INTERNATIONAL TRADE AND ITS IMPACT ON BIOLOGICAL DIVERSITY

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Abstract

Using a general equilibrium model, this paper shows how free trade can have negative impacts on the biodiversity stock of the South. It also shows that even without trade, the unsustainable population growth alone can deplete biodiversity resources. Free trade added with Southern rapid population growth and agricultural extensions are the main reasons of biodiversity loss. In the long run, as the terms of trade decreases for the South with increased biodiversity loss, the South eventually is worse off both with respect to trade and resources. Demand side mechanisms like discounting of biodiversity depleting products and supply side mechanism like eco-friendly agricultural technologies can have a positive impact to decrease biodiversity loss. But all these mechanisms can only slow down the depletion of the biodiversity stock, can not stop it fully. So, besides these mechanisms, we should probably look for other more pro-active measures.

1. INTRODUCTION

For the last 25 years, the world is moving towards a free trade regime. At the same time the concern for impact of free trade on environment is increasing. Most of the theoretical works on environmental impacts of free trade deal with the consumption and production side impacts of free trade towards environmental pollution. But this theoretical works can be extended to the impact of free trade on resources too. This paper uses a general equilibrium model to show and explain how free trade depletes the biodiversity resources and how that process of depletion can be slowed down. This paper theoretically explains how free trade combined with agricultural growth; population growth and unsustainable consumption patterns deplete biodiversity resources. Already, the depletion of biodiversity resources has outpaced than any other period in the history of mankind. It is a grave concern for human existence as it is an irreversible loss.

Another critical fact is that most of the world's biodiversity lies in the populated and poor south. The South is rich in natural resources and overburdened to meet the demand of their own population using these resources. Free trade puts an added pressure on the biodiversity resources of the South and they over exploit it. Trade liberalization may bring growth and development for the developing countries in the short run. But the development may not be sustainable and may lead to irreversible degradation of natural resources.

Population growth has been indicated as another major driving force for biodiversity degradation. 'The present population of the world is roughly 6 billion and it is projected to grow to 10 billions. Ninety five percent of the net births will be in developing countries. Average per capita income is rising 2% a year. At the current growth rate per capita income will double by 2035 and quadruple by 2070'[1]. But the natural resource base of the world is fixed. These huge population, consumption and production growths are putting enormous pressure on the fixed resource base. For example, 'between 1960 and 1990, 20% of the world's tropical forest was cleared; some 58% of world's coral reefs and 34% of all fish species are currently at risk from human activities'[2]. With this enormous population pressure the biodiversity rich south is faced with cyclical poverty. Almost two-third of the world population lives in the LDC's and on average 60%-80% of them are below the poverty level. 'Poverty, insecure and unsustainable livelihoods, uneven income distribution and unequal access to assets, resources and inputs are all contributory factors in the third world that accelerate natural resource degradation'[3].

Trade liberalization and population growth causes both extensification and intensification of the agriculture, forestry and fisheries. Extensification comes at the price of converting marginal lands like hillsides, forest and wetlands into agricultural land[4]. Both the extensification and intensification of agriculture uproot the small and subsistence farmers

[1] WTO Special Study, 2000.
[2] World Resource Institute, UNEP and WB, 1998.
[3] David Pearce et.al., (1991).
[4] WTO Special Study, 2000.

who move into marginal lands and degrade the natural resource base. 'The continuing emphasis on export-led agriculture mostly ignores the resource requirements of millions of subsistence farmers whose needs are not satisfied through the mechanism of market. Poor farmers lacking financial means and technical support overexploit the natural resource base'[5].

To capture these impacts of population growth, agricultural extension and free trade, we build a North-South trade model which uses just two inputs – labor and land. In our model biodiversity is measured by a proxy – undeveloped land in the South. We assume that only the South has biodiversity resource stock and this stock is located in the undeveloped land of the Southern countries. We are using undeveloped land as the proxy for biodiversity for several reasons. Firstly, there is definitional ambiguity and lack of consensus among academics on the unit of measurement of biodiversity resources. Secondly, using a spatial scale is better capture the ecosystem functions of biodiversity. Thirdly, it is never possible to value all the aspects of biodiversity like the direct and indirect use value, the option value, bequest value, the existence value, the cultural, aesthetic, religious, spiritual and social values, nor we should try to do so. Due to this valuation problem, it is better to use spatial measure like undeveloped land than the number of species. Fourthly, if we think biodiversity as an irreversible resource stock, then spatial scale will be a better safeguard from the conservation point of view. Fifth, a major shortcoming of economic valuation is that Economics try to analyze everything on the basis of marginal analysis. But the marginal value may be so small that it may not be economically efficient to conserve the biodiversity. If we rely on that economic principle of valuation of biodiversity, we may wait to conserve till the extreme end when the biodiversity stock is very small. So, it is better to preserve biodiversity in a spatial scale to preserve its enormous unknown potentials.

Another concept we are using in our paper is that preferences are sensitive to biodiversity loss. We assume that biodiversity is also a source of utility to the consumers. The concept of biodiversity as a source of utility was used by Cabo (1999). Caviglia-Harris et.al.

[5] Fantu Cheru, (1992).

(2003) tried to incorporate demand side policies to ensure sustainable use of natural resources. In this paper, by incorporating consumers' sensitivity towards biodiversity loss we also try to establish that demand side policies are also promising for biodiversity conservation.

In our model, we use the concept of international trade in vertically differentiated products. In the literature of industrial organization, product quality and product differentiation have been modeled extensively. Our analysis is in the line of the literature by Dixit (1978), Dixit and Norman (1978), Flam and Helpman (1982), Copeland and Kotwal (1995) on vertical differentiation of product quality. We assume that there are two types of agricultural products – one produced in the South that clears biodiversity rich land and hence is of lower quality and the other produced in the North that does not clear land and is assumed of higher quality. Under free trade this quality differentiated goods are traded in the international market. But most of the models on differentiated products are done in a partial equilibrium framework, whereas we follow a general equilibrium framework.

