz um bem que polui a atmosfera, e o outro um bem que destrói a sua floresta tropical. A poluição destrói a camada de ozônio, enquanto que a floresta tropical ajuda na sua reconstrução. Duas soluções são analisadas: a solução cooperativa, onde os dois países implementam a solução de otimização global; e a solução não-cooperativa, onde cada país separadamente implementa a melhor solução do ponto de vista nacional. O resultado principal deste artigo é que, sem coordenação internacional, a implementação de políticas que visam a proteção do meio ambiente podem levar a um decréscimo do bem-estar social. Este resultado é decorrente do fato dos países aproveitarem a oportunidade e, no pacote de medidas, introduzirem políticas protecionistas visando explorar o seu poder de monopólio no mercado mundial de bens.

Abstract

In a normative approach, this paper studies the use of economic policy when environmentally harmful externalities of production/consumption cross the countries' frontiers. In a model with two countries, one of the countries produces an air polluting good, while the other produces a good that destroys its rain forest. Pollution destroys the ozone layer, and the rain forest helps in rebuilding it. Two solutions will be analyzed: the cooperative solution, where the two countries implement the globally optimizing solution; and the non-cooperative solution, where each country separately implements the national best allocation. The main result of this paper is that, absent worldwide coordination, the implementation of environmental policies could actually worsen welfare. The reason is that the countries would take the opportunity to introduce protectionist policies to exploit their monopoly power in the world market for goods.

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1. Introduction.

There is a widespread concern about the environment. The "good health" of the planet, which has always been taken for granted, is now endangered. One of the difficulties of keeping a healthier environment is that most of the harm on the environment is the result of activities that are not harmful in the individual level, but are harmful if undertaken at a large scale, i.e., there is an externality problem. The ozone layer destruction is an example of such an externality, but it has a special feature: it affects all countries, and not only the one that causes the destruction. Economic policies that try to deal with this externality, which is one of the main concerns of the environmentalists¹, will be studied.

The ozone layer protects the living beings of the planet from the ultra-violet rays. The amount of ozone in the atmosphere, therefore, enters positively in the utility function of the consumers. In the past, when ozone was not a scarce good, some more or less ozone would not affect anyone's well being, presumably, because there was more than enough to ensure a satisfactory protection for the planet's life. The situation has changed considerably. In some parts of the planet the ozone layer has decreased so much that it threatens the health of the people who live in those places. In this case, an increase in the amount of ozone in the atmosphere does increase the utility of the individuals.

In the model studied two countries are interacting. One of the countries, "North", produces a good that pollutes the air with substances that destroys the ozone layer. The other country, "South", possesses a rain forest that helps rebuilding the ozone layer. It, however, produces a good that causes the destruction of the forest in its production process. The question that will be addressed is: how should economic policy be used in a situation where there is this environmentally harmful externality of consumption/production crossing the countries' frontiers?

This paper shows that the non-cooperative solution may lead to an allocation worse than the one in laissez-faire. The highest welfare

¹See, for example, *The Economist*, 05/03/92.

is achieved when the two countries act cooperatively in the implementation of their common welfare maximizing economic policy. If the two countries do not cooperate and each one pursues its own best allocation, not only they will not take into account the effect of their actions on the utility of the other country's consumers (which would make them value more environmental improving policies), but they would also use the economic policy to exploit their monopoly power in the international goods market. Hence, the allocation resulting from the non-cooperative policy could be worse than the free market allocation.

The paper is organized as follows. Section 2 presents the model with the free market allocation. The cooperative solution is described in section 3, and the non-cooperative one in section 4. Section 5 presents the conclusion.

2. Free Market.

The Model.

There are two countries, North and South, producing three goods, manufactures (M), wood (W) and baskets (B). North has an endowment of capital (K^*) and labor (L^*) that allows it to produce manufactures through the production function $f(K, L)$, which has constant returns to scale in both factors, but diminishing returns to labor when capital is held fixed. The country also produces baskets which uses only labor in its production function with constant returns to scale.

South has an endowment of rain forest $\bar{T}$ which can be used to produce wood. The production of wood requires one unit of forest (i.e., one tree) for each unit of wood produced, and no other factors of production. The rain forest reconstitutes itself at a rate that depends positively on its size, and it diminishes by the amount of trees that are cut. Hence:

$$T_t = G(T_t) - W_t, \quad (1)$$

where T_t is the size of the rain forest, and W_t the production of wood in period t .

The function $G(T_t)$ represents the natural reproduction of the rain forest. It is a concave function, as illustrated in figure 1.

Figure 1.

