Trade, migration, and environment: a general equilibrium analysis, Chapter 2.3

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2.3. Trade, Migration, and Environment: A General Equilibrium Analysis*

1. Introduction

Two major trends in the world economy are international migration and environmental degradation. The object of the paper is to analyze the connection between these two trends, which have generally been analyzed in isolation. Here we represent a world economy in which the exploitation of natural resources as well as the migration of labor have a global character. We discuss the welfare impact of migration and exploitation of natural resources and policies to address these issues.

Industrial development has reached a point where it adversely affects the natural environment. A large share of the world population could be harmed by the instability of the global climate caused by increased concentration of CO_2 in the atmosphere. The destruction of biodiversity on the planet has reached unprecedented proportions. Although these are world phenomena, Chichilnisky (1994) showed that environmental degradation can also be considered as a North-South issue. The international market is the vehicle through which the overproduction of natural resources by the South is reconciled with the overconsumption by the North. At the heart of this explanation there is the crucial role played by the different regimes of property rights prevailing in the resource extraction of the two regions.

Another world-wide phenomenon, the migration of labor, has recently intensified. Large migrant flows from Latin America to the USA and from North Africa and Middle East to Europe take place today. The collapse of the socialist economies in Eastern Europe has led to massive migration into the industrialized part of Europe.

Not surprisingly, governments and international organizations are concerned with these developments. Migrant labor has profound consequences

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not only on the host countries but also on the countries of origin. Besides social and political effects, the change in the availability of labor affects the employment structure and the distribution of income of the countries involved. Environmental damage can lead to disruptions of entire populations such as those caused by scarcity of water.

Migration is typically linked to wage and income differentials. Moreover, there is now evidence (e.g. Myers, 1993) that migration is particularly sensitive to the degradation of the environment and to the effects of climate change. Migrant flows are typically from the South to the North, since climate changes affect more the primary sector of the economy which is the basis of Southern economy. In addition developing countries have fewest (technical as well as economic) resources to confront the problem. It is also believed that environmental refugees, as they could aptly be called (Myers, 1993), are the result of tropical deforestation, soil erosion and desertification that occur in many areas of the South. Chichilnisky (1994) showed how all these phenomena are directly connected to trade and to the poor definition of property rights in the South.

Migration patterns reallocate production in the North and South economies, induce a change in trade patterns, and a modification of relative prices.

We develop a framework which follows Chichilnisky (1981, 1994), possessing the same logical structure as the Heckscher–Ohlin model that highlights the connection between labor migration and exploitation of natural resources. From our analysis we obtain answers to the following questions:

1. how does migration affect the exploitation of natural resources?
2. how do policies to check environmental degradation interact with migration flows?
3. how do trade policies affect migration flows and the exploitation of natural resources?

The main results of the paper are as follows. Migration is prompted by wage differentials as technology is different across countries. We show that migration from the South induces a decrease in the exploitation of the resource in the South. This increases the welfare of the South but can decrease that of the North. Migration can lead to higher prices of resources in the North and in the South, setting up a process of induced technical change in the North and better terms of trade for the South, altogether a positive outcome. As is intuitively obvious, migration reduces the wage differential between North and South in a model where, contrary to Heckscher–Ohlin assumptions, technologies differ between countries. Finally, we show that it is possible that a tax on the use of the resource in the South induces an increase in its extraction rather than a decrease. Trade policies could have a positive impact on resource extraction, could reduce the wage gap and therefore decrease the economic incentive to the mobility of labour.

The paper is organized as follows. Section 2 presents the basic model. Section 3 extends it to cover the case of migration and proves the main results

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2.1. *One Region Model*

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$$P_E = \frac{c_2 P_B - c_1}{D},$$

$$w = \frac{a_1 - a_2 P_B}{D},$$

on the effects of migration on the exploitation of the resource and the welfare of the South. Section 4 examines the tendency towards real wage equalization. Section 5 argues that tax policies on the use of the resource are unreliable in that they can have effects opposite from what is intended. Finally, we discuss how traditional trade policies could affect the degree of factor mobility and the exploitation of resources.

2. The Model

There are two regions, the industrialized countries (North) and the developing countries (South), two goods A and B and two factors. The formulation follows Chichilnisky (1981, 1994). The inputs are an environmental resource E and labor L, that are used to produce the two goods. In both regions the B good is more resource intensive than A. Constant returns to scale and fixed coefficients are assumed in the production of each good. Technology is different in the two countries:[1] there are four technical coefficients, $c_i(a_i)$, representing the quantity of labor (environmental resource) per unit of output of good i. Endowments of labor and environmental resource are not fixed but depend on relative rewards. Therefore, even if there are fixed coefficients in production, there is substitutability among factors in the economy as a whole as relative prices change.[2]

2.1. *One Region Model*

Consider first the economy of the South. Perfect competition in the goods market and constant returns to scale imply zero profits in equilibrium so that:

$$P_B = a_1 P_E + c_1 w, \tag{1}$$

$$P_A = a_2 P_E + c_2 w, \tag{2}$$

where P_A (respectively P_B) is the price of good A (B), $P_E(w)$ is the price of the environmental resource (labor), $a_i(c_i)$ $(i = 1, 2)$ are the coefficients of the environmental resource (labor) respectively in industry 1 (B) and 2 (A).

