Property rights and the dynamics of North-South trade, chapter 8

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AGRICULTURE, TRADE, & the ENVIRONMENT

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Discovering and Measuring the Critical Linkages

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8

Property Rights and the Dynamics of North-South Trade

Graciela Chichilnisky

Introduction

Property Rights, Trade, and Resource Dynamics

This chapter focuses on how the lack of property rights in North-South trade of primary resources can distort trade and threaten the sustainability of development. This issue is examined within a two-region world economy where one region, the North, represents the industrial countries, and the other, the South, the developing countries. The lack of property rights characterizes a class of environmental problems arising from the use of renewable resources as inputs in the production of traded goods. Typical examples are rain forests used for timber, or destroyed to give way to the production of cash crops such as coffee, sugar, and palm oil. In many developing countries, these resources are extracted from unregulated common property sources; and that ownership is shared with future generations. Focus is placed on renewable resources because it can be argued that sustainable development is all about the proper management of the world's renewable resources. The atmosphere can be considered a renewable or self-regenerating resource, as are bodies of water, forests, fisheries, and biodiversity in general. To a great extent, the global environment is described by the dynamics of the productive use of the earth's renewable resources.

There are two significant departures from traditional trade theory. The first is that one input in production is an environmental resource. This resource is self-renewable and in principle exhaustible, such as a forest or a fishery. Its *population dynamics* are represented by a differential equation which describes the demographic progress of the species, its stock through time. This is a major departure because it adds an underlying dynamic—an ecological dynamic—to the functioning of the market. Thus, this analysis blends elements of general equilibrium theory and dynamic analysis. The second major departure from traditional theory is that the regions are characterized by their property rights regimes based on the source from which resources are extracted. In the North, property rights are well defined, while in the South, the environmental resource is unregulated common property.

A seamless merging of a general equilibrium model of trade with a dynamic system describing population dynamics is a major contribution of this study. Their merging is achieved by a simple formalization: the two systems meet at one point; they use the resource as an input to the production of traded goods. This, in turn, affects all economic variables, including all prices of inputs and produced goods, in a typical general equilibrium manner.

This simple formalization carries unexpected explanatory power. It allows us to solve the entire two-country model and to analyze its properties in a simple, explicit fashion. Using this explicit solution, a rigorous comparative dynamics exercise is carried out to analyze the impact of different systems of property rights in the two regions on their prices, production levels, international trade, and welfare.

It is shown that differences in property rights are sufficient to explain differing trade patterns between two otherwise identical regions, even if these regions have the same endowments, preferences, and technologies. Private and public gains from trade, and private and public comparative advantages are shown to differ. The weaker the property rights, the larger the difference. The current pattern of specialization in resource-intensive goods by the South is shown to be inefficient for both the South and the North.

The succeeding sections of this chapter provide the following. Lemma 1 studies population dynamics, and the connection between property rights and the long-run supply curve of the renewable resource. The next step is to analyze market behavior. The general equilibrium model of North-South trade is defined, and solved in one explicit resolving equation provided in the Appendix. Theorem 1 then is used to establish the patterns of trade implied by the difference in property rights between the two regions. Corollary 1 establishes that the overuse of resources is not due to lower prices in the South. The Appendix formalizes the model of North-South trade with variable property rights for an environmental input.

Resource Dynamics

The Dynamics of Renewable Resources

The strategy for studying the dynamics of the renewable environmental resource E under different property rights regimes is as follows. Emphasis is first placed on the dynamics of the resources without, and then with, economic use. From this steady-state behavior, the supply curve of resources is derived as a function of market prices. Then, it is shown how the long-run supply curve of the resource varies with the property rights regimes.