The intuitive reasoning for this adjustment behavior is as follows. The soil of a rain forest is not very rich, so that if the forest is cut, the soil loses its fertility quickly. When the forest is too small, below T_m , the few sparse trees are not sufficient to nourish and seed the soil, then the size of the soil decreases. Forests in the interval $[T_m, T_c)$ reproduce themselves at an increasing rate, i.e., $G(T_t) > 0$. But the rate of increase is decreasing, because the area available for the forest to grow is constant, and so is the water supply. When the forest gets larger than T_c , the constancy of the elements begins to compromise its capacity to reproduce itself. For the interval $(T_c, T_M]$ the forest increases at a decreasing rate, and if the forest is larger than T_M it will actually decrease.

The interesting feature of the goods that will be explored in this paper are the externalities from their production/consumption. Good B 's production or consumption yields no externality, while good M 's

consumption causes air pollution and good W 's production destroys the rain forest. The air pollution is responsible for the destruction of the ozone that protects the planet's life from ultra-violet rays. The rain forest, on the other hand, helps in the ozone reconstruction. If too much of goods M and W are produced, a lot of the ozone will be destroyed without proper replacement. The amount of ozone is represented by the function;

$$z_\tau = h(T_\tau, P_\tau), \quad (2)$$

where z_τ is the amount of ozone and P_τ the amount of pollution in period τ . Air pollution depends positively on the total consumption of manufactures from the m consumers in the world:

$$P_\tau = p(C_{M\tau}^m). \quad (3)$$

where $C_{M\tau}^m = \sum_{i=1}^m c_{M\tau}^i$, and $c_{M\tau}^i$ is the consumption of manufactures from individual i .

Consumers derive their utility from the consumption of manufactures, wood and baskets, and from the amount of ozone in the atmosphere. They have identical, Cobb-Douglas preferences with respect to M , W and B . Hence, the utility of a representative consumer is represented by:

$$U_t = \int_t^\infty e^{\rho(\tau-t)} \{ \alpha_B \log C_{B\tau}^i + \alpha_M \log C_{M\tau}^i + \alpha_W \log C_{W\tau}^i + \Theta(z_\tau) \} d\tau. \quad (4)$$

where $\Theta(\bullet)$ is an increasing function, ρ is the (constant) intertemporal rate of substitution, and $c_{j\tau}^i$ is the amount of good j consumed by the representative consumer.

The main assumption in this paper is that the economic agents do not take into account the effect of the consumption/production on the ozone layer. This means that the agent's perception is that:

$$\frac{\partial U_t}{\partial c_{j\tau}^i} = \frac{\alpha_j e^{\int_t^\tau \rho_s ds}}{c_{j\tau}^i} \text{ and } \frac{\partial U_t}{\partial j_\tau} = 0 \quad \text{for } j = M, W, B, \text{ and } \tau \geq t. \quad (5)$$

Free Market Allocation.

In the market solution, firms will maximize their profits subject to the technology constraint, consumers will maximize their utilities subject to their budget constraint, and goods and labor markets will clear. Note that when maximizing their objective functions, neither consumers nor producers take into account the effect of their decision on the ozone layer. First, the equilibrium in North will be characterized.

North.

Producers in North have to decide how much to produce of manufactures and baskets. They have an endowment of capital to be used in the production of manufactures, and of labor to be used in the production of both goods. In perfect competition, they take prices as given, and hire factors up to the point where the value of marginal product of the factor equals its cost. In equilibrium, prices will adjust so that there is full employment of the factors of production. The profit maximizing condition in the baskets industry is given by:

$$ap_B = w, \quad (6)$$

where w is the wage rate and a is the constant marginal productivity of labor in the industry. This equation determines the equilibrium wage rate of the economy.

The rental rate of capital adjusts so that the manufactures industry fully employs its endowment of capital (figure 2.c). Labor is hired in the industry up to the point where the value of marginal product of labor equals its cost, given the wage rate and the price of manufactures (figure 2.a). Finally, the amount of capital and labor in the production determines the amount of manufactures produced (figure 2.b).

The labor market clearing condition will determine how much of good B will be produced. It is represented in Figure 3.

On the demand side of the economy, consumers maximize their utilities (equation (4)) subject to a budget constraint represented in

a

b

c

Figure 2.