The assumption that B is more intensive in the use of the resource than A translates into a positive value for $\mathsf{D} \equiv \mathsf{a}_1\mathsf{c}_2 - \mathsf{a}_2\mathsf{c}_1$. For future reference we derive the relation between P_B and the wage, w, and P_B and P_E, the price of the resource.

From Equations (1) and (2) we obtain:

$$P_E = \frac{c_2 P_B - c_1}{D},$$

$$w = \frac{a_1 - a_2 P_B}{D},$$

and, therefore,

$$\frac{\partial(P_E/P_B)}{\partial P_B} = \frac{c_1 P_B^{-2}}{D},$$

$$\frac{\partial(w/P_B)}{\partial P_B} = \frac{-a_1 P_B^{-2}}{D}.$$

Labor and resource supplied are a function of their rewards. The labor supply depends positively on the real wage w/P_B according to the following:

$$L^S = \beta w/P_B + L_0, \tag{3}$$

where β and L_0 are positive.

For simplicity, we assume that the resource is extracted using labor as the only input and according to a strictly concave production function, $E = E(N)$. It was shown recently (Chichilnisky, 1994)[3] that under these circumstances the amount of resource supplied is an increasing function of the price of the resource and that the precise form of the supply curve depends on the prevailing structure of property rights. We will assume that the South has common property (in particular open access) regimes for the pools from which the resource is extracted.

To solve the model we need to know the relative price of the resource with respect to labor. However, there is no developed labor market in the extraction sector of the South that we label the subsistence sector of the economy: hence there is no market wage. We need to define the opportunity cost of labor. Let us denote this opportunity cost by q and let us assume for the moment that it is a given quantity, equal for each worker. Later in the paper we will derive an expression for q in a general equilibrium fashion.

How is the opportunity cost q connected with the level of resource extraction? Following Chichilnisky (1994) a level of effort is chosen by the typical worker in such a way that q equals the common property marginal product of labor times the market price of the resource. The common property marginal product (CMP) is the change in the average yield that a typical worker i obtains as (s)he supplies one more unit of effort in a situation where the ownership of the pool is not restricted. We can express the relation that holds in the optimal situation as

$$P_E \cdot \mathrm{CMP} = q,$$

As the price of the resource P_E increases the optimal level of effort increases, given the assumption of strict concavity of the production function and the constancy of q. As a result the quantity supplied of the resource goes up as its price P_E increases.

These considerations give rise to a supply curve of the natural resource in the South that depends positively on its price P_E, for any given q. Note how property rights matter. If there were well defined private property rights in the South, then the supply curve w
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$$E^S = \alpha P_E/q + E_0,$$

where E_0 and $\alpha > 0$.

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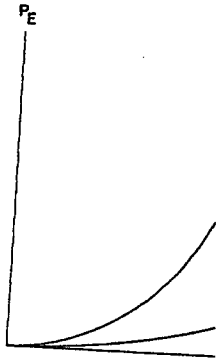

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The demand equations for the resour

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$$L^D = c_1 B^S + c_2 A^S,$$

where B^S (A^S) is the supply of the B
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$$L^D = L^S,$$

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The South exports the resource inte
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South, then the supply curve would have been steeper, as in this case q/P_E equals the private property marginal product which is lower than the CMP.[4]

This argument leads us to postulate a supply function of the resource (which is assumed to be linear for simplicity):

$$E^S = \alpha P_E/q + E_0, \tag{4}$$

where E_0 and $\alpha > 0$.

The parameter α is large when there is common property for the resource (as it is the case with the South) since it reflects the greater sensitivity of the supply of E to its price in comparison to the case where property rights are well defined.[5] In the model a large value for α formalizes the so-called "tragedy of the commons" which is known to lead to an exploitation of the resource which is larger than the one occurring with a private property regime.

The situation is summarized in the following diagram, where E_C^S is the common property supply curve and E_P^S the private property supply curve:

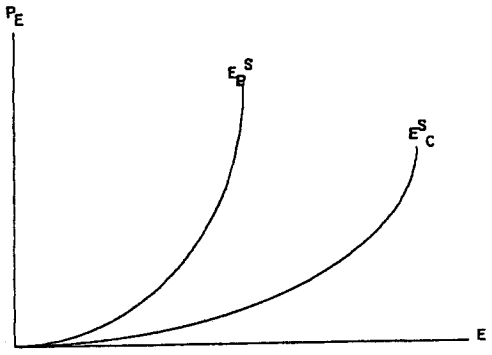

Diagram 1

The demand equations for the resources, E^D and L^D, are:

$$E^D = a_1 B^S + a_2 A^S, \tag{5}$$

$$L^D = c_1 B^S + c_2 A^S, \tag{6}$$

where B^S (A^S) is the supply of the B (A) commodity respectively.

