THE ENVIRONMENT AND INTERNATIONAL TRADE

Chien-fu Chou*, Jolyne Melmed-Sanjak*, and Oz Shy**

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Abstract

The relationship between international trade and environmental degradation is analyzed in this short paper. Environmental attributes are modeled as differentiated, non-tradeable goods. The results derived from the model indicate that when consumers view consumption goods and environmental attributes as substitutes and if consumers place a relatively higher value on environmental variety than on commodity variety, the opening of trade may reduce the welfare of the trading countries. A net welfare loss may occur as exchange gains from trade are reduced or eliminated by environmental losses.

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0*State University of New York at Albany, Albany, NY 12222.
0**Tel-Aviv University, 69978 Tel-Aviv, Israel.

The issue of environmental spending is ever more prominent as people have become keenly aware of the trade-off between continuing commercial development and sustaining the environment. Thiesenhusen (1989) presents a good review of the relevant literature in the less developed country context and Anas (1988) presents a discussion of the issues as developed in the U.S. context. While the role of international trade in environmental degradation is mentioned in these papers, it is not a focal point. Yet, international trade is a key factor in many contemporary environmental issues. For example, the popular media has made us aware how trade in ivory has nearly led to the demise of the African elephant. Similarly, the process of destroying rainforests in Latin and Central America has its roots in early colonial trade. The recent alarming increase in such destruction is also attributed, in part, to the international economy, particularly in Central America. (See the discussion in De'Ath (1989), McNeil (1986), and Myers and Tucker (1987)). Perrings (1989) also presents a useful discussion of the implications of an open economy for resource degradation in a paper which focuses on poverty as a force of rapid desertification in Sub-Saharan Africa. His work contributes a theory of the response of agricultural producers to the risks of world markets and the long-run growth impediments such response may generate. The environment, in his model, is conventionally treated as a productive input. Rational factor allocation can lead to environmental degradation which, in turn, leads to future declines in productivity. In this context, the opening of trade affects the environment indirectly via inducing behavioral changes in low-income producers. Finally, in a recent paper on free trade agreements, Thompson (1989) notes that such agreements "could affect our ability to protect the environment and to manage renewable resources for better or for worse." It, however, was not his intent to analyze the "for better or for worse." He focuses, instead, on environmental policy as a potential barrier to trade.

It is our view that trade has a direct and independent impact on the state of the environment which may offset the gains from trade. In this paper, we construct a

general equilibrium trade model which incorporates the environment and allows us to support our view via a static comparison of autarky versus world open economy. In the international trade literature, one cannot find a general equilibrium analysis of the effects of trade on the environment. In our opinion, this gap follows from the fact that the 'commodity' which we call the environment is very hard to define, nevertheless to formalize, in a general equilibrium welfare model. In this paper, we resolve this difficulty by defining the environment as a collection of items. The variety of species of animals and plants, natural resources etc. is viewed as defining the composition of this collection.[1] We formalize environmental degradation, then, as the process in which the variety and/or number of items, which we subsequently label environmental attributes, declines. Using this novel technique, we are able to find precise and testable conditions on consumer preferences which would explain when it is likely that the opening of trade hurts the environment by reducing its attributes. The general equilibrium approach developed in this paper allows us, also, to find precise and testable conditions which would predict the welfare effects of trade in the presence of environmental degradation.

Because our objective is to isolate the impact of trade in the world economy on environmental degradation, our model deliberately deviates from conventional approaches to characterizing the environment and its relation to the economy (e.g., see the summary of such work found in Maler, 1985). We postulate a world in which rights over environmental attributes are exclusive and that there is one producer of services for each attribute [2] In this model, the production side of the economy is not explicit in the

[1]This specification resembles the so called 'green indicators' which are used in practice as environmental measurements. A recent meeting of the 24 OECD environment ministers used these indicators to compare environmental degradation among countries. These indicators include species, pollution levels, stock of fish and timber, fresh water, and more. See, *The Economist*, February 2nd 1991, p. 48.

[2]Note that Maler, in his formulation of the welfare problem, uses an analytical construct in which environmental services are technically treated as private. He provides ample discussion of possible interpretations of his formulation and of the various possible mechanisms for achieving equilibrium given the actual public goods character of environmental service provision. In our framework, alternative formulations in which environmental service provision is specified as a public good are possible.

model and the environment is not explicitly considered as an intermediate input in the production of traded commodities. One can, however, interpret the process of using the environment for raw materials to produce manufactured goods as a reallocation of the initial endowment from the non-tradeable sector (environmental attributes) to tradeable goods sector. Moreover, the model's structure does not preclude the incorporation of a more rich characterization of the economy. Some interesting extensions of the model will be noted in the text of the paper.