Figure 3.

the following equation².

$$\int_t^\infty e^{-[R(\tau)-R(t)]} (p_{B\tau} c_{B\tau}^i + p_{M\tau} c_{M\tau}^i + c_{W\tau}^i) d\tau \leq \int_t^\infty e^{-[R(\tau)-R(t)]} \left(\frac{w_\tau L^* + r_\tau K^*}{m^n} \right) d\tau, \quad (7)$$

where $w_\tau = ap_{B\tau}$, $r_\tau = p_{M\tau} f_k(K^*, L_{M\tau})$, $R(\tau) = \int_t^\tau i_s ds$, i is the interest rate, and m^n is the amount of individuals living in North. To simplify the analysis, it is assumed that each individual receives as income an equal share of the country's total income.

This yields the following consumption pattern:

$$p_{j\tau} c_{j\tau} = \frac{\alpha_j}{\alpha_B + \alpha_M + \alpha_W} E_\tau \quad \text{for } j = B, M, W, \quad (8)$$

where expenditure $E_\tau = \frac{w_\tau L^* + r_\tau K^*}{m^n}$ in equilibrium.³

²Good "wood" is chosen to be the numeraire, and its price is set to equal 1.

³Although consumers may borrow or lend, they do not do so in equilibrium from the solution of their dynamic optimization problem.

Furthermore, the demand conditions yield:

$$\frac{E_\tau}{E_\tau} = i_\tau - \rho \quad (9)$$

After characterizing the equilibrium conditions in South, the general equilibrium of the economy will be determined.

South.

Consumers in South are the owners of the forest, so that their income is the revenue from the wood production. They maximize their utility (equation (4)) subject to the following budget constraint:

$$\int_t^\infty e^{-[R(\tau)-R(t)]} (p_{B\tau} c_{B\tau} + P_{M\tau} c_{M\tau} + c_{W\tau}) d\tau \leq \int_t^\infty e^{-[R(\tau)-R(t)]} (W_\tau) d\tau, \quad (10)$$

where m^s is the amount of individuals living in South, and, here again, the income of each individual is an equal share of the country's total income.

The conditions for solving the intertemporal maximization problem are the same as in North, i.e., equations (8), and (9) also hold for South.

The Wood industry uses as factor of production an exhaustible resource it owns: the rain forest. Hence, at any point in time, the amount of wood produced will affect the production possibilities in the future. The production decision in the Wood industry is, therefore, the result of an inter-temporal maximization problem. It maximizes the present value of its profits, subject to the forest's adjustment path constraint, and the fact that the amount of trees cut cannot exceed the size of the forest (the initial size of the forest is T).

$$\max \int_t^\infty \left[e^{i_\tau(\tau-t)} W_\tau \right] d\tau \quad (11)$$

$$\text{s.t. } \dot{T}_\tau = G(T_\tau) - W_\tau$$

$$W_\tau \leq T_\tau$$

$$T_t = \bar{T}$$

Assuming that the second constraint is not binding, i.e., that the optimal schedule for cutting trees will not be the destruction of the entire forest (which will be checked later), the first order conditions for the maximization of the problem are:

$$\begin{aligned} (i) \quad & 1 - \mu_\tau = 0 \\ (ii) \quad & \dot{\mu}_\tau - \mu_\tau[i_\tau - G'(T_\tau)] = 0 \\ (iii) \quad & \lim_{\tau \rightarrow \infty} e^{-i_\tau(\tau-t)} \mu_\tau T_\tau = 0 \\ (iv) \quad & W_\tau - T_\tau \leq 0 \end{aligned} \tag{12}$$

where $e^{-i_\tau(\tau-t)} \mu_\tau$ is the costate variable associated with T_τ . Its value is the marginal value of the forest at time τ from the point of view of time t .

Equation (12.iii) represents the transversality condition. When time goes to infinity, either the "present marginal value" of the forest (i.e. the costate variable) goes to zero, or the size of the forest goes to zero.

Equations (13.i) and (13.ii) imply that $i_\tau = G'(T_\tau)$. Using equation (9), the rate of growth of wood production is given by:⁴

$$\frac{\dot{W}_\tau}{W_\tau} = G'(T_\tau) - \rho. \tag{13}$$

Figure 4 illustrates the dynamics of the problem. All points in the positive orthand and below the $W = T$ schedule are feasible. The

⁴Remember that, in equilibrium, $p_{B\tau}c_{B\tau} + p_{M\tau}c_{M\tau} + c_{W\tau} = W_\tau$.

locus $\dot{W} = 0$ is a vertical line on T_s , which is the size of the forest that makes $G'(T_s) = \rho$. The intuition behind the relation between ρ and T_s is the following: the less patient the consumers are (i.e., the higher ρ), the lower will be the present value of consumption far in the future. Demand conditions will make the firm prefer to cut more trees today, instead of having a larger forest for the future. Hence, the less patient the economic agents are, the lower will be the optimal size of the forest. The locus $\dot{T} = 0$ was described in figure 3.