In equilibrium demand for resources equals supply so that:

$$L^D = L^S, \tag{7}$$

$$E^D = E^S. \tag{8}$$

The South exports the resource intensive good, B and imports A. Indeed it has been shown (Chichilnisky, 1994) that when the two countries have identical technology and preferences, a sufficient reason for them to engage in trade is the difference in the property rights regime of the natural resource that is used as an input of production. In particular the South has an apparent

comparative advantage in, and exports, the resource intensive good. The South exports good B, even if North and South share similar technology and preferences.

In the context of the present, more general model, where technologies and preferences may differ among countries, the assumed pattern of trade can always be sustained by a suitable choice of the value of the demand for the A good in the two countries, as it is apparent from inspection of diagram 2 below.

Exports of the South equal the difference between domestic supply and demand, namely:

$$X_B^S = B^S - B^D, \tag{9}$$

whereas imports of commodity A equal the difference between demand and domestic supply, namely:

$$X_A^D = A^D - A^S, \tag{10}$$

where A^D (B^D) is the demand for the A (B) good.

We assume that trade balances:

$$P_B X_B^S = P_A X_A^D. \tag{11}$$

2.2. *Two Region Model*

Equations for the North are similar except for different values of the parameters and of the exogenous variables, reflecting different technologies, preferences and property right regime. In the North it is possible that labor supply responds little to the real wage.[6] Property rights for the resources are well defined in the North so that the supply curve for the North is steeper reflecting the private property marginal product.

In Equation (4) we approximate q, the opportunity cost of labor, by P_B for the South where subsistence labor is employed in the extraction sector.[7] For the North we approximate q by P_A as there is no subsistence sector in the North. Equation (4) now reads for the South:

$$E^s = \alpha P_E / P_B + E_0$$

and for the North:

$$E^s(N) = \alpha_N P_E / P_A + E_0(N).$$

The North imports the resource intensive good B and exports the (skilled) labor intensive good A.

There are other self explanatory conditions to be fulfilled in an international equilibrium:

$$P_A(S) = P_A(N), \tag{12}$$

$$P_B(S) = P_B(N), \tag{13}$$

$$X_B^S(S) = X_B^D(N$$

$$X_A^D(S) = X_A^S(N$$

Finally, we choose the nu

$$P_A = 1.$$

To close the model we but we could equally con results:[9]

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It turns out that the mo it reduces to a quadratic e from the equilibrium con

$$A_0^D(S) + A_0^D(N$$

and using Equations (1–8

$$[A(N)]\, P_B^2 +$$

$$-$$

where

$$A(N) = \alpha_N(c_1$$

$$C(S) = (1/D)$$

$$C(N) = (1/D)$$

$$V(S) = \beta a_1^2 / I$$

$$V(N) = \beta_N(a_1^2$$

Equation (19) has one and the quadratic is posit

Once the terms of trad be computed (Chichilnis complete.

$$X_B^S(S) = X_B^D(N), \tag{14}$$

$$X_A^D(S) = X_A^S(N). \tag{15}$$

Finally, we choose the numeraire:

$$P_A = 1. \tag{16}$$

To close the model we follow the original Chichilnisky's model (1981)[8] but we could equally consider other assumptions which would lead to similar results:[9]

$$A^D(S) = A_0^D(S), \tag{17}$$

$$A^D(N) = A_0^D(N). \tag{18}$$

The model is composed of 12 equations for the South ((1–11) and (17)) plus 12 analogous equations for the North (denoted (1'–11') and (18)) plus (12), (13), (15) and (16). Indeed, Equation (14) is always satisfied when trade is balanced and (12), (13), and (14) hold. There are 28 endogenous variables, 14 in each region: P_B, P_A, w, P_E, L^S, L^D, E^S, E^D, B^S, B^D, A^S, A^D, X_B^S, X_A^D.[10]

It turns out that the model can be solved analytically in a very simple way: it reduces to a quadratic equation in the Southern terms of trade, P_B. Starting from the equilibrium condition in the world market for the A good

$$A_0^D(S) + A_0^D(N) = A^S(S) + A^S(N)$$

and using Equations (1–8) we obtain:

$$[A(N)]\,P_B^2 + \left[A_0^D(S) + A_0^D(N) + C(S) + C(N)\right] P_B - [V(S) + V(N)] = 0, \tag{19}$$

where

$$\begin{aligned}
A(N) &= \alpha_N (c_1 c_2)_N / D_N^2, \\
C(S) &= (1/D)[c_1 E_0 - a_1 L_0 + (a_1 a_2 \beta + c_1 c_2 \alpha)/D], \\
C(N) &= (1/D)_N [(c_1 E_0 - a_1 L_0)_N + (a_1 a_2 \beta - c_1^2 \alpha)_N / D_N], \\
V(S) &= \beta a_1^2 / D^2 + \alpha c_1^2 / D^2, \\
V(N) &= \beta_N (a_1^2)_N / D_N^2.
\end{aligned}$$

Equation (19) has one positive solution since the constant term is negative and the quadratic is positive.

Once the terms of trade are known all the other endogenous variables can be computed (Chichilnisky, 1981). The solution of the model is, therefore, complete.