We are modeling a two sector economy where one of the sectors is manufacturing and the other is agriculture. The agricultural sector is land intensive and the manufacturing is labor intensive. The land intensive agricultural sector destroys biodiversity by clearing land. Though we are considering agriculture, but the model and its results will not differ substantially if we consider any other product that is produced using land or other natural capital and where that same natural capital or land also provides biodiversity when untouched. The South is land abundant and the North is labor abundant. Here the labor is more in the sense of skilled labor. The South has a comparative advantage in the land intensive agricultural goods and the North in the skilled labor intensive manufacturing goods. So, when the two countries open up for free trade, the South exports agricultural goods and the North exports manufacturing goods.

With this very simple model, we get some very important results. First, we find that free trade increases the clearing of undeveloped land in the South and in that way destroys

biodiversity. Second, the price of the Southern agricultural good initially rises when it moves from Autarky to free trade, but in the long run the terms of trade for the South decreases and the South eventually loses. This is due to the preference related discounting of the Southern agricultural goods by the Northern consumers as it destroys biodiversity. Third, if the Southern consumers also become sensitive towards biodiversity loss, their utility decreases with opening up the economy for free trade. Fourth, if the situation is more realistic and there are two types of consumers in the North – one is the 'green' consumers who are sensitive to biodiversity loss and the other is the 'gray' consumers who are insensitive to the biodiversity loss like the Southern consumers, free trade destroys more biodiversity. Fifth, as the income share of the 'green' consumers increases in the North, the biodiversity loss decreases. Sixth, even with the absence of trade, only Southern population growth can decrease the stock of biodiversity. Free trade puts an added pressure on this trend. Under free trade, population increase of the North also increases biodiversity loss. But the population increase in the South affects the biodiversity at a greater extent than the population increase in the North. Lastly, if there is some technology that decreases the use of land in the Southern agriculture and if the North subsidizes that technology, then the biodiversity loss decreases. This transfer increases the utility of the Southern consumers, but decreases the utility of the Northern consumers.

The structure of the paper is that: section 2 describes the model, section 3 explains the impact of free trade on biodiversity, section 4 explains the impact of trade on biodiversity when there are two types of consumers in the North – one 'green' and the other 'gray', section 5 explains the impact of population growth on biodiversity, section 6 explains the impact of technology and subsidy on biodiversity and section 7 concludes the paper.

2. THE MODEL

2.1. *Technologies*

Consider a world in which there are two countries – called country 1 (the North) and country 2 (the South), respectively. Each of these countries produces two goods – one manufacturing good, called good 1, and one agricultural good, called good 2, from labor and land. In what follows the countries will be indexed by $i, i = 1,2,$ and the goods by $j, j = 1,2.$ In each country, the industries producing the two goods are assumed to be perfectly competitive.

For each i and each j, let

$$(1) \qquad Y_{ij} = \min\left[\frac{L_{ij}}{\ell_{ij}}, \frac{A_{ij}}{a_{ij}}\right]$$

be the technology for producing good j in country i. In (1), $Y_{ij}, L_{ij},$ and A_{ij} denote, respectively, the output of good j produced in country i, the labor input, and the land input, respectively, used to produce this output. Also, ℓ_{ij} and a_{ij} are two positive constants representing, respectively, the labor input and the land input required to produce one unit of the good in question.

The labor endowment and the land endowment of country i are denoted by $\overline{L}_i$ and $\overline{A}_i$, respectively. In each country, part of the land endowment has already been developed and is ready for use as input in the production process; the remaining part is still in a state of wilderness, and must be cleared before being used as a factor of production. Let A_i be the amount of land in country $i, i = 1,2,$ that has already been cleared and is currently available for use as input in the production process. We shall assume that all the land in the North has been developed, i.e., $A_1 = \overline{A}_1$. In the South, the wilderness region, with area $\overline{A}_2 - A_2$, is rich in biological diversity and part or all of this region can be cleared and used for food production or conserved. We shall assume that the total amount of labor needed to clear ΔA_2 units of wilderness land in the South is

(2) $$C(\Delta A_2) = \gamma_0 + \gamma_1 \Delta A_2 + \frac{1}{2}\gamma_2 (\Delta A_2)^2,$$

where $\gamma_0, \gamma_1, \gamma_2$ are positive parameters. Thus if ΔA_2 unit of wilderness land is cleared, the total amount of land offered for rent in the South will be $A_2 + \Delta A_2$.

2.2. *Preferences*

In what follows, we shall assume that the land input used in the manufacturing sector comes from the stock of developed land. The land input in the agricultural sector comes from what is left of the stock of developed land and, possibly, from part of the wilderness land after it has been cleared. This assumption reflects the prevailing view that increasing agricultural production, driven by population pressure, is the main cause of the biodiversity loss in the South. Consumers in the North who are sensitive to this biodiversity loss will discount the benefits of the agricultural goods produced in the South when these goods are produced by converting wilderness land into agricultural land. Therefore, the utility of the northern consumers is affected not only by the amount of these goods but also the damage inflicted on the environment by their production. To capture these ideas, we shall assume that the preferences of a consumer in the North are represented by the following utility function:

(3) $$u_1(x_{11}, x_{12}^1, x_{12}^2) = x_{11}^{1-\alpha_1}\left[x_{12}^1 + (1 - \frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2})x_{12}^2\right]^{\alpha_1}.$$

In (3), x_{11} represents the amount of the manufacturing good consumed by a consumer in the North, while x_{12}^1 and x_{12}^2 represents, respectively, the amount of the agricultural good whose origin is from the North and the amount of the agricultural good whose origin is from the South that such a consumer purchases. Also, ε_1 and α_1 are two parameters in the range $(0,1)$. As can be seen from (3), the expression $\left[1 - \varepsilon_1 \Delta A_2 / (\overline{A}_2 - A_2)\right]$ represents the weight assigned to one unit of the agricultural good produced in the South. Note that when $\Delta A_2 = 0$, there is no further biodiversity loss, and the agricultural goods produced in the South are considered to be of the same quality as those produced in the North. This

weight declines linearly as more and more new land is brought into production and is equal to 0 when all the wilderness land is converted into agricultural land.