A standard manner in which renewable resources—such as forests and fisheries—are modeled is to assume a "population growth curve" that describes the demographic progress of the species. If z_t is the stock or population size at time t, then changes in z over time are denoted by:

$$\dot{z}_t = H(z_t), \tag{1}$$

where the function H has the form like an inverse U, i.e., it is increasing in z (population size) first, and then decreasing as overcrowding occurs. A well-known case is when $H(z)$ is quadratic in z, i.e.,

$$\dot{z} = H(z) = \beta z - \gamma z^2, \text{ with } \beta, \gamma > 0. \tag{2}$$

Integrating both sides of (2) yields the classic logistic curve:

$$z_t = \beta z_o / [\gamma z_0 + (\beta - \gamma z_o)\exp(-\beta t)]. \tag{3}$$

Equation (3) represents the population growth without economic intervention and within a stable ecological environment.

Now assume that the resource is *harvested*, or extracted for use as an input to production. Let $E_t \geq 0$ be the total harvest at time t. The new growth equation (ecology with economic intervention) is:

$$\dot{z} = H(z_t) - E_t. \tag{4}$$

E depends on the stock of z and input x:

$$E = F(z, x) \tag{5}$$

Let q be the opportunity cost of the input x, where x, for example, is labor or capital, and let p_E be the market value of the resource; q and p_E are constant over time. The profit from the production of E is:

$$\pi_t = p_E F(z_t, x_t) - q x_t. \tag{6}$$

The optimal behavior under a private property regime implies that:

$$F' = \partial F(x)/\partial x = q/p_E. \tag{7}$$

The problem then is reduced to analyzing a single first-order differential equation.

To examine the stability of the steady-state solution, the adjustment mechanism for the input x is the quantity of the input applied to harvesting the resource, which increases with profits, i.e.,

$$\dot{x}_i = \mu\pi_i, \text{ where } \mu > 0. \tag{8}$$

The solution path of the adjustment process defined by (8) depends on its initial value; the natural initial value is the long-run population size in its natural environment, i.e., the long run-stock without economic encroachment. In this event, the population size tends in the long run to the steady state z^s, where z^s is a function of p_E and q:

$$z^s = z^s(p_E/q). \tag{9}$$

The corresponding harvest or extraction is

$$E^s = E^s(p_E/q). \tag{10}$$

Resource Supplies in the Long Run

The solution $z^s(p_E/q)$ in (9) describes the behavior of the renewable resource stock under private property regimes. Note that $E^s = z^s(p_E/q)$ is an increasing function of the relative market value of the resource, p_E. For each q, let $E^s = E^s(p_E)$ denote the supply curve of the resource E in a stationary state as an increasing function of p_E. $E^s(p_E)$ represents the social supply of the resource E as it is derived from (7), i.e., maximizing profits and internalizing fully the impact of each unit's extraction on the productivity of the following units. The next step is to study the variation of the stationary stock of E, or, equivalently, of the steady-state solution z^s, with respect to different property rights regimes.

Comparative Dynamics of the Stock of Resources with Respect to Property Rights

For each property rights regime, the production function in (5) is redefined to reflect the extent to which the harvester takes into consideration the externalities that its harvesting produces on the other harvesters within that regime. For example, in the private property regime, the harvester fully internalizes the impact of its catch on the productivity of the next unit of input by taking into account the marginal productivity of the catch (7). With unregulated common property

resources, this may not be the case, leading in a limiting case to the so-called "tragedy of the commons," as discussed in Lemma 1 below. In order to compare the supply curves in each case, the private marginal cost curves associated with the production of a *common property resource* (E) are derived explicitly.

Let there be N "harvesters" of a common property resource, indexed as $I = 1, ..., N$. Let x_i be the input of harvester I to harvest the common property resource E. Let $x = \Sigma x_i$. It is assumed that the inputs of all harvesters are identical and interchangeable, so that for each stock z, the total harvest can be expressed as a function $E = F(x)$ of the total input. It is also assumed that all harvesters are symmetric, so that for a stock z, each harvester obtains as its output a fraction of the total output equal to the fraction that it supplies of the total input, formally $E_i = F(x)(x_i/x)$. For a stock z, each harvester chooses its input level x_i to maximize the value of its share of outputs net of costs, $p_E E_i(x_i) - qx_i$, taking as given the output levels of others, E_j, for $j \neq I$. Here, p_E is the market-induced price of the resource, which is an exogenous parameter for the competitive harvester, and q is the "opportunity cost" of the input x_i. Finally, $F(x)$ is assumed to be strictly concave, so that for each stock z, the production of the environmental good E is characterized by diminishing returns, arising perhaps from the application of increasing amounts of variable input x, to a fixed body of land or water.