The market for the A good can be illustrated in the following diagram, where the continuous line indicates the equilibrium level of the terms of trade at which the Southern demand for exports equals the Northern supply of exports:

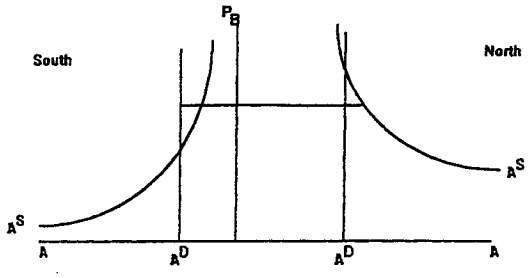

Diagram 2

2.3. *The Opportunity Cost of Labor in the Subsistence Sector*

Typically, the opportunity cost of labor, q is equal to the wage but in the South there is no formal labor market in the subsistence sector. Therefore, in the following we will derive an endogenous value for q in a general equilibrium fashion, following (Chichilnisky, 1994).

We assume that the typical worker maximizes a utility function $U = U(A, N_0 - N)$ depending on the consumption of good A and on leisure, $N_0 - N$, subject to the following constraint: $P_A A = P_E E(N)$, where E has already been defined in Section 2.1, and N_0 is the total available amount of time. In the preferred situation it is true for the typical worker that:

$$\frac{\partial U/\partial(N_0 - N)}{\partial U/\partial A} = \frac{P_E(\partial E/\partial N)}{P_A}.$$

Previously we have shown (in Section 2.1) that q must be equal to the value of the common property marginal product; since in our North-South model $P_A = 1$, it follows that:

$$\frac{\partial U/\partial(N_0 - N)}{\partial U/\partial A} = q.$$

So q, which is a function of P_E/P_A, is the ratio of the marginal utilities of the typical worker. This fully defines an endogenous value for q, once P_B is known. From the latter we can compute P_E using Equations (1) and (2).

The next step is to show that as the price of the resource which the typical worker sells goes down, (s)he has to work more and not less to secure a minimum level of subsistence when the price of consumption goods has increased (in relative terms). Hence our next step is to ascertain what happens to the worker's choice of leisure and good A when (s)he is confronted with a different price of the resource and we allow the opportunity cost q to change.

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For this purpose only, we assume that the utility function U has an elasticity of substitution between leisure and A less than one.[11] In this case an increase in the relative price of A implies a reduction in the leisure consumed or, which is the same thing, an increase in the supply of effort. Hence we establish:

PROPOSITION 1. *If the elasticity of substitution between leisure and consumption is less than one, a worker in the subsistence sector who maximizes* $U = U(A, N_0 - N)$ *subject to* $P_A A = P_E E(N)$, *increases his (her) effort when the price of resource* E *decreases vis-à-vis the price of good* A.

Proof. The supply curve E^S we derived (Equation (4)) was parameterized by q. As P_E/P_A decreases, the quantity of effort increases and with it the supply of the resource. By the strict concavity of the production function, also $(\partial E/\partial N)$ decreases so that q has to decrease as well. In terms of our supply curve for the resource this means that such a curve shifts downwards signalling in equilibrium a higher supply of the resource as P_E/P_A decreases, once changes in q are taken into account. □

A geometrical explanation of the result is provided in the Appendix.

3. Why Does Labor Migrate?

Since technologies are different across countries factor prices are not equalized after trade, as the Heckscher–Ohlin theory (which is based on the assumption of equal technologies) asserts.[12] Indeed real wages are equal across countries only when the terms of trade take on a particular value, P_B^M, given by the following expression:

$$\frac{(a_1/D)_N - a_1/D}{(a_2/D)_N - a_2/D} \equiv P_B^M. \tag{20}$$

The value in this expression depends exclusively on technological parameters so that only by a coincidence does it equal the equilibrium terms of trade that reflects the solution of the general equilibrium model. In addition the value of the terms of trade given by (20) could be such as to entail a negative value for the equalized real wage.

A similar argument applies for the price of the resource, which in general is not equalized either. We can show that to have an equalized price for the resource E, the terms of trade should take on a value, P_B^F, given by the following expression:

$$\frac{(c_1/D)_N - c_1/D}{(c_2/D)_N - c_2/D} \equiv P_B^F. \tag{21}$$

While in equilibrium either (20) or (21) could occur by coincidence, both cannot occur at the same time, as it is clear by comparing them: hence

simultaneous equalization of real wages and resource price across countries is ruled out.

If real wages are different across countries there is an incentive for workers to move from the low wage to the high wage region.[13] We can easily establish under which conditions labor moves to the North (South). As every endogenous variable can be computed when the terms of trade are determined, we know that $w/P_B < (>)(w/P_B)_N$ implies:

$$\left[\left(\frac{a_2}{D}\right)_N - \frac{a_2}{D}\right] P_B < (>) \left(\frac{a_1}{D}\right)_N - \frac{a_1}{D}.$$

Let us make the following by now standard[14]

ASSUMPTION 1. *In the South technologies are dual.*

By dual technologies in the South we mean that the B sector is much more resource intensive than in the North. This can be translated into the model by assuming a much larger value for D with respect to D_N (see the definition of D in Section 2.1). If then $D \gg D_N$ then we can establish that labor leaves the South whenever

$$P_B < \frac{(a_1/D)_N - (a_1/D)}{(a_2/D)_N - (a_2/D)} \equiv P_B^M.$$

In a similar way we can establish (under the same conditions) that the price of the resource is lower in the South than in the North whenever

$$P_B > \frac{(c_1/D)_N - (c_1/D)}{(c_2/D)_N - (c_1/D)} \equiv P_B^F.$$

In addition to the real wage gap, other factors have recently been highlighted in the migration phenomenon. In particular there is evidence (Myers, 1993) that among the consequences of environmental damage is the fact that people move away from their homes. It is also believed that environmental refugees are due to tropical deforestation, soil erosion and desertification.