Figure 4.

The dynamics is as follows. On points above $\dot{T} = 0$, the size of the forest is decreasing. The amount of trees that are being cut is higher than the reproduction rate of the forest, hence the forest shrinks. Below $\dot{T} = 0$ the forest reproduces itself faster than the trees are taken away, and the forest gets larger. As for the variation

of wood production, to the right of the $\dot{W} = 0$ schedule the amount of trees cut over time decreases, and to the left it increases.

There exists one saddle path in the solution to the problem, i.e., one trajectory (T_τ, W_τ) that satisfies the adjustment equations (1) and (13), the feasibility constraint (12.iv), and the transversality condition (12.iii). Appendix A shows why the only saddle path is the *ss* trajectory that leads to point E in figure 4.⁵

The final step to characterize the market equilibrium is to make sure that the goods' market clear:

$$C_j^n + C_j^s = j \quad \text{for } j = B, M, W, \quad (14)$$

where C_j^n and C_j^s represent the total consumption of good j by consumers at North and South, respectively.

With the three equations for consumption in North and in South represented in equation (8), and any two of the market clearing equations in equation (14), then C_j^n , C_j^s and p_j (for $j = B, M, W$) can be derived in terms of B , M , and W . W at each point in time is a point at the saddle path *ss* in figure 4. Finally, the profit maximizing conditions for the production of B and M , represented in figures 2 and 3, combined with the price equations determine the equilibrium prices and the equilibrium production level of B and M . Those, in turn, are substituted back into the consumption equations to determine the equilibrium consumption levels of each good in each country.

The market equilibrium, however, is not efficient. When taking their decisions, the producers of wood did not take into account the effect of their activity on the ozone layer, nor the consumers took into account the effect of their consumption of manufactures on air pollution.

Next section derives the global planner's solution to the problem, which indicates the efficient allocation for the world economy. The countries may implement the global planner's allocation if they act cooperatively on an intervention scheme. In section 4, the allocation resulting from the solution of national planners is derived, and com-

⁵Observe that in the optimal path for cutting trees the second constraints is actually not binding, as was assumed above.

pared to the global planner's one. The national planners' solution is the result of a policy intervention designed non-cooperatively.

3. The Cooperative Solution.

The cooperative solution is the resulting allocation when the two countries implement policies to maximize worldwide welfare. To derive the cooperative solution to the problem, it is necessary to derive the optimal allocation resulting from the maximization of welfare of a global planner, i.e., a planner that takes into account the utility of consumers in both countries.

The global planner maximizes the present value of its welfare function, which has as arguments the utility of each consumer, subject to the rain forest adjustment rule, the production functions, and the factor endowments constraints. The problem is represented as:⁶

$$\begin{aligned} \max \int_t^\infty e^{-\rho(\tau-t)} \Omega[U(c_{M\tau}^1, c_{W\tau}^1, c_{B\tau}^1, z_\tau), \dots, U(c_{M\tau}^n, c_{W\tau}^n, c_{B\tau}^n, z_\tau)] d\tau \\ \text{s.t.} \end{aligned} \quad (15)$$

$$M \leq f(K^*, L_M);$$

$$W \leq T;$$

$$B \leq aL_B;$$

$$C_M^n + C_M^s = M;$$

$$C_W^n + C_W^s = W;$$

$$C_B^n + C_B^s = B;$$

$$L_M + L_B = L^*;$$

$$z = h(T, f(C_M^n + C_M^s));$$

$$T = G(T) - W;$$

⁶The time subscripts are omitted wherever it is not confusing to do so.

$$T_t = \bar{T};$$

where $\Omega[\cdot]$ is the welfare function $C_i^n = \sum_{j=1}^{m^n} c_j^i$ and $C_i^s = \sum_{j=1}^{m^s} c_j^i$ represent the consumption of the m^n Northerners and the m^s Southern consumers, respectively.

Solving the dynamic optimization problem, the following adjustment pattern is derived for the consumption of wood for the representative consumer:⁷

$$\frac{\dot{c}_W^i}{c_W^i} = G'(T) - \rho + c_W^i \frac{\sum_{k=1}^m \Omega_k U_z^k h_t}{\Omega_i}, \quad (16)$$

where $\Omega_k = \frac{\partial \Omega}{\partial U(C^k, z)}$, $U_z^k = \frac{\partial U(c_M^k, c_W^k, c_B^k, z)}{\partial z}$, and $h_T = \frac{\partial h(T, P)}{\partial T}$.