The paper is organized as follows. In section 1, a simple model is presented from which implications for the condition of the environment can be derived. The next section presents such derivation in the context of autarky and in the context of an open economy, respectively. Section 3 then uses the results derived to state two key propositions. These propositions confirm that trade may be harmful to the environment and state that, under certain conditions, this "badness" may decrease welfare enough to offset the exchange gains from trade. The interpretation of the propositions and the conditions under which they are valid conclude the paper.

1. The Model

Consider a world with two identical countries, each is inhabited with $n > 0$ identical consumers. Each consumer is endowed with L units of resources measured in dollars. Since the two countries are assumed to be identical, it is sufficient to consider only one representative country. The welfare of a representative consumer of the country depends on his/her utility gains from the quality of the environment and from his/her consumption of a variety of traded goods. We denote by T the representative consumer's subutility from the consumption goods sector (i.e., the traded goods sector)

Using a simple equilibrium mechanism which is similar to the Lindhal equilibrium notion in the sense that consumers contribute their individual marginal rate of substitution to 'purchase' environmental quality would yield similar conclusions regarding the possibility of Pareto inferior trade. Further analysis, however, is required to consider all the complexities of the public good problem.

and T is assumed to take the form of[3]

$$T \equiv (V_T)^{\theta_T} E_T \quad \text{where } \theta_T > 0. \tag{1}$$

In this expression V_T measures the variety or number of consumption goods and E_T measures the aggregate expenditure on these goods. The parameter θ_T measures the degree of importance of variety to consumers and can be shown to be inversely related to the degree of product substitution.

The environmental welfare index is denoted by H. Similar to (1), we assume that H takes the form of

$$H \equiv (V_H)^{\theta_H}(E_H) \quad \text{where } \theta_H > 0. \tag{2}$$

In the above, E_H measures the expenditure on the environment which is determined by the consumer.[4] The variable V_H in equation (2) measures the "attributes" or features of the environment. V_H may, for example, be viewed as indicating the variety of species in the environment. Conceptually, we suppose that each environmental attribute is used to produce a service under monopolistic competition. The monopolistic competition framework characterizes the production of environmental services because such services are appropriately viewed as differentiated products. More importantly, the number of attributes, while treated parametrically by consumers, is not fixed but is determined in the market equilibrium. The parameter θ_H measures the degree of importance of quality (variety of environmental attributes).[5] Note, thus,

[3] If the consumption goods industry consists of monopolistically competitive firms, then the consumers' welfare level depends on the variety of goods consumed as well as the consumers' total expenditure on these goods (see Dixit and Stiglitz (1977), Krugman (1979), or Chou and Shy (1991)). When consumers have CES preferences, T takes this form (see appendix 1).

[4] "Expenditure on the environment" needs some interpretation. One component of such expenditure is the opportunity cost of maintaining environmental diversity and quality. Consumers, by choosing conservation, give up the opportunity for commercial exploitation and, therefore, should be considered as spending on the environment. There may also be direct costs of maintenance and resource management, see Anas(1988).

[5] The parameter θ_H captures option value and existence value. See Anas (1988) for explicit definition and discussion of option and existence value. In a model with explicit prices, these would be included as a premium paid for the luxury of environmental conservation.

that the model is flexible enough to apply to different states of consumer concern for and knowledge of the environment.

The total welfare of a representative consumer of a country is assumed to be given by

$$U = H^{\beta} + T^{\beta} = [(V_H)^{\theta_H} E_H]^{\beta} + [(V_T)^{\theta_T} E_T]^{\beta} \text{ where } 0 < \beta < 1. \tag{3}$$

Here the parameter β is monotonically related to the degree of substitution between environmental attributes and consumption goods. The consumer chooses how to allocate his/her expenditure on traded goods (E_T) and on the environment (E_H) to maximize (3). The first order condition yields:

$$MU_{E_H} = \beta(V_H)^{\beta\theta_H}(E_H)^{\beta-1} = \beta(V_T)^{\beta\theta_T}(E_T)^{\beta-1} = MU_{E_T}. \tag{4}$$

Using $E_T = L - E_H$ and substituting (4) into (3), we obtain the utility of consumers as a function of the attributes of the environment and the expenditure on the environment. Thus,

$$U = (V_H)^{\beta\theta_H} L (E_H)^{\beta-1}. \tag{5}$$

To simplify, we assume that the variety of consumption goods equals the aggregate expenditure on these goods and that the environmental quality (the variety of attributes or species) is equal to the total expenditure on the environment. Formally, let [6]

$$V_H = nE_H \text{ and } V_T = nE_T. \tag{6}$$

A possible interpretation to this assumed relationship between V_H and E_H is that the amount of environmental attributes (V_H) is initially determined by nature but the aggregate expenditure (nE_H) effects the level of "degradation" of V_H. That is,