As for consumers in the South, the preferences of each of them are represented by the following utility function:

(4) $$u_2(x_{21}, x_{22}^1, x_{22}^2) = x_{21}^{1-\alpha_2}\left[x_{22}^1 + (1 - \frac{\varepsilon_2 \Delta A_2}{\bar{A}_2 - A_2})x_{22}^2\right]^{\alpha_2},$$

where $x_{21}, x_{22}^1,$ and x_{22}^2 represent, respectively, the consumption of the manufacturing good, the consumption of the agricultural goods produced in the North, and the consumption of the agricultural goods produced in the South. Also, ε_2 and α_2 are two positive parameters strictly less than 1. As specified by (4), the preferences of consumers from the South are allowed to be different from those of consumers from the North. First, consumers from the North and consumers from the South might have different preferences about biodiversity loss. We shall assume that $\varepsilon_2 < \varepsilon_1$, i.e., consumers in the South care less about biodiversity loss than consumers in the North. Second, their preferences between the manufacturing and agricultural goods are also allowed to be different when $\alpha_1 \neq \alpha_2$.

2.3. *Profit Maximization*

Let $p_j^i, i = 1,2, j = 1,2,$ be the price of good j whose origin is in country i. Because the manufacturing sector in the South is not assumed to damage the environment, the same price must apply to the manufacturing goods produced in both the North and the South; that is, $p_1^1 = p_1^2 = p_1$. However, if some of the wilderness area in the South is converted into agricultural land to grow food, we might have $p_2^1 \neq p_2^2$. Also, let ω_i and r_i denote, respectively, the wage rate and the rental rate of land in country $i, i = 1,2$.

For each i and each j, the representative firm in sector j of country i solves the following profit maximization problem:

(5) $$\max_{(L_{ij}, A_{ij})}\left[p_j^i Y_{ij} - \omega_i L_{ij} - r_i A_{ij}\right]$$

As for the competitive firms that hire labor to convert wilderness land into agricultural land in the South, they solve the following profit maximization problem:

(6) $\max_{\Delta A_2}\left[r_2\Delta A_2 - \omega_2 C(\Delta A_2)\right],$

where, we recall, ΔA_2 represents the part of the wilderness area cleared to be used as input the production of the agricultural goods.

2.4. *Utility Maximization*

The representative consumer in the North solves the following utility maximization problem:

(7) $\max_{(x_{11},x_{12}^1,x_{12}^2)} x_{11}^{\ 1-\alpha_1}\left[x_{12}^1 + (1-\frac{\varepsilon_1\Delta A_2}{\overline{A}_2 - A_2})x_{12}^2\right]^{\alpha_1}$

subject to the following budget constraint:

(8) $p_1x_{11} + p_2^1x_{12}^1 + p_2^2x_{12}^2 - m_1 = 0,$

where m_1 represents her income. The solution of this utility maximization problem is simple. First, observe that a fraction of income equal to α_1 will be spent on the agricultural goods and the remaining fraction to the manufacturing goods. More precisely, the demand for the manufacturing goods is given by

(9) $x_{11} = \frac{(1-\alpha_1)m_1}{p_1},$

and the demands for the agricultural goods from the North and from the South are given, respectively, by

(10) $x_{12}^1 = \frac{\alpha_1 m_1}{p_2^1}, \quad x_{12}^2 = 0 \text{ if } p_2^1(1-\frac{\varepsilon_1\Delta A_2}{\overline{A}_2 - A_2}) < p_2^2,$

(11) $x_{12}^1 = 0, \quad x_{12}^2 = \frac{\alpha_1 m_1}{p_2^2} \text{ if } p_2^1(1-\frac{\varepsilon_1\Delta A_2}{\overline{A}_2 - A_2}) > p_2^2,$

(12) $x_{12}^1 + (1-\frac{\varepsilon_1\Delta A_2}{\overline{A}_2 - A_2})x_{12}^2 = \frac{\alpha_1 m_1}{p_2^1} \text{ if } p_2^1(1-\frac{\varepsilon_1\Delta A_2}{\overline{A}_2 - A_2}) = p_2^2.$

The representative consumer in the South solves the following utility maximization problem:

(13) $$\max_{(x_{21},x_{22}^1,x_{22}^2)} x_{21}^{1-\alpha_2}\left[x_{22}^1+(1-\frac{\varepsilon_2\Delta A_2}{\bar{A}_2-A_2})x_{22}^2\right]^{\alpha_2}$$

subject to the following budget constraint:

(14) $$p_1x_{21}+p_2^1x_{22}^1+p_2^2x_{22}^2-m_2=0,$$

where m_2 is this consumer's income. The solution of this utility maximization problem is given by

(15) $$x_{21}=\frac{(1-\alpha_2)m_2}{p_1},$$

(16) $$x_{22}^1=\frac{\alpha_2 m_2}{p_2^1},\quad x_{22}^2=0 \text{ if } p_2^1(1-\frac{\varepsilon_2\Delta A_2}{\bar{A}_2-A_2})<p_2^2,$$

(17) $$x_{22}^1=0,\quad x_{22}^2=\frac{\alpha_2 m_2}{p_2^2} \text{ if } p_2^1(1-\frac{\varepsilon_2\Delta A_2}{\bar{A}_2-A_2})>p_2^2.$$