Equation (16) yields:

$$\frac{\dot{W}}{W} = G'(T) - \rho + W \frac{\sum_{k=1}^m \Omega_k U_z^k h_T}{\Omega_i}. \quad (17)$$

Figure 5 illustrates the dynamics of the problem.⁸

It is straightforward to check that the dynamics of the global planner's solution for the production of wood is very similar to the market solution. The only difference between the two is the optimal adjustment path for the production of wood. Here the locus in which $\dot{W} = 0$ is an upward sloping curve starting at point $(0, T_s)$, whereas in the market solution it was a vertical line at $T = T_s$. Using the same arguments as in the market solution, here there is only one saddle path, $s_c s_c$, leading to point E_c .

Comparing the trajectories of W from the two problems, it is clear that the global planner solution indicates a lower production of wood at each point in time (supposing the size of the rain forest is initially the same in both problems). It also reaches the steady state at a larger forest size, and possibly at higher production level of wood. When the effect of the size of the forest on the ozone layer is

⁷The derivation of the equation is in appendix B.

⁸Note that T_s in figure 5 represents the same value as T_s in figure 4.

Figure 5.

taken into the account, it is preferable to give up some consumption of wood at each point along the optimal path in order to have, in the future, a larger forest, and therefore more ozone.

The global planner solution also differs from the market one regarding the production/consumption of manufactures decision. The first order condition from the global planner's maximization with respect to c_M^i is:

$$\sum_{k=1}^M \Omega_k U_z^k h_M + \pi_m - \phi_m = 0, \quad (18)$$

where π_M and ϕ_M are Lagrange multipliers associated to the market clearing and production function of manufactures constraints, respectively.

π_M and ϕ_M in the optimal solution are interpreted as the shadow value of an extra unit of manufacture for the consumers, and an extra

unit of manufacture for the producers, respectively. In a market equilibrium, these values stand for the consumer and the producer price of manufactures. In the market solution derived in section 2 those two values were equal, whereas here the consumer price of manufactures is higher than the producer price. This difference implies a different optimal decision of production and consumption.

To implement the central planner's allocation the governments have to make transfers to each consumer so that $\Omega_i = 1/\alpha_i$, where α_i is the Lagrange multiplier associated to the consumer's budget constraint in the market solution, and impose two taxes: The Northern government has to impose a production tax on manufactures equal to $\sum_{k=1}^m \Omega_k U_z^k h_M$, and the Southern government has to make a transfer to each forest owner equal to $\frac{\sum_{k=1}^m \Omega_k U_z^k h_T}{m\Omega_i}$ per unit of tree owned⁹. The production tax makes the producers of manufactures incorporate the effect of their production on the consumers' utility, and the transfer to forest owners makes the wood industry incorporate the effect of the size of the rain forest on the consumers' utility. Assuming that the function $h(\cdot)$ is linear in M and T , so that the taxes do not depend on the size of C_M and T , the tax on manufactures will be constant over time while the transfer to forest owner will change proportionally to changes in W .

The solution presented above represents a cooperative solution, where both countries act in coordination to achieve a worldwide efficient allocation. However, it may be the case that political or institutional barriers prevent the two countries from cooperating. In that case, each country separately should seek the best way to improve its welfare. It may also be the case that one country gains from deviating singly from the cooperative solution, then it would not be sustainable without some mechanism to offset the incentive to deviate. Each country's national planner optimal allocation will now be investigated.

⁹Each producer of wood takes the transfer as an exogenous value. Each producer is relatively small so that she does not take into account the effect of her own production on the value of the tax.

4. The Non-Cooperative Solution.

The non-cooperative solution is the solution when the countries individually implement policies to maximize only their own welfare. The solution of the maximization of national planners' welfare indicates the allocation achieved without cooperation between the countries. North and South will be studied in turn.

North.

The Northern planner wants to maximize the present value of a welfare function of the utilities of Southern consumers, subject to the factor endowments, goods endowments, production functions, and the external balance constraints. Note that the Northern planner takes into account the effect of their consumption and their export of manufactures on the ozone layer.¹⁰ The maximization problem faced by the Northern planner is represented by:

$$\max \int_t^\infty e^{-\rho(\tau-t)} \Omega[U(c_{M\tau}^1, c_{W\tau}^1, c_{B\tau}^1, z_\tau), \dots, U(c_{M\tau}^{m^n}, c_{W\tau}^{m^n}, c_{B\tau}^{m^n}, z_\tau)] d\tau \quad (19)$$

s.t.