It is because migration is such a complex phenomenon that at first we do not intend to establish a strict, quantitative relation between the number of workers who migrate and the real wages gap in the two countries. Though we maintain that, among economic factors, real wages differential is a major force in shaping labor migration, at this stage our analysis can accommodate the case where (at least part of) migration occurs for environmental motivations.

In order to accommodate the analysis of migration in our framework we simply reinterpret the equilibrium described in the model of the previous section as an equilibrium occurring in an interval of time within which migration is not allowed.[15] At the end of each period workers check whether real wages are higher in the North than in the South and decide to move towards the higher wage country.

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4. The Effects of Migrat
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We can now establish th

PROPOSITION 2. *If Assu*
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Proof. Using Equation (

$$\frac{\partial P_B}{\partial L_0} = \frac{}{2P_B\,[A(N$$

$$\frac{\partial P_B}{\partial L_0(N)} = \frac{}{2P_B\,[A(N$$

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The number of workers who at the junction between one period and another leave any one country can be represented in the model as a change in L_0. If workers leave the South (North) it will be a fall (increase) in L_0 for the South and an increase (fall) of $L_0(N)$ in the North of exactly the same amount. Then a new equilibrium is reached within the second period at the end of which the story repeats itself.

4. The Effects of Migration on Wage Differential and Resource Extraction

Let us now suppose, quite reasonably, that real wages are lower in the South than in the North so that workers move from the South to the North. In our model this is captured by an increase in $L_0(N)$ and a fall in L_0 of exactly the same magnitude.

We can now establish the following

PROPOSITION 2. *If Assumption 1 holds, migration from the South to the North is associated with a higher level of the South's terms of trade.*

Proof. Using Equation (24) and the implicit function theorem we compute:

$$\frac{\partial P_B}{\partial L_0} = \frac{[a_1/D]\, P_B}{2P_B\,[A(N)] + [A_0^D(S) + A_0^D(N) + C(S) + C(N)]},$$

$$\frac{\partial P_B}{\partial L_0(N)} = \frac{[(a_1/D)_N]\, P_B}{2P_B\,[A(N)] + [A_0^D(S) + A_0^D(N) + C(S) + C(N)]}. \quad (22)$$

In the denominator when α is large in the South the sign of the term in α determines the sign of $C(S)$ and $C(N)$. Since the term in α in $C(S)$ is $c_1c_2\alpha$, a positive quantity, the denominator is positive in this case. If Assumption 1 holds, then the numerator of the second expression is larger in absolute value than the numerator of the first and the net effect will be dominated by the Northern component. As a consequence of the assumed changes in L_0, the change in the terms of trade will be positive. □

The intuitive economic explanation of the above result is as follows. An increase in $L_0(N)$ and a fall in $L_0(S)$ means that for any level of the terms of trade the supply of labor is larger in the North and smaller in the South. This triggers a shift in the production mix in each country, the North increasing the production of A (at the expense of B), the South the production of the resource intensive good B (at the expense of A). Take the market for the A good: if the fall in production in the South is smaller than the increase in the North, then the terms of trade of the South increase. This happens precisely

when, according to our terminology, technologies are dual in the South (using Equations (5–8)):

$$\frac{\partial A^S(S)}{\partial L^S(S)} = \frac{a_1}{D} < \left(\frac{a_1}{D}\right)_N = \frac{\partial A^S(N)}{\partial L^S(N)}.$$

The situation is illustrated in the diagram below where P'_B is the new level of the terms of trade and A'^S is the level of supply of A after migration.

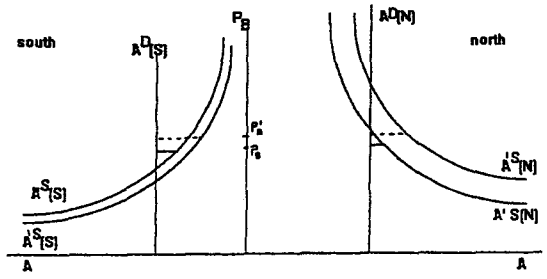

Diagram 3

To proceed with our analysis we need to determine whether the wage differential decreases after migration. When workers leave the South the terms of trade are lower than the level at which real wages are equalized. Since as a consequence of migration flows, the terms of trade increase, it is clear that the gap in the terms of trade will be lower:

PROPOSITION 3. *When Assumption 1 holds, migration will reduce the wage differential.*