[6]It seems as if equation (6) assumes an externality in the sense that consumers' expenditure affects the utility through the change in the variety of products. However, appendix 1 shows that this is not the case, for example, in a monopolistically competitive environment. In a monopolistic competition framework (Dixit and Stiglitz (1977) and Krugman (1979)) the equilibrium variety of goods is proportional to the consumers' aggregate expenditure.

if society spends more on the environment then nature maintains a higher level of attributes.

2. Equilibrium Characterizations: Autarky vs. Free Trade

In this section, we solve for the equilibrium variety of consumption (traded) goods and the equilibrium variety of environmental attributes under autarky. Substituting (6) into (4) and using $E_T = L - E_H$, we obtain

$$(V_H)^{\beta\theta_H+\beta-1} = (V_T)^{\beta\theta_T+\beta-1} = (nL - V_H)^{\beta\theta_T+\beta-1} \tag{7}$$

Equation (7) implicitly determines the equilibrium environmental attributes under autarky (V_H^{at}) and, hence, the autarky variety of consumption goods (V_T^{at}).

We now assume that the two countries described previously are allowed to trade. Under free trade, the two countries completely specialize in the production of different sets of differentiated consumer goods.[7] Therefore, under *free trade*, all consumers are exposed to twice the variety of consumer goods. Formally, under free trade, equation (6) becomes

$$V_H = nE_H \quad \text{and} \quad V_T = 2nE_T \tag{8}$$

In the above, E_H and E_T measure the expenditure by a *representative* individual on the environment and on consumption goods, respectively. Substituting (8) into (4), the analog of (7) is given by

$$(V_H)^{\beta\theta_H+\beta-1} = 2^{\beta\theta_T}(V_T)^{\beta\theta_T+\beta-1} = 2^{\beta\theta_T}(nL - V_H)^{\beta\theta_T+\beta-1}. \tag{9}$$

Equation (9) can be solved for the *free trade* equilibrium amount of environmental attributes V_H^{ft}.

[7]For example, in the context of North-North trade, while there is significant overlap across countries in traded-product categories, brand name and model differentiation distinguishes the sets of consumer goods. Furthermore, it is possible to extend the model to incorporate a sector of non-tradeable, non-environmental goods and/or tradeable environmental goods. It is also possible to consider an international public good. Such extensions are interesting and would make the model appear more realistic but would not fundamentally alter the conclusion we choose to focus on.

3. The Effects of Trade on the Environment

In this section, we analyze the effects of the opening of trade on the environment and on the welfare of consumers. Consider the situation where consumers view conservation of environmental attributes (V_H) to be very important relative to the maintenance of a great variety of consumable products (V_T). Formally, this is stated as the assumption that

$$\theta_H > (1/\beta) - 1 > \theta_T. \tag{10}$$

This condition can also be interpreted as assuming that the degree of substitution among environmental attributes ($(1/\theta_H) + 1$) is lower than the degree of substitution among consumption goods ($(1/\theta_T) + 1$), and that the degree of substitution between environmental attributes and consumable products ($1/(1-\beta)$) lies in between the two. Krutilla (1967) suggests that this is a reasonable hypothesis. In fact, in that paper he argues that, over time, technology will advance the substitutability among consumer products but may never do so for the set of geomorphologic environmental attributes. Thus, the relative importance of environmental conservation (which is reflected in θ_H) should increase over time. Recall that the equilibrium amount of environmental attributes under autarky and free trade can be found from (7) and (9), respectively. Also, observe that the left-hand side of (7) is the same equation as the left-hand side of (9) which is defined as $F(V_H)$. By (10), the power of $F(V_H)$ is positive. Define $G^{at}(V_H) \equiv (nL - V_H)^{\beta\theta_T+\beta-1}$ which is the right hand side of equation (7) and $G^{ft}(V_H) \equiv 2^{\beta\theta_T}(nL - V_H)^{\beta\theta_T+\beta-1}$ which is the right hand side of equation (9). By (10), the functions G^{at} and G^{ft} are upward sloping and diverge to infinity as $V_H \to nL$. The intersection of F and G determine the equilibrium environmental quality under the two regimes (see figure 1).