$$M \leq f(K^*, L_M);$$

$$B \leq aL_B;$$

$$C_M^n = M + m_M;$$

$$C_W^n = m_W;$$

$$C_B^n = B + m_B;$$

¹⁰The Northern planner problem as presented below does not incorporate the effect of the Northerners consumption of wood on its production, and, consequently, on the size of the rain forest. If she did, she would possibly impose restrictions on their imports or consumption of wood, in order to induce a lower production of wood by South. This simplification does imply that the solution to this problem is not the second best, but it makes the problem analytically tractable.

$$z = h(T, f(C_M^n - m_M));$$

$$L_M + L_B = L^*;$$

$$P_M(m_M, m_W, m_B)m_M + p_W(m_M, m_W, m_B)m_W \\ + p_B(m_M, m_W, m_B)m_B$$

where m_j represents the net imports of good j , and $p_j(m_M, m_W, m_B)$ is the inverse of the supply function for good j .

The first order conditions for the maximization above imply a different allocation compared to the market equilibrium conditions. The difference comes from two sources: the first one is that the local planner takes into account the negative effect of the world consumption of manufactures on the utility of Northern consumers through its effect on the ozone layer, and the second one is that the local planner perceives the possible exploitation of the country's monopoly power in the international goods' market.

To implement the allocation derived from the maximization above, the Northern government makes transfers to the consumers so that $\Omega_i = 1/\alpha_i$, and prices are normalized so that the multiplier of the balance of payments constraint equals zero. To deal with the distortions the planner can use a combination of three different policies: trade policies, which include export taxes or subsidies and import tariffs or subsidies; consumption taxes or subsidies; and production taxes or subsidies. In this case the local planner will introduce a production tax on manufactures equal to $\sum_{k=1}^n \Omega_k U_z^k h_m^{11}$; an export tax on manufactures equal to $\sum_{k=M, W, B} \left[m_k \frac{\partial p_k(m_M, m_W)}{\partial m_M} \right]$; and an export tax on baskets¹² equal to $\sum_{k=M, W, B} \left[m_k \frac{\partial p_k(m_M, m_W, m_B)}{\partial m_B} \right]$; and an import subsidy on wood equal to $\sum_{k=M, W, B} \left[m_k \frac{\partial p_k(m_M, m_W, m_B)}{\partial m_M} \right]$ in absolute value. It is important to observe that the three latter policies are due to the exploitation of the monopoly power of the country

¹¹Note that a production tax is equivalent to a combination of an export tax and a consumption tax of the same amount.

¹²If the country is a importer of baskets, it should impose an import subsidy of the same absolute value.

in the international goods market, and does not relate to the main externality problem we are concerned about here. The tax on manufactures production is constant over time, but the other taxes may vary during the adjustment period for the wood industry. The change in the production of wood affects the world supply function for the three goods.

After deriving the Southern planner solution and its implementation scheme, the local planners' allocation will be compared to the central planner's one.

South.

The Southern planner maximizes the present value of a welfare function of the utilities of Southern consumers, subject to the production function, the good's endowments, the external balance constraints, the forest adjustment path, and the initial rain forest endowment:

$$\max \int_t^\infty e^{-\rho(\tau-t)} \Omega[U(c_{M\tau}^1, c_{W\tau}^1, c_{B\tau}^1, z_\tau), \dots, U(c_{M\tau}^{m^s}, c_{W\tau}^{m^s}, c_{B\tau}^{m^s}, z_\tau)] d\tau \quad (20)$$

s.t.

$$W \leq T$$

$$C_M^n = -m_M;$$

$$C_W^n = W - m_W;$$

$$C_B^n = -m_B;$$

$$z = h(T, f(C_M^n + C_M^s));$$

$$p_M(m_M, m_W, m_B)m_M +$$

$$p_W(m_M, m_W, m_B)m_W + p_B(m_M, m_W, m_B)m_B = 0;$$

$$\dot{T} = G(T) - W;$$

$$T_t = \bar{T}.$$

Solving the dynamic optimization problem, the following adjustment path for the consumption of wood for a representative Southern consumer is derived:¹³

$$\frac{\dot{c}_w^{is}}{c_w^{is}} = -\rho + c_w^{is} \frac{\sum_{k=1}^{m^s} \Omega_k U_z^k h_T}{\Omega_{is}}. \quad (21)$$

Figure 6.