Proof. When Assumption 1 holds, workers leave the South whenever $P_B < P_B^M$. As a consequence of migration from the South terms of trade increase. Ergo the gap in the terms of trade reduces. On the other hand, from the comparison of Equations (1) and (2) with the corresponding Northern equations, an increase in the terms of trade will induce a fall in the Southern real wage which is less than the fall in the Northern, if Assumption 1 holds. Therefore, there is a tendency towards wage rates equalization. A similar argument holds when real wages are higher in the South than in the North, namely when $P_B > P_B^M$. □

The situation[16] is illustrated in diagram 4 where the different slopes of the two curves depends on Assumption 1, namely on the large value of D with respect to D_N:

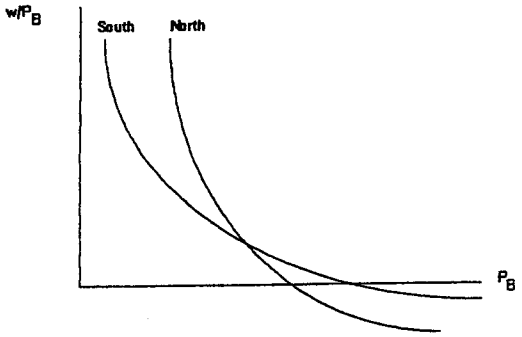

Diagram 4

The next point is to explore the impact of migration on the resources. We wish to determine whether differences in P_E across countries *increase*.

The outcome depends on the sign of the differential gap before migration has taken place. We have established that after migration from the South, the terms of trade rise. This in turn will increase P_E as is clear from Equations (1) and (2). In particular the price of the resource will increase more in the North than in the South, if Assumption 1 holds, thus increasing the difference in prices between the North and the South. Only if before migration the price of the resource were lower in the North than in the South, would migration result in reducing the differential in the resource price. In other words, if the equilibrium terms of trade are such that at the same time $P_B < P_B^M$ and $P_B < P_B^F$, then labor migration will induce a reduction in both the labor and the resource prices gaps.[17]

From the policy point of view the effects of a yawning gap between the price of the resource across regions could be to foster more direct investment from the North to exploit the lower level of the resource price in the South; secondly it could set up a process of induced technical progress in the North. These developments are not dealt with here and deserve further analysis.

The final point in this section is to examine the effects of migration on the exploitation of resources. What will be the general equilibrium effects of the migration pattern?

When migration takes place from South to North a new equilibrium is established with a higher level of the terms of trade. In turn this implies a new level for the price of the resource and a new value for the opportunity cost of labor employed in the subsistence sector to extract the resource. As a result the quantity supplied of the resource will change. In which direction it changes can be inferred by making use of a result already established (Proposition 1). It was shown there that as the price of the resource increases, the typical worker in the subsistence sector will supply less effort and therefore less of the resource will be extracted. Since after migration the terms of trade increase and, as is clear from Equations (1) and (2), the price of the resource increases as well, it follows:

PROPOSITION 4. *After migration from the South to the North, if Assumption 1 holds, the new equilibrium is characterized by a higher level of the resource price and a yawning gap in resources prices in the North and the South, potentially leading to induced technical change in the North. If the elasticity of substitution between leisure and the consumption good is less than one for the subsistence worker, this leads to a higher opportunity cost of subsistence labor in the South. At this new equilibrium the worker applies less effort and less resource is extracted in the South.*

Proof. This is a corollary of Propositions 1 and 2. From Proposition 2 migration from the South will increase the terms of trade. From Equations (1) and (2) the increase in the terms of trade will increase the price of the resource (relative to P_A). This, via Proposition 1, induces an increase in leisure and, therefore, a fall in effort of the typical worker and a decrease in the exploitation of the resource. □

5. The Effects of Migration on Welfare

We finally consider the effects on the welfare of the two countries. Since the quantity consumed of the A good is given in each country, one has to look at the response of the demand for the B good (when terms of trade change) to analyze welfare improvements. Indeed if, following migration, the demand for basic goods increases in the South, then South's welfare increases. To show this, first we recall that exports are the difference between domestic supply and demand. Secondly, we notice that the supply of B depends positively on its price, P_B. If we can show that exports fall when the terms of trade increase, then it is clear that demand has to increase.

PROPOSITION 5. *Migration of labor from the South to the North increases the South's welfare, if Assumption 1 holds.*

Proof. From

$$X_B^S = B^S - B^D$$

using (5) and (6) and Walras' Law, we get

$$X_B^S = (c_2E - a_2L)/D - (P_EE + wL - A_0^D)/P_B.$$

This reduces to

$$\begin{aligned} X_B^S &= \alpha c_1c_2/D^2P_B - \alpha c_1^2/D^2P_B^2 + P_B^{-1} \\ &\quad \times [E_0c_1/D - L_0a_1/D + A_0^D - \beta a_1^2/D^2P_B + \beta a_1a_2/D^2]. \end{aligned}$$

If we differentiate with respect to P_B we get

$$\begin{aligned} \partial X_B^S/\partial P_B &= (\alpha/D^2P_B^2)[-c_1c_2 + 2c_1^2P_B^{-1}] - P_B^{-2} \\ &\quad \times [A_0^D + E_0c_1/D - L_0a_1/D + \beta a_1a_2/D^2 - \beta a_1^2/D^2P_B]. \end{aligned}$$

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The sign of the expression is dominated by the terms in α which is very large for the South. From Equations (1) and (2) it is immediate to see that the sign of the term in square brackets is negative if $c_2/D < 2P_E/P_B$. The latter is satisfied when Assumption 1 holds, namely D is very large. On the other hand,

$$\partial B^S/\partial P_B = [\alpha c_1 c_2/D^2 + \beta a_1 a_2/D^2]P_B^{-2} > 0.$$

Therefore, when the terms of trade increase, supply of B goods increases and exports decrease: hence demand for B, being the difference of the two, has to increase and the welfare of the South increases as well. □

Without more information it is impossible to determine the sign of the demand for basics in the North, as there α is not large. We conclude that as workers move from the South to the North, South's welfare increases and North's can either decrease or increase, if we measure welfare by the amount of consumption goods available in each economy.