(18) $$x_{22}^1+(1-\frac{\varepsilon_2\Delta A_2}{\bar{A}_2-A_2})x_{22}^2=\frac{\alpha_2 m_2}{p_2^1} \text{ if } p_2^1(1-\frac{\varepsilon_2\Delta A_2}{\bar{A}_2-A_2})=p_2^2.$$

2.5 *Autarkic Equilibrium*

First we will look into the autarkic equilibrium. In autarky, the economies are closed and they consume what they produce domestically. By a price system we mean a list $\mathcal{P}=\left((p_j^i)_{j=1}^2,\omega_i,r_i\right)_{i=1}^2$, and by an allocation we mean a list $\mathcal{A}=\left(\left((Y_{ij},L_{ij},A_{ij})_{j=1}^2\right)_{i=1}^2,(X_{i1},X_{i2})_{i=1}^2\right)$. For the South, ΔA_2 is added in this list. A pair $(\mathcal{P},\mathcal{A})$ is said to constitute equilibrium if the following conditions are satisfied:

First, for each i and each j, the production plan (Y_{ij},L_{ij},A_{ij}) maximizes the profit of the representative firm in sector j of country i when the price system $\mathcal{P}$ prevails.

Second, ΔA_2 is the part of the wilderness area converted to agricultural land in the South when the price system $\mathcal{P}$ prevails.

Third, (X_{i1}, X_{i2}) is the consumption bundle that maximizes the utility of the representative consumer in country $i, i = 1,2,$ subject to the aggregate budget constraint. More precisely, (X_{11}, X_{12}) is the solution of the problem constituted by (7) and (8), where the income of the representative consumer in country 1 is given by

(19) $m_1 = GDP_1 = p_1^1 Y_{11} + p_2^1 Y_{12}$

For simplicity and without loss of generality, we assume that $\varepsilon_2 = 0$, i.e., consumers from the south are totally insensitive to biodiversity loss.

Then the solutions are:

(20) $x_{11} = \dfrac{(1-\alpha_1)m_1}{p_1^1},$

(21) $x_{12} = \dfrac{\alpha_1 m_1}{p_2^1},$

(X_{21}, X_{22}) is the solution of the problem constituted by (13) and (14), where the income of the representative consumer in country 2 is given by

(22) $m_2 = GDP_2 = p_1^2 Y_{21} + p_2^2 Y_{22}$

The solutions are:

(23) $x_{21} = \dfrac{(1-\alpha_2)m_2}{p_1^2},$

(24) $x_{22} = \dfrac{\alpha_2 m_2}{p_2^2},$

Fourth, the following market-clearing conditions must hold for the North and South:

(25) $Y_{i1} = \dfrac{(1-\alpha_i)(p_1^i Y_{i1} + p_2^i Y_{i2})}{p_1^i},$

(26) $Y_{i2} = \dfrac{\alpha_i (p_1^i Y_{i1} + p_2^i Y_{i2})}{p_2^i},$

(27) $\overline{L}_1 = Y_{11}\ell_{11} + Y_{12}\ell_{12},$

(28) $\overline{L}_2 = Y_{21}\ell_{21} + Y_{22}\ell_{22} + C(\Delta A_2),$

(29) $A_1 = a_{11}Y_{11} + a_{12}Y_{12},$

(30) $A_2 + \Delta A_2 = a_{21}Y_{21} + a_{22}Y_{22}.$

In what follows, we consider an equilibrium under which the output of each sector in each country is positive, i.e., $Y_{ij} > 0, i = 1,2, j = 1,2.$ Because the technology in each sector is linear, profit maximization implies that the representative firm in each sector makes zero profits. The zero profit conditions are expressed by the following equations:

(31) $p_j^i = \omega_i \ell_{ij} + r_i a_{ij}, i = 1,2, j = 1,2.$

Furthermore, in the South wilderness land will be cleared until the marginal cost of land clearing is equal to the rental rate of land, i.e.,

(32) $r_2 = \omega_2(\gamma_1 + \gamma_2 \Delta A_2).$

For the South, equations (22), (23), (24), (25), (26), (28), (30), (31), (32) constitute a system of 9 equations in 9 unknowns: $p_j^2, j = 1,2, \omega_2, r_2, \Delta A_2, Y_{2j}, j = 1,2, X_{21}, X_{22}.$ Due to Walras' law, only 8 of these equations are independent. Choosing the wage rate in the South as the numeraire, we will have 8 independent equations in 8 unknowns, which can be solved to find the equilibrium of this autarky in the South.

For the North, equations (19), (20), (21), (25), (26), (27), (29), (31) constitute a system of 8 equations in 8 unknowns: $p_j^1, j = 1,2, \omega_1, r_1, Y_{1j}, j = 1,2, X_{11}, X_{12}.$ Due to Walras' law, only 7 of these equations are independent. Choosing the wage rate in the North as the numeraire, we will have 7 independent equations in 7 unknowns, which can be solved to find the equilibrium of this autarky in the North.

Although the model can be solved algebraically, the large number of parameters makes it difficult to interpret the results. Therefore, we have tried to solve the model numerically by assuming some reasonable values for the parameters that characterize the model. Numerical solutions are useful because they reveal a number of important results of the model. For simplicity and without loss of generality, we assume that $\varepsilon_2 = 0$, i.e.,

consumers from the south are totally insensitive to biodiversity loss and that $\gamma_0 = \gamma_1 = 0$. Also, we assume that the technology used by the agricultural good is land intensive and the one by the manufacturing good is labor intensive. It costs more to produce agricultural good in the North i.e. the North uses more per unit labor and land to produce the agricultural good than the South. In the same line of argument, we assume that it costs more to produce manufacturing good in the South.

The solutions to the Autarky equilibrium give us the following results and conclusions. From the assumptions, we find that the South is more land abundant and it has technological advantage to produce the land intensive agricultural product at a lower cost. On the other hand, the North is more labor abundant and it has technological advantage to produce the manufacturing good at a lower cost. So, the South has a comparative advantage to produce the agricultural good and the North has a comparative advantage to produce the manufacturing good. It is also reflected through the prices of the two goods in the North and South in Autarky. The following table shows the results.