LEMMA 1. *Under the assumptions listed above, the long-run private supply curve for the common property resource lies below the social supply curve.*

Proof. Consider a given level of the stock z, and let $F(z, x) = F(x)$. Then the marginal product of the input x is $F'(x)$, and the average product is $F(x)/x$. By strict concavity, $F(x)/x = F'(x)$. Let the private marginal product of the input be Pmp and the social marginal product be Smp. With identical harvesters, if harvester I uses inputs x_i, his/her yield is, by assumption, $y_i = x_i F(x)/x$, i.e., average yield per unit of input times amount of input. Thus, harvester I's production function for E is given by $y_i = x_i F(x)/x$. Hence,

$$Pmp_i = F(x)/x + x_i\{[xF'(x) - F(x)]/x^2\} = F(x)/x + x_i/x[F'(x) - F(x)/x].$$

Note that as the number of harvesters becomes large, x_i/x goes to zero, and the private marginal product becomes the average product. In this limiting case, we recover the well-known result that harvesters equate input prices to average return rather than to marginal product, the basis of the "tragedy of the commons." Since $Smp_i = F'(x)$,

$$\begin{aligned} Smp_i - Pmp_i &= F'(x) - F(x)/x - (x_i/x)[F'(x) - F(x)/x] \\ &= [F'(x) - F(x)/x](1 - x_i/x) < 0. \end{aligned} \tag{11}$$

Therefore, the social marginal product of the input is lower than the private one. Since F is concave in x, for each given z and p_E, the steady-state quantity harvested under a common property regime is larger than the corresponding amount under private property. Thus, the long-run steady state of the stock is smaller in the case of common property resources than the same steady state with private property. In a limiting case, the extraction with common property regimes is sufficiently high so that no steady state with a positive stock exists.

The dynamics of the renewable resource show how the stock depends on property rights. The supply of resources is clearly dependent on their relative market price, p_E/q, and increasing with the price p_E/q.

The next step is to explain prices through market behavior. To simplify matters, the input used in the extraction of E will be capital K in the following, and hence $q = r$, the rental rate of capital. The two systems, resource dynamics and market equilibrium, determine simultaneously prices and resource use. This is formalized using a model of North-South trade.

A General Equilibrium Model of North-South Trade

The model is a two-good, two-input, two-country model similar to the classic Heckscher-Ohlin model. Its equations and its solution are given in the Appendix. In terms of its underlying analytical structure, however, there is a major difference with the classic model. Here, one input is a renewable environmental resource with its own ecological dynamics. In the Heckscher-Ohlin model, inputs are exogenously fixed throughout. In particular, the supplies of inputs, such as environmental resources E, are price dependent here, in contrast with the Heckscher-Ohlin theory where they are fixed. This difference is crucial, because it permits treatment of the relationship between the market and the ecological dynamics.

The steady-state behavior of the supply of the resource, $E^s = E^s(p_E)$, is generally an increasing function so that its inverse is $p_E = p_E(E)$. This equation is used to compute the solution of the model. Its variation with property rights, which was established in Lemma 1 above, is crucial for determining the patterns of trade and welfare in the world economy under different property rights regimes. The slope of the supply equation for resources, equation (A.3) in the Appendix, varies with property rights—namely the parameter α. Thus, property rights are linked with the supply of resources to the economy in a crucial way.