To end this section we stress that dual technology in the South is a crucial assumption for some of our results. If the hypothesis were true for the North (an unlikely event, though) migration from the South would bring about a decrease in the terms of trade rather than an increase. Consequently, when labor leaves the South resource extraction would expand rather than contract. However, the conclusions about the tendency towards a reduction of the wage (and resource price) gap would be unaffected.

6. Effects of Tax and Trade Policies

In this section we examine the effects of a tax policy in the South aimed at reducing the exploitation of the resource and of a change in the property rights in the South. We will also consider the effects of trade policy in the South.

It is generally believed that taxes on the use of the resource will lead to a reduction in demand and therefore will help environmental preservation. However typically this kind of analysis assumes that all other prices remain constant. Here we would like to examine the effect of a tax on the use of the resource in the general equilibrium model we have just presented.

Let us assume that a unit tax T on the use of the resource (paid by those who utilize it) is levied in the South. Assume also that the revenue from this tax is used to increase the domestic demand for the non-resource intensive good, A. In this case we establish:

PROPOSITION 6. *A unit tax T on the use of the resource, whose proceeds are used to increase demand for the A commodity, will reduce the terms of trade, the price of the resource, and increase the output of the resource in the South.*

Proof. Levying a unit tax on the use of the resource and allocating the revenue to the demand for good A is tantamount to assuming a shift of demand in favor of good A. By using the implicit function theorem and (24), let us compute:

$$\frac{\partial P_B}{\partial A^D(S)} = \frac{-P_B}{2P_B\,[A(N)] + A_0^D(S) + A_0^D(N) + C(S) + C(N)}.$$

The above expression is negative since the denominator is positive as in (25). The decrease in the terms of trade induces a lower level of the resource price, via Equations (1) and (2), an increase in the output of the resource and a fall in the opportunity cost of subsistence labor via Proposition 1. □

We have shown that partial equilibrium result could be misleading since after the tax the price of the resource actually falls rather than increases and this leads to more extraction, not less. If the above policy were enacted when real wages were lower in the South, one further effect of this policy would be that of encouraging migration from the South as it widens the wage gap and induces more degradation.

Can one resort to some other policy to reduce the exploitation of the resource? An alternative policy in the South would be to define property rights in a better way so that the extraction of the resource is less sensitive to its price and the tendency to an overexploitation of the resource is kept in check (see Chichilnisky, 1994).

Finally, we discuss the effects of trade policy, in reference to results derived in a context of a similar model. Di Matteo (1993) proved that an export duty in the South increases its terms of trade.[18] Therefore, a move towards protectionism by increasing the terms of trade and the price of the resource will reduce the amount of resource produced and exported in the South.

In addition, Di Matteo (1993) proved that a tax on the production of the B good in the South increases its terms of trade and therefore, as a result, exploitation of the resource falls.

As a result of these policy actions, the real wage differential is reduced and, other things equal, we also expect migration to reduce.

7. Conclusions

We have analyzed the relations between degradation of the environment and labor migration, two phenomena which are at the centre of today's economic debate. In the South, contrary to the North, property rights in the extraction sector are not well defined. The South exports the resource intensive good.

Migration occurs due to wage differentials. Under our conditions migration leads to better terms of trade for the South, the price of the resource goes up and less resource is extracted in the South: the welfare in the South increases.

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8. Appendix

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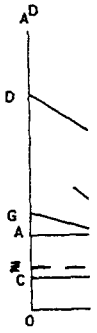

In the diagram we pos
we know (using Thales's

$$\frac{(OA - OC)/OI}{OA/OB}$$

namely

$$1 - \frac{OC}{OA} = 1 -$$

Under our hypotheses migration from the South to the North helps reducing the extraction of the natural resources.

We also analyze the effect of a unit tax on the resource in the South with the revenue spent by the government in buying the less resource intensive good. This reduces the terms of trade and therefore increases the extraction of the resource. Our conclusion is that partial equilibrium analysis of taxes can be misleading in that the overall effects of the imposition of a tax are opposite from what is intended.

Finally, we notice that a less liberal trade policy has positive effects on the level of actual exploitation of the resource.