INSERT FIGURE 1

Observe that equation (4) implies that the function F is proportional to the marginal utility of the expenditure on the environment while the function G measures the marginal utility of expenditure on consumer goods. We say that an interior equilibrium is stable if at the equilibrium point the slope of the curve representing the marginal utility of expenditure on consumer goods (G) exceeds that of the curve representing the marginal utility of expenditure on the environment (F). Intuitively, in a stable equilibrium, a small decrease in environmental spending will make the marginal utility of such expenditure higher than the marginal utility of consumption spending ($F > G$). Therefore, there would be a tendency for the expenditure on the environment to increase toward its equilibrium value. Thus, from figure 1, it is clear that there is only one stable equilibrium.[8]

Condition (10) implies that $2^{\beta\theta_T} > 1$, and therefore G^{ft} lies above G^{at}. Hence, figure 1 shows that the opening of trade reduces the amount of environmental attributes maintained. Proposition 1 reiterates our point:

Proposition 1 *Given that consumers treat consumption goods and environmental attributes as substitutes ($\beta > 0$), then the opening of trade reduces environmental quality.*

Proposition 1 can be explained as follows. The opening of trade enlarges the variety of consumption goods, thereby motivating consumers to increase expenditure on these products. Thus, the expenditure on the environment declines implying a reduction in the quantity of environmental attributes. In this model, prices remain constant when trade is introduced. Therefore, an increase in spending on consumables necessitates shrinkage in the environmental sector. Shrinkage in this context means a decrease

[8]It may happen that for some parameter values the curves do not intersect. In this case, a boundary equilibrium exists in which $V_H = 0$. Since this case is unrealistic, we concentrate only on the case where an interior stable equilibrium exists.

in the number of environmental attributes. The importance of this result is that we identify trade as a distinct source of environmental degradation in addition to the traditionally discussed property rights issues.[9]

Finally, our model allows us to formally ask whether the welfare loss from a deteriorating environment due to trade can be so large as to dominate the welfare gains from an increase in the variety of consumption products. Note that by (8), substituting V_H/n for E_H in (5), one obtains the welfare as a function of environmental attributes. Therefore,

$$U = Ln^{1-\beta}(V_H)^{\beta\theta_H+\beta-1}. \tag{11}$$

By (10), the power of V_H in (11) is positive implying that the equilibrium utility level is an increasing function of equilibrium environmental attributes. From proposition 1, we have that $V_H^{ft} < V_H^{at}$. Thus, proposition 2 follows:

Proposition 2 *If consumers value environmental attributes more than they value the variety of consumption goods, i.e., if condition (10) is satisfied, then consumers are worse-off with free-trade than with autarky.*

Thus, our model suggests that even if consumers would internalize intergenerational and contemporaneous externalities, welfare reducing trade will occur when condition (10) is satisfied.[10] Similar to the prisoners' dilemma game, here agents act optimally

[9]Property rights over many environmental attributes *are* such that individuals cannot appropriate any scarcity value which might exist. Even under private tenure, institutions are not developed such that the full social cost of environmental exploitation are born by producers of commercial, resource-based products. (See Krutilla (1967) and Tietenberg (1988).)

[10]While the definition of geomorphologic environmental attributes as non-tradable or non-marketable would more typically stem from the nature of property rights, in the present model domestic consumers are assumed to assign appropriate values to these resources in their utility functions. In this model the services of environmental attributes are traded within the countries but not internationally. International non-tradability stems from the fact that consumers in one country do not gain utility from the environmental attributes of the other country. For example, the quality of water in one country may not enter into the utility function of a citizen of another country. We recognize that there are other examples for which attributes in foreign countries do matter to domestic consumers and could extend our model to account for this (see footnote 7).

and end up with a lower welfare level.[11] Note that since consumers behave competitively and hence collusion is ruled out, no single consumer can by himself prevent the decline in the environmental attributes (V_H) if the number of consumers (n) is large, since the amount of environmental attributes is determined by the aggregate expenditure on the environment (nE_H). In other words, as each individual decides to partake of the increased variety of consumable goods available, he/she *is cognizant* of his/her decreased expenditure on the environment and its implications. He/she, however, does not utilize the aggregate change (nE_H) in making choices. The problem arises, therefore, because of aggregate market effects rather than externality.

4. Conclusion

Proposition 1 recognizes trade as a *distinct* source of environmental degradation. In essence, the opening of trade implies an increase in commercial exploitation of the environment at the expense of environmental quality as long as consumers express some degree of substitutability between consumable goods and environmental goods.[12] Recall that in our model, variety adjusts to the opening of trade rather than prices as would be the case in the more conventional Heckscher-Ohlin genre of models. A model in which prices respond to the opening of trade would yield a similar story. The demand for foreign exchange would increase because of the greater availability of importables, thereby increasing the cost of maintaining the environment (i.e., the opportunity cost of conservation). An adjustment in the quantity of environmental attributes would then be expected.