The general equilibrium for this North-South model is formalized as follows. Assume that the two regions are identical in most respects except property rights. The endowment of capital input, $\overline{K}$, is fixed in each region. Part of capital is used to extract E, and the remaining capital endowments, together with the extracted E, are used as inputs in the production of two goods, A and B, where B is assumed to be more intensive in the use of the environmental resources, and A is capital intensive. The production functions of A and B, where $A = f(K_A, E_A)$ and $B = g(K_B, E_B)$, are concave and constant returns to scale. The utility function, $U(A, B)$, is strictly concave, homothetic, and identical across regions. $E^s = E^s(p_E)$ was derived in the previous section from the ecological dynamics of the renewable resource interacting with the optimal economic extraction rate. To simplify the computation of the solution, E^s is assumed to have a simple form, i.e., $E^s = \alpha P_E/P_B + E^\circ$, where $\alpha > 0$ depends on the property rights regimes for E. A large α represents ill-defined property rights, such as the case of common property resources.

Utility $U(A, B)$ is maximized subject to a budget constraint at given price vector (p_E, r, P_A, p_B). Under appropriate (strict) concavity assumptions, this yields an *aggregate demand* vector for commodities, denoted (D_A, D_B) in each region.

Given price vector, the quantity of the input E supplied according to the supply functions $p_E = p_E(E)$, and the remaining K used for the production of goods, the supply of goods and the demand for inputs can be derived from input market-clearing conditions.

The *excess demand* for each region is $\Phi(p_B, r, p_E) = D(p_B, r, p_E) - S(p_B, r, p_E)$. At equilibrium, the excess demand in the world is zero. Thus, the world equilibrium price vector $(P_A^*, P_B^*, r^{*N}, P_E^{*N}, r^{*S}, P_E^{*S})$ is solved by zero excess demand condition, where superscripts indicate regions.

The difference in the property rights determines trade. As mentioned, *two* types of supply curves for the environmental common property resource are considered. One is the *private supply curve*, derived from the private marginal cost of extracting the resource, the other, the *social supply curve*, is derived from the social marginal costs of extraction, which takes account of the negative externalities that one user has on others (see Lemma 1). One supply curve for the North is considered, its social supply curve, and two for the South, both the social and the private supply curves. Using the two different curves in the South (private and social) leads to different concepts of comparative advantages and of gains from trade.

A new concept of comparative advantage must now be defined: Region S is said to have a comparative advantage in the production of good B, which is intensive in the use of the input E, when for each price p_E the supply of E relative to that of K in region S is larger than the corresponding relative supply in region N at the same time. It is necessary to differentiate between private and public comparative advantages as follows. *Private comparative advantage* in region S is defined by using the private supply curve for E in the South; *public comparative advantage* is defined by using the social supply curve for E.

Different supply curves will also give rise to different production possibility sets; these are used in the following analysis to define gains from trade. Consider at each price vector the quantity of E supplied according to the private supply curve $E = E^{\pi}(P_E)$, and the corresponding quantity of $K = K(r)$. With these two quantities of E and K, it is possible to compute all of the combinations of outputs A and B which are feasible using the production functions f and g. This set is denoted $PP^{\pi}(P)$. Taking the union for all p, the private production possibility set $PPS^{\pi} = U_p PP^{\pi}(P)$, which is assumed to be convex, is obtained. Performing the same procedure, but using the social supply curve $E = E^{\sigma}(P_E)$, yields the public production possibility set $PPS^{\sigma} = U_p PP^{\sigma}(P)$, which is also convex.

Gains from trade are defined as usual. They are given by the increase in utility $U(A, B)$ associated with a move from an equilibrium allocation in autarchy (each country in isolation) to a world equilibrium. *Public gains from trade* are computed by comparing welfare in autarchy and at a world equilibrium, with respect to the model with public production possibility sets. *Private gains from trade* are defined in the same fashion, but using the private production sets.