8. Appendix

To show that as the price of the resource falls relative to P_A the typical worker will supply more effort as we claimed at the end of Section 2, we first examine the implication of such a change in the case of a utility function with a unitary elasticity of substitution. There are two goods, A and leisure, $N_0 - N$. The definition of unitary elasticity of substitution is:

$$\frac{\partial(A/N_0 - N)}{\partial(P_A/q)} \frac{P_A/q}{A/(N_0 - N)} = 1.$$

In words the ratio between the proportionate rate of change of the demand ratio and the proportionate rate of change of the marginal rate of substitution (which in an ideal situation coincides with the price ratio) is equal to one.

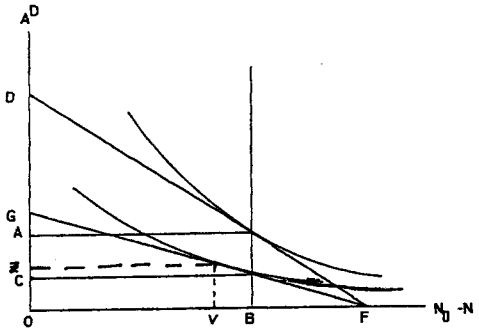

Diagram 5

In the diagram we postulate an increase in P_A, i.e. a move from D to G: we know (using Thales's theorem) that in this case:

$$\frac{(OA - OC)/OB}{OA/OB} = \frac{(OD - OG)/OF}{OD/OF},$$

namely

$$1 - \frac{OC}{OA} = 1 - \frac{OG}{OD}.$$

However, the left-hand side of (28) is the proportionate rate of change of the demand ratio and the right-hand side is the proportionate rate of change of the price ratio, when the elasticity of substitution is equal to one. In this situation the worker will consume the same amount of leisure and a smaller amount of the A good but in such a way that the proportion in value terms of the goods is unaltered after the increase in the price of A.

If, on the contrary, the elasticity is less than 1 then for the left-hand side to be less than the right-hand side, it is necessary that the amount of A chosen, say OZ, is greater than the amount chosen in the case of unitary elasticity, i.e. OC. This means that at the new tangency point the amount of leisure will be to the left of OB, say OV: this entails a higher level of A consumed and a smaller level of leisure than in the case of unitary elasticity. Therefore, more resources are extraced.

Notes

1. Here we deal with the interdependence between migration and environmental degradation, whereas in (Chichilnisky, 1994) the focus was on how differences solely in the property rights regime in the extraction of the resource could lead to an overexploitation of the resource in the South.
2. Capital is not explicitly included among the factors of producton. However, one can consider that labour is skilled and embodies a certain degree of training and use of capital. Such training could have been acquired by working with machines.
3. The reader is referred to (Chichilnisky, 1994, appendix A) for a detailed proof.
4. The latter equals the average product when the number of workers is very large, as it is sensible to assume in the South. In this case it is immediate to notice that for a strictly concave production fuction the average product is greater than the marginal. For a more general argument, see (Chichilnisky, 1994, appendix A).
5. See (Chichilnisky, 1994, section 3).
6. A very low value for β does not affect results.
7. Following (Chichilnisky, 1994, appendix B).
8. They imply a given structure of the indifference curves as shown in (Chichilnisky, 1986, appendix f).
9. The assumption about demand is not in contrast with the hypothesis (as expressed at the end of this section) about the behaviour of the subsistence workers in the South, as the latter are not part of the rest of the market economy.
10. The last two for the North are X_B^D and X_A^S.
11. In the case of a developing country the assumption can be justified on the following grounds. Suppose on the contrary, and take an extreme case, that the good A and leisure were perfect substitutes. The worker would be indifferent between consuming no A and enjoying leisure only: in a situation where the typical worker has only labour to sell this implication is totally unrealistic. On the other hand, to suppose that A and leisure were perfect complements would go too far, as it implies that, no matter what prices are, the typical worker will consume a given proportion between A and leisure (in physical terms). The case we are considering takes into account the fact that as the price of the resource the typical worker sells go down, (s)he has to work more and not less to secure a minimum level of subsistence whose price has gone up (in relative terms).
12. We have analyzed the effects of labour and capital migration and its relation with H–O model in (Chichilnisky and Di Matteo, 1992).
13. Probably migration flows re
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would greatly complicate the
14. See, e.g. the recent analysis b
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13. Probably migration flows respond to differences in real income per capita rather real wages. We maintain however the classical assumption used in trade theory as the other would greatly complicate the analysis.
14. See, e.g. the recent analysis by Barba Navaretti (1994).
15. The reason why migration occurs at discrete intervals of time is that to migrate is generally costly and the decision requires some time.
16. As we argued (Chichilnisky and Di Matteo, 1992), in general we do not possess enough empirical information to know whether when the terms of trade equal P_B^M the equalized real wage is negative: in this case a real wages gap could persist even after migration.
17. This outcome is in accord with a recent result (Chichilnisky and Di Matteo, 1992) where in a model with labour and capital we showed that for some values of the terms of trade it is possible that as one factor moves the reward differential for the other factor widens. In other words, we identified an interval for the terms of trade with the property that when equilibrium terms of trade belong to that interval the movement of one factor reduces its own price differential but increases the price differential of the other factor.
18. It has to be stressed that in (Di Matteo, 1993) Lerner's theorem does not hold. Also the reaction of the other country after the introduction of the tariff is not considered as it calls for different instruments of analysis.

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