Table 1

Autarky Prices of the Agricultural and Manufacturing Goods

	Price of Agricultural Good	Price of Manufacturing Good
North	0.55	0.40
South	0.14	0.43

The above table clearly shows that under Autarky, the price of the agricultural good is lower in the South than the North and the price of the manufacturing good is lower in the North than the South. It proves that the South has a comparative advantage in agricultural good and North in manufacturing good. So, when the two economies will open up for trade, South will export agricultural good and North will export manufacturing good.

2.6. *General Equilibrium under Free Trade*

When the two economies are opened up for free trade, the world markets will clear up. The solution procedure will be similar as before except that few more variables and equations will be added in the system of general equilibrium.

Now we assume that two types of good 2 are produced. One is in the South that destroys biodiversity while producing it and the other one is in the North. These are denoted by $(X_{i2}^1 \ \& \ X_{i2}^2)$ respectively. $(X_{i1}, X_{i2}^1, X_{i2}^2)$ is the consumption bundle that maximizes the utility of the representative consumer in country $i, i = 1,2,$ subject to the aggregate budget constraint. More precisely, $(X_{11}, X_{12}^1, X_{12}^2)$ is the solution of the problem constituted by (7) and (8), where the income of the representative consumer in country 1 is given by

(33) $$m_1 = GDP_1 = p_1^1 Y_{11} + p_2^1 Y_{12},$$

Here the solutions are:

(34) $$x_{11} = \frac{(1-\alpha_1)m_1}{p_1^1},$$

(35) $$x_{12}^1 + (1 - \frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2})x_{12}^2 = \frac{\alpha_1 m_1}{p_2^1},$$

and $(X_{21}, X_{22}^1, X_{22}^2)$ is the solution of the problem constituted by (13) and (14) where the income of the representative consumer in country 2 is given by

(36) $$m_2 = GDP_2 = p_1^2 Y_{21} + p_2^2 Y_{22}$$

The solutions are:

(37) $$x_{21} = \frac{(1-\alpha_2)m_2}{p_1^2},$$

(38) $$x_{22}^1 + (1 - \frac{\varepsilon_2 \Delta A_2}{\overline{A}_2 - A_2})x_{22}^2 = \frac{\alpha_2 m_2}{p_2^2},$$

Also, the following world market-clearing conditions must hold:

(39) $$Y_{11} + Y_{21} = \frac{(1-\alpha_1)(p_1^1 Y_{11} + p_2^1 Y_{12})}{p_1^1} + \frac{(1-\alpha_2)(p_1^2 Y_{21} + p_2^2 Y_{22})}{p_1^2},$$

(40) $$Y_{12} = X_{12}^1 + X_{22}^1,$$

(41) $Y_{22} = X_{12}^2 + X_{22}^2,$

Equations (27) to (32) must also hold for this free trade case. Here also, we consider an equilibrium under which the output of each sector in each country is positive, i.e., $Y_{ij} > 0, i = 1,2, j = 1,2.$

Also, because the manufacturing good produced in the South is assumed not to be harmful to the environment, its price must be identical to the price of the manufacturing goods produced in the North. Hence

(42) $p_1^1 = p_1^2.$

Now in general equilibrium if the North imports the agricultural goods produced in the South, then we must have

(43) $p_2^1(1 - \frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2}) = p_2^2.$

When (43) holds, (12) applies for the representative consumer in the North, and we have

(44) $X_{12}^1 + (1 - \frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2}) X_{12}^2 = \frac{\alpha_1 (p_1^1 Y_{11} + p_2^1 Y_{12})}{p_2^1}.$

Also, when (43) holds, (17) will apply for the representative consumer in the South due to the assumption $\varepsilon_2 < \varepsilon_1$, and we have

(45) $X_{22}^1 = 0,$

(46) $X_{22}^2 = \frac{\alpha_2 (p_1^2 Y_{21} + p_2^2 Y_{22})}{p_2^2}.$

Together, equations (33), (34), (36), (37), (39) to (41), (27) to (32), (42) to (44) and (46) constitute a system of 17 equations in 17 unknowns: $p_j^i, i = 1,2, j = 1,2, \omega_i, i = 1,2, r_i, i = 1,2, \Delta A_2, Y_{ij}, i = 1,2, j = 1,2, X_{12}^1, X_{12}^2, X_{22}^1, X_{22}^2.$ Due to Walras' law, only 16 of these equations are independent. Choosing the wage rate in the South as the numeraire, we will have 16 independent equations in 16 unknowns, which can be solved to find the equilibrium of this two-country world.

In the same fashion as the autarky solution and with the same assumptions, we have tried to solve the model numerically by assuming some reasonable values for the parameters that characterize the model. We found some very interesting results through these solutions.

3. IMPACT OF TRADE ON BIODIVERSITY

3.1. *From Autarky to Free Trade*

There is a dominant view in the literature that free trade degrades the environment and accelerates biodiversity loss. The model can be simulated to find out if this viewpoint can be supported. In the numerical solutions, we compute the amount of new agricultural land cleared by labor in the South and used in food production. The following table shows the result for different levels of population or labor force.