Figure 6 illustrates the dynamics of the problem. It is very similar to figure 4, but instead of having the amount of wood produced on

¹³ The derivation of the following equation is analogous to the derivation of equation (16), presented in appendix B.

the vertical axis, we have the amount of wood consumed by a representative Southern consumer. The schedule $W = T$, below which all points are feasible, has an inclination of $1/m^s$, instead of 1 as before. The locus $\dot{c}_W^{is} = 0$ is represented by the line $\dot{c}_{W1} = 0$ and it is derived from equation (21). The locus $\dot{T} = 0$ from the problem's constraints is rewritten as:

$$c_W^{is} = \frac{G(T) - m^n c_W^{in}}{m^s} \quad (22)$$

where c_W^{in} is the consumption of wood from a representative Northern consumer. Observe that when the consumption of wood from Northerners increases, the $\dot{T} = 0$ schedule shifts down as its concavity decreases. Similarly to the dynamics depicted in figure 4, the problem represented in figure 6 has only one saddle path, $s1s1$, leading to point E_l .

The Southern planner solution to the problem implies a different allocation compared to the market solution for three reasons: the planner incorporates the effect of the consumption of manufactures on the ozone layer, she takes into account the effect of the production of wood on the size of the rain forest and its effect on the ozone, and she exploits the country's monopoly power in the international goods' market.

The implementation of the Southern planner allocation is achieved in a market environment by government transfers to consumers to ensure that $\Omega_i = 1/\alpha_i$, prices normalized so that the multiplier of the balance of payments constraint equals one, and the introduction of: a transfer to each forest owner equal to $\frac{C_W^s}{C_W^s + C_W^n} \left[C_W^s \frac{\sum_{k=1}^{m^s} \Omega_k U_z^k h_T}{m^s \Omega_i} \right] - \frac{C_W^n}{C_W^s + C_W^n} [G'(T) - \rho]$ per tree owned¹⁴; a consumption tax on manufactures equal to $\sum_{k=1}^{m^s} \Omega_k U_z^k h_M$; an export tax on wood equal to $\sum_{k=M,W,B} \left[m_k \frac{\partial p_k(m_M, m_W, m_B)}{\partial m_W} \right]$; an import subsidy on baskets equal to $\sum_{k=M,W,B} \left[m_k \frac{\partial p_k(m_M, m_W, m_B)}{\partial m_B} \right]$; and an import subsidy on manu-

¹⁴The value of the transfer is derived by writing equation (21) in terms of W , using $W = m^n c_W^{in} + m^s c_W^{is}$, so that we can compare it to equation (14). Here, again, each producer of wood takes the transfer as an exogenous value.

factures equal to $\sum_{k=M,W,B} \left[m_k \frac{\partial p_k(m_M, m_W, m_B)}{\partial m_M} \right]$ in absolute value. Similarly to the Northern planner case, here the three latter taxes deal with the exploitation of the monopoly power of the country in the international market. The tax on manufactures production is constant over time, and the other taxes change due to changes in the consumption/production of wood along the saddle path.

5. Comparing the Different Allocations.

Now the non-cooperative solution will be compared to the cooperative one. First, let's look at the treatment of the manufactures consumption externality. Each national planner does not care about the externality of the consumption of manufactures on the utility of the consumers of the other country. That is the reason for the tax on manufactures (production tax equal to $\sum_{k=1}^{m^n} \Omega_k U_z^k h_M$, for North, and consumption tax equal to $\sum_{k=1}^{m^s} \Omega_k U_z^k h_M$, for South) to be lower than the tax related to the global planner's optimal allocation (production tax equal to $\sum_{k=1}^{m^n+m^s} \Omega_k U_z^k h_M$). If this were the only difference between the non-cooperative and cooperative solution, then the latter would prescribe a lower consumption level of manufactures, and a larger ozone "consumption". The non-cooperative solution would yield a higher utility level for the consumers compared to laissez-faire, but inferior to the cooperative allocation.

The treatment of the wood production externality requires a more careful analysis. The Northern planner does not address the problem as it should, incorporating the effect of Northerners consumption of wood on the size of the forest. The Southern planner does deal with the problem, but, here again, she does not care about the Northerners utility, so that she will prescribe a lower transfer to forest owners than the central planner's prescription. In figure 6, the locus $c_W = 0$ and $c_{Wc} = 0$ represent the market equilibrium and the central planner schedules, respectively¹⁵. For a given consumption level of wood by foreign consumers, the optimal path for Southerners consumption in the local planner solution is lower than

¹⁵The equation for the $\dot{c}_{Wc} = 0$ schedule comes from equation (16), and for the $\dot{c}_W = 0$ schedule from equation (13), using that $W = m^n c_W^n + m^s c_W^s$.

the market equilibrium and higher than the central planner solution at each point in time, if they start at the same forest size. It means that when both countries are acting cooperatively and implementing the central planner solution, the Southern government will have an incentive to deviate from it, increase their consumption of wood and improve their welfare. If the Northerners respond to that by changing their consumption of wood as well, the $\dot{T} = 0$ schedule will shift, and it may be the case that the result will be a lower consumption of wood for Southerners. The size of the forest in the local planner's steady state is unambiguously in between that of the market and central planner solutions.