Since private and public supply curves are similar in the North, the North's public and private production possibility sets are also similar. Thus, private and public gains from trade are the same in the North. This is not so in the South. The weaker the property rights in the South, the larger will be the divergence between the public and private supply curves, and between the private and public production possibility sets. Therefore, the weaker the property rights in the South, the larger will be the divergence between its private and its public gains from trade.

North-South Trade and the Dynamics of Renewable Resources

The next step is to integrate all of this information into a coherent whole. The following result analyzes the properties of the market equilibria of the North-South model, and uses Lemma 1's results on the long-run behavior of resources with different property rights regimes.

In order to emphasize the role of property rights, we can assume that both countries are entirely symmetric except for property rights. Therefore, both have the same endowment of capital, which is used either as an input to the extraction of resources E with the identical technology, or as an input, together with E, for the production of two internationally tradable goods. The technologies of the production are identical, and the utility $U(A, B)$ is identical across countries as well.

According to the Heckscher-Ohlin model, these countries have no motive for trade: autarky should prevail. Indeed, if private property regimes would hold in both countries, these two regions will not trade. The autarkic solution is a Pareto-efficient world equilibrium.

Now consider the differences in property rights across the regions. Even though both countries extract E using K and the same technology, as shown in Lemma 1, for any given market price, the quantity extracted in a steady state will be higher in the South, which has ill-defined property rights. This introduces an illusory difference between the countries, with the South appearing to have more abundant resource supplies than the North. Hence, the two countries trade.

It is possible to compute the level of trade and prices by considering another world economy identical to this—without considering property rights, but taking into account that the South (for whatever reason) has a different supply function for E than the North. Indeed, the South has a more price-responsive or "flatter" supply curve for E than does the North, as established in Lemma 1. An interesting and useful property of the North-South model which was developed in Chichilnisky (1993) is the existence of a single equation, called the "resolving equation," which depends on all the exogenous parameters of the model and from which the equilibrium values of the terms of trade P_B^* can be computed. Once this value P_B^* is known, all other endogenous variables of the model can be computed from it. This resolving equation, which has been used previously to carry out detailed comparative static exercises explicitly and rigorously in the North-South model, allows us to carry out comparative dynamics as well, since one of the parameters relates to the long-run dynamic behavior of stock in the resource as a function of the property rights.

THEOREM 1. Assume that the North and the South have the same technologies, preferences, and natural endowment of environmental inputs. If the South has ill-defined property rights for the environmental input, then at a world equilibrium, the South will export environmentally-intensive goods. The South will exhibit private gains from trade, but in a steady state it extracts more environmental resources, and it produces and exports more environmentally-intensive goods (B) than is Pareto efficient.

Proof. Recall that the two regions are identical, but because of the differences in property rights, the South's supply of E is given by the private supply curve $E^{\pi}(P_E)$ while the North's is its social supply $E^{\sigma}(P_E)$. Consider at world equilibrium prices, p_A^* and p_B^*; the corresponding factor prices, p_E^* and r^*, are the same in both regions because the two regions have the same technologies. From Lemma 1 above, the South supplies more environmental resources than does the North at the same prices; hence, the South produces a larger amount of the traded good B than does the North. Intuitively, this is a consequence of the fact that B is intensive in the input E, which is more "abundant" in the South. Since this theorem assumes that the two regions have the same homothetic utilities, and the two regions face the same relative prices for goods A and B, the North and the South demand goods A and B in the same proportions. Since, in equilibrium, the supply of B in the South is proportionately larger when the international markets clear, the South must export B and the North must import B; that is, the South is an exporter of environmentally-intensive goods.

Since the two countries are identical except for property rights, when the two have well-defined property rights, they do not trade (autarky). By the first welfare theorem, the private property competitive equilibrium is Pareto efficient. Moving from autarky to trade increases the equilibrium price of B, and hence E increases in the South, which implies that the South produces more than Pareto efficiency requires. □

Note that the environmental overuse described in Theorem 1 is induced by a competitive market response to the lack of property rights in the South.