Perhaps more importantly, proposition 2 argues that such deterioration could offset any gains from trade and leave the society in an inferior welfare position. This result

[11]The result may stem from the assumptions of increasing returns to scale and of monopolistic competition which deviate from the standard competitive equilibrium assumptions (see appendix 1).

[12]The previously mentioned arguments of Krutilla suggest that at some point in the future the parameter β may fall to zero in which case propositions 1 and 2 are no longer relevant.

depends explicitly on how individuals value the environment. Thus, another potential contribution of the model we present is that the parameters which define how consumers value the variety within the aggregate goods categories i.e., θ_H and θ_T, can be very telling. A possible extension of the present model is to introduce heterogeneous consumers such that θ_H and θ_T are variable across groups of individuals. The degree to which increased variety of consumer goods and the quality of the environment are valued may vary with income and levels of development of a particular nation or group within a nation. (Gladwin, Ugelow and Walter (1982) provide a discussion of income as a prime determinant of the demand for environmental quality.) For example, θ_T is big for those who face rather low standards of living and stand to increase their conditions via trade (with a large marginal gain in utility) e.g., the ivory poachers and cocaine producers. The microdynamics of peasant agriculture depicted in Perrings would imply a low θ_H for much of the rural sectors of less developed nations. θ_H on the other hand may be relatively big for those who have already achieved some subjectively adequate standard of living, e.g., members of groups like the Sierra Club.

In conclusion, it is not a profound observation that in a world where environmentalism is a luxury that many may not be able to afford, trade will continue to exacerbate resource degradation. However, our model leaves us with the bleak conclusion that even if their were knowledge of and concern about the environment, environmentally damaging, welfare-reducing trade might occur. This is a result of a *variety effect* of opening trade in the presence of environmental attributes which are viewed here as differentiated, non-traded goods.

Appendix 1: Determination of the number of products in a monopolistically competitive industry

Consider a monopolistically competitive industry. There is a continuum of potential firms producing differentiated products indexed by x, $x \in [0, \infty)$. With no loss of generality, we assume that each (monopoly) firm produces one product and the set of actually produced products is $[0, V], V \geq 0$. The quantity produced of product x is denoted by $q(x)$. The total cost of producing $q(x)$ units of product x is given by

$$TC(q(x)) = F + mq(x).$$

Therefore, to produce a product x requires a fixed cost of $\$F$ (the cost of developing the product and constructing the firm) and a constant marginal cost of $\$m$.

We assume that there are n identical consumers each endowed with $\$E$ to be spent on the products. Let $c(x)$ denote a representative consumer's consumption level of product x. The utility of the consumer is defined as

$$U = \left\{ \int_0^V [c(x)]^\alpha dx \right\}^{1/\alpha}, \qquad 0 < \alpha < 1,$$

which is a CES utility function with elasticity of substitution equal to $1/(1-\alpha)$. Denote by $p(x)$ the price of product x. Given the expenditure, E, the set of produced products, $[0, V]$, and the price of each product, $p(x)$, the consumer has to choose $c(x)$ for $0 \leq x \leq V$ to

$$\max \int_0^V [c(x)]^\alpha dx \qquad \text{subject to} \quad \int_0^V p(x)c(x)dx = E.$$

The first order condition implies that the consumer's demand function for product x is

$$c(x) = \left[\frac{\alpha}{\lambda p(x)} \right]^{1/(1-\alpha)}, 0 \leq x \leq V, \tag{12}$$

where λ is the Lagrange multiplier, which is not a function of x.

Given the constant elasticity demand function (12), the profit maximizing price is given by $p(x) = m/\alpha$. Because of the symmetry of the utility function and the constant price, $c(x)$ is constant. Substituting $p(x) = m/\alpha$ into the budget constraint, we have

$$c(x) = \frac{\alpha E}{mV}, \quad 0 \leq x \leq V.$$

The indirect utility function is given by

$$U = \frac{\alpha}{m} V^{\frac{1}{\alpha}-1} E. \tag{13}$$

Since there are n consumers, the profit of firm x is given by

$$\Pi(x) \equiv p(x)nc(x) - [F + mnc(x)] = \frac{nE}{V} - F - \frac{\alpha nE}{V} = \frac{(1-\alpha)nE}{V} - F.$$

Using the monopolistic competition equilibrium zero profit condition, $\Pi(x) = 0$, the equilibrium number of products is given by

$$V = \left(\frac{(1-\alpha)}{F}\right) nE. \tag{14}$$

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