Table 2

Change in the Amount of Cleared Land under Autarky and Free Trade for Different Sizes of Population

Variables	$L_2 = 1.5$		$L_2 = 2$	
	Autarky	Free Trade	Autarky	Free Trade
ΔA_2	0.1729	1.3370	0.6394	1.6486
U_2	3.3217	3.6021	4.3153	4.5112
U_2/L_2	2.2145	2.4014	2.1577	2.2556
U_1	5.5509	6.7349	5.5509	6.5491
U_1/L_1	1.8503	2.2449	1.8503	2.1830
P_2	0.11	0.18	0.14	0.19

Note: In the above table,
L_2 = The size of the labor force in the South
ΔA_2 = The change in agricultural land or the amount of cleared land
U_2 = The total utility of the Southern consumers
U_2/L_2 = The per capita utility of the Southern consumers
P_2 = The price of the agricultural good

The results from the above table clearly show that the amount of cleared land increases as the South moves from autarky to free trade for both the population sizes. It supports the much-proclaimed view in the literature that free trade increases biodiversity loss. The result is quite intuitive. As the South has a competitive advantage in agricultural goods, it will export these goods as the economy opens up for trade. In autarky, the South was

producing food only to feed its own people, but now it will also produce food for exports. This increases the pressure on land resources. To produce more agricultural goods, the South clears the untouched biodiversity-rich land and brings it into agriculture. Also, as the utility of Southern consumers is not sensitive to biodiversity loss, moving from autarky to free trade increases both total and per capita utility in spite of the increase in biodiversity loss. This increase in utility provides an incentive for the South to push for more export by clearing more land and in the process causing biodiversity loss. Observe that the price of the agricultural good rises when the economy moves form autarky to free trade.

For the North, both the gross and per capita utility of the Northern consumers increase as it moves from autarky to free trade. It is obvious, as they can now consume more agricultural good at a lower price. But it is also important to note that both the gross and per capita utility of the Northern consumers decrease in free trade as the population in the South increases. This is due to the population growth induced increase in biodiversity loss in the South which in turn affects the utility of the Northern consumers.

3.2. *The Impact of Positive Environmental Sensitiveness of the Southern Consumers*

In the model above we assumed that the Southern consumers are insensitive to the loss of biodiversity i.e. we assumed that $\varepsilon_2 = 0$. But instead if we assume that $\varepsilon_2 > 0$, there will be an impact on the utility of the Southern consumers. The solutions for the variables will be the same as before. But a positive sensitiveness of the Southern consumers for the biodiversity loss will decrease the gross and per capita utility of the Southern consumers. This result is very straight forward. As the Southern consumers also now care about the loss of biodiversity and as free trade increases the loss of biodiversity, the utility of the Southern consumers decreases than the case when they had no sensitivity towards biodiversity loss. This is shown by the following table.

Table 3

Impact of Positive Environmental Sensitivity of the Southern Consumers on their Utility

ε_2	U_2 *[Autarky]*	U_2 *[Free Trade]*
0.00	4.3153	4.5112
0.15	4.1775	4.1394
0.25	4.0854	3.8915

It is interesting to see in the above table that, both in Autarky and free trade, the gross utility of the Southern consumer's decreases as their sensitivity towards biodiversity loss increases. Moreover, when the South moves from autarky to free trade and the Southern consumers have positive sensitivity towards biodiversity loss (i.e. $\varepsilon_2 > 0$), the gross utility of the Southern consumers decreases. It implies that free trade may decrease both the utility of the Southern consumers and the stock of biodiversity if the Southern consumers are sensitive to biodiversity loss. If the sensitivity of the Southern consumers become highly positive and $\varepsilon_2 > \varepsilon_1$, then the South may lose the comparative advantage in agricultural goods and start importing it also from the North.

3.3 *The Impact of Biodiversity Loss on the Terms of Trade*

The model assumes that Northern consumers are sensitive to biodiversity loss and these preferences are reflected in their utility function. The consumption of the agricultural good produced in the South, which destroys biodiversity, is discounted by the northern consumers through the discount factor $(1-\frac{\varepsilon_1 \Delta A_2}{\bar{A}_2 - A_2})$. Also, when the Northern consumers purchase both the agricultural goods produced at home and the agricultural good produced in the South, then we have: $p_2^1(1-\frac{\varepsilon_1 \Delta A_2}{\bar{A}_2 - A_2}) = p_2^2$, according to (43).

Now the terms of trade for the South which is given by the ratio of the price of the exported good over the price of the imported good, i.e.,

(47) $$\frac{P_2^2}{P_2^1} = 1 - \frac{\varepsilon_1 \Delta A_2}{\bar{A}_2 - A_2}$$

It can be seen from (47) that the terms of trade deteriorates when ΔA_2 rises, i.e., when biodiversity loss increases the South. As more wilderness land is cleared, more biodiversity will be lost, with the ensuing decline in the weight of the Southern agricultural goods in the utility function of the Northern consumers. As the good becomes less desirable, the Northern consumers are less willing to pay a premium price for the Southern agricultural goods, which causes the South's terms of trade to deteriorate.

4. TWO TYPES OF CONSUMERS IN THE NORTH

In this section, we extend the model to the case in which there are two types of consumers in the North. One type, called the "green" is sensitive to biodiversity loss and the other type, called the "gray" is indifferent to biodiversity loss. Furthermore, the later is assumed to behave like the Southern consumers who are also insensitive to the degradation of their environment. The greens are assumed to constitute a fraction θ, $0 < \theta < 1$, of the Northern population. The size of the grays, as a fraction of the total population is thus equal to $1-\theta$. To concentrate on the question of how different preferences for biodiversity affect biodiversity loss, we shall assume that all the Northern consumers, except their different preferences for biodiversity, have the same income. Furthermore, the utility functions of the two types of consumers in the North are given by:

(48) $$u_{1green}(x_{1green,1}, x^1_{1green,2}, x^2_{1green,2}) = [x_{1green,1}]^{1-\alpha_{1green}} \left[x^1_{1green,2} + (1 - \frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2}) x^2_{1green,2} \right]^{\alpha_{1green}}$$

(49) $$u_{1gray}(x_{1gray,1}, x^1_{1gray,2}, x^2_{1gray,2}) = [x_{1gray,1}]^{1-\alpha_{1gray}} \left[x^1_{1gray,2} + (1 - \frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2}) x^2_{1gray,2} \right]^{\alpha_{1gray}}$$

The budget constraint of a green Northern consumer and the budget constraint of a gray Northern consumer are given, respectively, by -