Finally, the local planners prescribe export taxes and import tariffs to exploit their monopoly power in the world market for goods. These taxes, if taken individually, yield higher welfare for the country that imposes them. However, if the other countries do the same, they result in a lower welfare for everyone. Hence, the improvement in welfare achieved by the policies addressing the other externalities may be suppressed by the "tariff war", resulting in a lower welfare compared to the free market equilibrium.

6. Concluding Remarks.

This paper characterizes a situation very similar to the north-south dilemma we witness in the world. The southern countries of the world, mostly underdeveloped, are the depositories of what remains from the world's natural forests, and they usually use that resource in a destructive way. The preservation of the forests is seen as essential to the planet. The northern, developed, countries, on the other hand, are responsible for much of the air pollution in the world. These two phenomena are linked through their effect on the ozone layer. What sort of policy intervention should be used in a situation where there is an environmentally harmful externality of consumption/production that crosses countries' frontiers?

A simple model that incorporates the main features needed to characterize the situation described above is constructed. First, the free market equilibrium for the model is identified, and next the world cooperative solution for the problem is derived. With a prescription

of a set of taxes, we indicated how the global planner's efficient allocation could be reached in a market situation. The same procedure is taken for national planners, identifying a situation where countries acts individually in pursuing an allocation that yields higher social welfare.

The best alternative to deal with the sort of externality presented in this paper is when both countries act cooperatively to implement a global planner allocation. The local planners' allocation deals with the environmentally harmful externality problem in a less efficient way compared to the central planner, but yet it is better than the market allocation with respect to that. However, when both countries implement the local planner solution they may be worse off than in the market solution because of their imposition of import tariffs and export taxes that try to exploit their monopoly power in the international goods' market.

A further development of this analysis should explore whether the cooperative solution is a Nash equilibrium. If the two countries try to implement the global planner allocation, will each country have an incentive to deviate and pursue the national planner allocation? If so, how could the global planner solution be enforced?

Appendix A

This appendix checks why other trajectories do not satisfy the first order conditions for the maximization problem in section 2. First, suppose that the initial size of the forest is $T', T' > T_s$. Consider a trajectory starting at $W = s', s' > s$. This trajectory will eventually reach the $W = T$ line (point F' in Figure 4). At that point conditions (12.iv) and (13) become inconsistent. Hence it cannot be an optimal path.

Now consider a trajectory starting at $s'', s'' < s$. This trajectory goes to point F'' in the figure. But at F'' the amount of wood produced is equal to zero, and the optimal adjustment path for the production of wood (equation(13)) becomes indeterminate. It cannot be an optimal path either.

Appendix B

From the first order conditions for the dynamic maximization problem in equation (15) we have:

$$-\frac{\partial H}{\partial T} = \frac{\partial [ye^{-\rho(\tau-t)}]}{\partial \tau} \quad (\text{B1})$$

where H is the Hamiltonian equation associated to the problem, and $ye^{-\rho(\tau-t)}$ is the costate variable.

Equation (B1) can be rewritten as:

$$\dot{y} = [\rho - G'(T)]y - \sum_{k=i}^m \Omega_k U_z^k h_T \quad (\text{B2})$$

When maximizing with respect to W and c_W^i we get, respectively:

$$\begin{aligned} (i) \quad \pi_W - y &= 0 \\ (ii) \quad \Omega_i U_{c_W}^i - \pi_W &= 0 \end{aligned} \quad (\text{B3})$$

where π_W is the Lagrange multiplier associated to the wood market clearing condition.

Combining equations (B2) and (B3) we get:

$$\Omega_i U_{c_W c_W}^i \dot{c}_W^i = [\rho - G'(T)] \Omega_i U_{c_W}^i - \sum_{k=1}^m \Omega_k U_z^k h_T. \quad (\text{B4})$$

Assuming that all consumers are equally treated in the welfare function, i.e., Ω_i is the same for any i . Using equation (2) to derive $U_{c_W}^i$ and $U_{c_W c_W}^i$, and substituting in (B4) equation (16) is derived. Remembering that in equilibrium all consumers will consume the same amount of each good ($mc_W^i = W$), then equation (16) can be rewritten as equation (17).

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