COROLLARY 1. *If exports of the environmentally-intensive good B by the South lead to the equalization of the price of environmental resources used as inputs in the two regions, the South will still use more environmental resources than the North (and more than is Pareto optimal) unless property rights for the common property resources are improved in the South. If property rights are not improved in the South, then the exports of environmentally-intensive goods and their domestic production would have to be curtailed in order to achieve patterns of consumption which duplicate the social optimum.*

This follows directly from Theorem 1 and Lemma 1. The significance of this corollary is to emphasize that the overuse of environmental resources by the South is not necessarily caused by prices being lower in the South than in the North, as it is often thought. Equalizing prices through the international market will not resolve the problem of overuse of environmental resources.

Conclusions

It has been shown that different property rights regimes for environmental resources can account for the pattern of trade between the North and the South. The South exports environmentally-intensive goods, even if it is not well endowed with them. Improving the property rights will lead to higher prices for the environmental inputs, lower extraction and exports by the South, and lower consumption by the North. All in all, property rights improvements in the South could check the main economic source of overuse: prices which are below social costs.

Similar examples hold for land resources. Recently, the government of Ecuador allocated a piece of the Amazon (the size of the state of Connecticut) to its Indian population, a clear property rights policy. Under the conditions of our theorem, this policy should lead to a better use of the forests' resources and to a more balanced pattern of trade between Ecuador and the U.S. Jose Maria Cabascango, the representative of the Indigenous Nationalities of Ecuador (which comprises about two million people), has expressed their resistance to the overuse of the Amazon for oil exploitation, or for growing cash crops for the international market.

Property rights may change slowly, however, because they require expensive legal infrastructure and enforcement. Poor countries may find themselves unable to accommodate such policies quickly. But the improvement of property rights for indigenous populations in developing countries, which comprise most of the world's population, certainly should be considered a major policy goal. This represents a small but apparently growing trend in Brazil, Bolivia, Colombia, Ecuador, the French Guyana, and Venezuela. Support from international organizations in establishing legal frameworks and enforcing the rights of indigenous populations should be more desirable. Conversely, any policy designed to remove the rights of locals and increase the land available for cash crops oriented solely to the export market should be suspect. Indeed, recent studies show that 90 percent of the tropical deforestation occurs with the purpose of transforming forests for agricultural use, much of it for cash crops for the international market (Amelung 1991; Barbier, Burger, and Markandya 1991; Binkley and Vincent 1990; Hyde and Newman 1991). The World Bank's emphasis on exports of agricultural cash crops as a foundation for development is, in this light, contradicting the North's stated desire to preserve global environmental assets. Such policy contradictions should be resolved immediately, since they lead to an enormous and dangerous waste of resources.

It seems worth noting that environmental overuse in the South does not occur solely because the locals overconsume their resources, but because they export these resources to a rich international market at prices which are below social costs. This is why the global environmental issue is inextricably connected with North-South trade. The South overproduces, but primarily because the North overconsumes. The international market transmits and enlarges the externalities of the global commons. No policy which ignores this connection can work.

Appendix

The Equilibrium Solution of the North-South Model

Factor endowments in the two regions are variable, depending on factor prices. Taking the South as an example: The fixed endowment of capital $\bar{K}$ is used in the extraction of E^s and in goods production. Hence,

$K^E < \bar{K}$, and the supply of capital for the production of goods A and B is $K^s = \bar{K} - K^E$. By a fixed-proportions technology in each sector, efficient production plans satisfy $B^s = E^B/a_1 = K^B/c_1$, and $A^s = E^A/a_2 = K^A/c_2$, where the superscript s denotes supply. Recall that $E^A + E^B = E^s$ varies with prices, and so does $K^A + K^B = K^s = \bar{K} - K^E$.