(50) $$p_1 x_{1green,1} + p^1_2 x^1_{1green,2} + p^2_2 x^2_{1green,2} - \theta m_1 = 0.$$

(51) $$p_1 x_{1gray,1} + p^1_2 x^1_{1gray,2} + p^2_2 x^2_{1gray,2} - (1-\theta) m_1 = 0.$$

The world market clearing conditions provides that,

$$p^1_2 (1 - \frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2}) = p^2_2.$$

The solutions to this maximization problem for the green consumers will be as the following. The demand for the manufacturing goods will be -

(52) $$x_{1green,1} = \frac{(1-\alpha_{1green})\theta m_1}{p_1},$$

And the demand for the agricultural goods from the North and from the South is:

(53) $$x^1_{1green,2} + (1-\frac{\varepsilon_1 \Delta A_2}{\overline{A}_2 - A_2})x^2_{1green,2} = \frac{\alpha_{1green}\theta m_1}{p^1_2} \quad .$$

As from the world market clearing condition we get, $p^1_2 > p^2_2$ and the gray consumers in the North are insensitive to biodiversity loss, they will only consume agricultural goods exported from the South as it is cheaper to them. So, their utility maximization will provide demand for the manufacturing and agricultural goods as the following:

(54) $$x_{1gray,1} = \frac{(1-\alpha_{1gray})(1-\theta)m_1}{p_1},$$

(55) $$x^2_{1gray,2} = \frac{\alpha_{1gray}(1-\theta)m_1}{p^2_2} \quad .$$

With these new utility maximization values we can get a different set of solutions for this two consumer group case. The results that we get through the numerical solutions for this extension of the model are interesting and support our previous claim. The following table shows the comparative picture of the key variables under autarky, free trade and free trade with two types of Northern consumers.

Table 4
Change in the Amount of Cleared Land under Autarky, Free Trade when All Northern Consumers are Green and Free Trade with Two Types of Northern Consumers

Variables	$L_2 = 2$		
	Autarky	Free Trade	Free Trade with Two Groups
ΔA_2	0.6394	1.6486	1.7894
U_2	4.3153	4.5112	4.5623
U_2/L_2	2.1577	2.2556	2.2812
P^2_2	0.14	0.19	0.21
P^2_2 / P^1_2	-	0.43	0.44

Note: In the above table, P^2_2 / P^1_2 = The terms of trade for the South

The above table also clearly establishes our previous claim that biodiversity loss through clearing of land increases if a country moves form autarky to free trade. It even increases further if a portion of the northern consumers is insensitive to biodiversity loss. Both the total and per capita utility in the south increases from autarky to - free trade to - free trade with two groups of northern consumers. Also the price of good 2 and the terms of trade for the South increase from free trade to free trade with two types of Northern consumers. Both of the above two events work as incentives for the Southern economies to clear more land and increase the export of agricultural goods.

Next we look at the case when the income share of the Northern green consumers increases. Table 4 shows, as the income share of the 'green consumers' in the North becomes larger, the clearing of land and in the process, biodiversity loss decreases further. It implies that only preference related discounting of the northern consumers could slow down the biodiversity loss in the south. As more northern consumers discount the southern agricultural goods, the biodiversity loss slows down in the south. But this is true only if there is no population growth in the south.

Table 5

Change in the Amount of Cleared Land under Free Trade with Two Types of Northern Consumers and Different Levels of Income Shares for the 'Green Consumers' ($L_2 = 2$)

Different Values of θ	ΔA_2
0.5	1.8239
0.6	1.7894
0.7	1.7546

5. IMPACT OF POPULATION GROWTH ON BIODIVERSITY

We can also get important insight from the above models on what is the impact of population growth on biodiversity. It is a popular claim that rapid population growth in the South is a major cause of global biodiversity decline. As the population grows in the

South, they try to feed the increased population by clearing more land which is biodiversity rich and bringing it into agriculture. Our results support this claim.

Table 6

The Impact of Population Increase in the South on Biodiversity

Variables	Autarky		Free Trade		Free Trade with two groups	
	$L_2 = 1.5$	$L_2 = 2$	$L_2 = 1.5$	$L_2 = 2$	$L_2 = 1.5$	$L_2 = 2$
ΔA_2	0.1729	0.6394	1.3370	1.6486	1.4864	1.7894
U_2	3.3217	4.3153	3.6021	4.5112	3.6666	4.5623
U_2/L_2	2.2145	2.1577	2.4014	2.2556	2.4444	2.2812
P_2^2	0.11	0.14	0.18	0.19	0.19	0.21
P_2^2 / P_2^1	-	-	0.397	0.43	0.41	0.44

Table 6 shows that in all three cases - autarky, free trade and free trade with two groups of Northern consumers - as population size increases, the amount of cleared land also increases which in the process increases biodiversity loss. Population growth joined with free trade make the situation worse and population growth joined with free trade with two northern consumer groups make the situation worst. Also under both the cases of free trade, the total utility of the South and its terms of trade improve with population increase. These two factors work as an incentive to increase the export of agricultural goods and causes more land clearing. But at the same time the per capita utility declines with population increase in the South and it should also be taken into account by the South. So, population increase may bring growth in total utility of Southern consumers and improve the trade scenario for the South, but it is accompanied with per capita utility decline and biodiversity losses. The later two trends may deteriorate the national welfare in the long run.

Not only the population increase in the South, but the population increase in the North can also create pressure on biodiversity and increase its loss. Though the Northern consumers are sensitive to biodiversity loss, yet with increased population, their demand

for agricultural good will increase and they will import more of the Southern agricultural good. This will help to expand the agricultural sector in the South and it will clear more untouched land which will eventually increase biodiversity loss.

Table 7
The Impact of Population Increase in the North on Biodiversity under Free Trade

Variables	Free Trade		
	$L_1 = 3$	$L_1 = 3.5$	$L_1 = 4$
ΔA_2	1.6486	1.9131	2.1729
U_2	4.5112	4.6108	4.7226
U_2/L_2	2.2556	2.3054	2.3613
P_2^2 / P_2^1	0.43	0.45	0.47

It is evident from the results presented in table 7. Also note that with population increase in the North, the gross and per capita utility of the Southern consumers and the terms of trade of the South increase too. This will again work as an incentive for further expansion of the Southern agricultural sector and increase biodiversity loss.

Biodiversity loss increases most if the population in both the North and South increases. It is evident from table 8. If we compare columns 2 to 3, only the Northern population increases and the amount of cleared land increase from 1.6486 to 1.9131. Between columns 2 and 4, only the Southern population increases and the amount of cleared land increases from 1.6486 to 1.9457. So, more land is cleared for an increase in population in the South than in the North. Finally if we compare columns 2 and 5, both the Southern and Northern population increases and the amount of cleared land are highest in this case. It implies that population increase is one of the main reasons for biodiversity loss. Also under free trade, biodiversity is destroyed more in the case of population increase in the South than population increase in the North.

Table 8

The Impact of Population Increase on Biodiversity under Free Trade when Population Increases both in the North and South

Variables	$L_1 = 3$ $L_2 = 2$	$L_1 = 3.5$ $L_2 = 2$	$L_1 = 3$ $L_2 = 2.5$	$L_1 = 3.5$ $L_2 = 2.5$
ΔA_2	1.6486	1.9131	1.9457	2.2019
U_2	4.5112	4.6108	5.3565	5.4395
U_2/L_2	2.2556	2.3054	2.1426	2.1758
P_2^2 / P_2^1	0.43	0.4507	0.4536	0.48

6. IMPACT OF SUBSIDY

We make a final extension of the model, to find the impact of subsidy on biodiversity and on the utilities of the Northern and the Southern consumers. The model will be same as the 'free trade' case with minor extensions. We assume that the North provides a lump-sum subsidy of the amount 'T' to the South. This subsidy 'T' is subtracted from the Northern GDP and added to the Southern GDP. We further assume that this subsidy is used by the South to improve technological efficiency in the agricultural sector, so that less amount of per unit land is used to produce the agricultural good. In this way it decreases land clearing in the South and decreases biodiversity loss. It is reflected through the following equation that is added to the model.

(56) $a_{22} = \delta - \sigma.\ell_0$

where $\delta \,\&\, \sigma$ are two parameters and $\ell_0 = T / \omega_2$ i.e. it is the amount of labor used to invent new technology that uses lower amount of land in the agricultural sector. Using this extra assumption if we solve the model we find interesting results. The results are summarized in table 9.

Table 9

The Impact of Subsidy on the 'Cleared Land' and the Utility of the Northern and Southern Consumers

Variables	Amount of Subsidy		
	T = 0.05	T = 0.08	T = 0.11
ΔA_2	1.2811	1.2445	1.2053
U_2	3.6937	3.7488	3.8040
U_1	6.7296	6.7275	6.7261

The results above clearly show that under free trade, if a subsidy is provided from the North to the South that improves the land use efficiency in the South, decreases the amount of land cleared in the South and in that way decreases the biodiversity loss. It also increases the gross utility of the Southern consumers. But the Northern consumer's gross utility decreases slowly.

8. POLICY IMPLICATIONS AND CONCLUSION

The paper explains the current reality faced in the biodiversity rich developing countries. This paper has shown theoretically that the concern of anti-globalization activists that free trade depletes world's biodiversity stock is true. On the other hand, it has shown that the concern of environmental and resource economists that even without trade, the unsustainable population growth alone can deplete biodiversity resources is also true. Free trade added with Southern rapid population growth and agricultural extensions are the main reasons of biodiversity loss. It is also true that the developing countries are short sighted. In the long run, as the terms of trade decreases for the South with increased biodiversity loss, the South eventually is worse off both with respect to trade and resources. But the reality is that the developing countries do not have any other alternative. They have to deplete their rich biodiversity resource stock to feed the current population though it may hurt the future generation of these countries in particular and the world at large.

There are very important policy implications of the results found in this paper. This paper shows that demand side mechanisms like discounting of biodiversity depleting products and supply side mechanism like eco-friendly agricultural technologies can have a positive impact to decrease biodiversity loss. Above all, population growth has to be controlled so that it can be sustainable with respect to the biodiversity stock. Population should not exceed the ecological limit of the earth.

All these mechanisms can only slow down the depletion of the biodiversity stock, but can not stop it fully. So, besides these mechanisms, we should probably look for more pro-active measures. We have to look for alternative measures like bio-prospecting or eco-tourism to create economic values from the conservation efforts of the biodiversity stock. Also the biodiversity rich developing countries have to diversify with respect to domestic production and trade. They need to decrease their dependence on export of natural resource intensive products and diversify their export towards manufacturing products. Above all, given the current reality of the developing countries, only green activism like avoiding consumption of biodiversity depleting goods or anti-globalization activism like blocking free trades or free market activism like leaving everything to the hand of market will not work in the long run. If as a citizen of the globe, we value biodiversity as a global public good that has to be conserved, we have to act as global citizens too. As proud national citizens, we are already spending our tax dollars to preserve the national heritages. Similarly, we have to spend our tax dollars for conservation of the global heritages like biodiversity stock too. Like at the national level, the rich people pay more tax dollars and donations for the conservation effort, so should be the case at the world level. The rich North should pay more to conserve the world's biodiversity stock. The efforts like the global environmental fund should be the principle mechanism to conserve biodiversity stock of the world. Also as the benefits of the conservation of national heritages are enjoyed equally by all the citizens of a country at present and in future, sometimes with a smaller fee, the benefits of the conservation of the world's biodiversity stock should be enjoyed equally by all the citizens of the world in present and in future.

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