Assume that B is more resource intensive when compared to A, so that $D = (a_1c_2 - a_2c_1) > 0$. Equations (A.1) and (A.2) define an equilibrium:

$$P_A = a_1 p_E + c_1 r, \tag{A.1}$$

and

$$P_B = a_2 p_E + c_r, \tag{A.2}$$

where P_A and P_B are the prices of A and B, respectively, p_E is the price of the resource, and r is the rental on capital. As shown in the text, the environmental resource E supplied in equilibrium E^s is an increasing function of P_E for any given $q = r$. To simplify the computation of solutions, let

$$E^s = \alpha p_E / p_B + E^o, \tag{A.3}$$

where $\alpha > 0$ depends on the property rights regimes for E. A large α represents ill-defined property rights, such as the case of common property resources. The parameter α can vary as a continuum, indicating a variety of "shades" of property rights between the two extreme cases. Because of Lemma 1, the less the externalities which one harvester produces for others are internalized, the larger will be the slope of E^s, α. Similarly,

$$K^s = \bar{K} - K^E, \text{ so that } K^s = \beta r + \bar{K}, \text{ for some } \beta > 0, \tag{A.4}$$

indicating that when the opportunity cost of capital r is higher, less capital is used in extracting E, and K^E is lower (as shown in Lemma 1); therefore, more capital K^s is available for the production of goods A and B. For a given property rights regime, factor supplies vary with factor prices, so that *the overall production possibility frontier exhibits substitution in the total use of capital and environmental resources.* In equilibrium, all markets clear. Since the economies are identical except for property rights, there are nine exogenous parameters: a_1, a_2, c_1, c_2, β, $\bar{K}$, E^o, and $\alpha(N)$ and $\alpha(S)$. After adding a price-normalization condition, a total of twenty-six independent equations is obtained. There are twenty-eight endogenous variables, fourteen for each region: p_A, p_B, p_E, r, E^s, E^d, K^s, K^d, A^s, A^d, B^s, B^d, X_B^d, so the system is underdetermined so far up to two variables, which reflects the fact that demand has not yet been specified.

We consider a demand specification which allows us to obtain the simple analytic forms:

$$U(A, B) = B + k, \text{ if } A \geq A^{d*}, k > 0, \text{ and}$$
$$U(A, B) = B + \gamma A \text{ otherwise}, \gamma = -k/A^{d*} < 0.$$

Then for $p_B > 1/\gamma$, agents demand A^{d*}, thereby choosing k and γ in U appropriately.

Thus, we have a system of twenty-eight equations on twenty-eight variables, depending on nine exogenous parameters. The economies of the two regions are identical except for the parameters $\alpha(N)$ and $\alpha(S)$, which depend on the property rights for the common property resource in each region.

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Environment, Welfare and Gains from Trade: A North-South Model in General Equilibrium

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Introduction

Environmental effects on welfare and gains from North-South trade are modeled by adapting the traditional Heckscher-Ohlin framework to account for pollution generated from production and affecting health and utility. As incomes grow, a greater proportion of income is spent on health including expenditures to mitigate environmental effects. Expenditures on health range from a high of 12 percent of gross national product in the U.S. to an average of about 4 percent in developing countries (World Bank 1993). Based on data from 25 countries, Gertler and van der Gaag (1990) estimate that health care expenditures rise by about 1.32 percent for every one percent increase in a country's gross national product. Consequently, health has become an important impetus for environmental protection in wealthy countries, as trade disputes between U.S. and Mexico over phyto-sanitary standards (Robert and Orden 1995), and the EC's ban on beef imports from the U.S. and other developing countries containing growth hormones (Runge and Nolan 1990) suggest. Agricultural pollutants that enter the food chain have received considerable attention in the U.S. (Caswell 1991). U.S. epidemiological evidence suggests that 2-3 percent of all cancers associated with environmental pollution occur from exposure to pesticide residues on food stuffs. Emissions of particulates are suspected of causing 20,000 to 30,000 premature deaths each year in the U.S. (Chivian 1993). High levels of morbidity and shortened life expectancies in developing countries have direct environmental linkages. The World Bank