ISSN 0819-2642
ISBN 0 7340 2540 8

THE UNIVERSITY OF MELBOURNE

DEPARTMENT OF ECONOMICS

RESEARCH PAPER NUMBER 884

NOVEMBER 2003

TRADE LIBERALIZATION, RESOURCE DEGRADATION AND INDUSTRIAL POLLUTION IN DEVELOPING COUNTRIES: AN INTEGRATED ANALYSIS

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Trade Liberalization, Resource Degradation and Industrial Pollution in Developing Countries: An Integrated Analysis*

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"Environmental damage" is in reality many different types of phenomena, each with a unique set of causes and characteristics. We present an analytical model identifying intersectoral and interregional links of economy and environment and explore consequences of trade policy and world price changes. The model contains explicit spatial and institutional features relevant to developing economies. We show that similar trade or policy shocks can have different effects, depending on initial economic structure, trade orientation and policies. Further, when there is more than one sectoral source of environmental damage, a policy or price shock may have unexpected environmental and welfare results.

Key Words: Trade policy, pollution, deforestation, developing countries.

JEL: F18, O24, Q28

* The authors would like to thank Peter Warr, Max Corden, seminar participants at the University of Melbourne, and participants at the European Association of Environmental and Resource Economists (Bilbao, Spain, June 2003) for their helpful comments on earlier drafts. Remaining errors are ours alone.

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1 Introduction

The links between trade and economic growth and the environment have generated a large literature in recent years. Economic growth and trade are thought to be related in a non-linear way (World Bank 1992; Grossman and Krueger 1993). The relationship can be teased apart into three strands: scale effects, associated with increases in the overall size of the economy; technique effects, due to changes in production technology; and composition effects, capturing induced changes in the structure of production and factor demand. Of these, the first is unambiguously negative (in the sense of creating more pollution or increasing demands on depletable natural resource stocks), and the second is most likely to be positive since new technologies are by and large cleaner than old. These have provided the theoretical basis for the notion of an 'environmental Kuznets curve (EKC)' as in, for example, Antweiler et al. 2001.

However, obvious difficulties in aggregating across environmental problems of different types mean that in practice, nearly all contributions to this literature address narrow subsets of environmental indicators, primarily industrial emissions contributing to air and water pollution. This approach may be adequate for highly industrialized economies. But in developing countries with relatively large resource sectors, the degradation of forest, land and water resources shares top billing or even outranks industrial pollution as a leading environmental problem (Jha and Whalley 1999; Asian Development Bank 1997). Given the sectoral specificity of many environmental phenomena, in developing economies interest in the trade-environment nexus shifts to the composition effect, about which there are no general prior hypotheses.

Because discussions of environmental and distributional effects of trade reform evoke strong political and emotive responses, there is a premium on theoretical and analytical rigor to guide empirical research and to draw policy conclusions. In their wide-ranging review of the literature on trade, growth and pollution, Copeland and Taylor (2003) have used a simple unifying model to address most of the key issues. They nevertheless emphasize the sensitivity of the results to economic structure, and recognizing that simplifications required to achieve theoretical rigor imply some loss of generality, deliberately limit the scope of their study and leave out issues relating to resource use or sustainability.[1] But these are issues of great importance for developing countries and need to be addressed.

The aim of this paper is to provide a similar unifying framework for analyzing the impact of trade policy changes on resource use *and* industrial pollution—both key components of environmental degradation— in a small developing economy. We present a simple general equilibrium model that captures interdependencies between resource degradation (such as deforestation) and industrial pollution arising from trade induced composition effects, in contrast to most analyses in this area that focus on either one or the other.[2] However, the economies with which we are concerned also typically exhibit other special features— such as a limited degree of spatial and sectoral factor mobility, and the absence or incomplete enforcement of property rights over natural resources—that can critically affect resource use and the environmental outcomes of trade. The design of our model also reflects these key stylized facts.

The model is used to illustrate the direct and indirect effects of manufacturing and agricultural trade policy changes, and to show how these outcomes are affected by institutional reforms in the area of property rights over natural resources such as forests. Specific characteristics of economic structure (together with the country's comparative advantage) are shown to be critical for environmental and welfare outcomes of policy changes. In some cases, both manufacturing and agricultural sector trade reforms can be broadly pro-environment, reducing both emissions and natural resource pressures. In others, trade reforms may cause industrial emissions and natural resource degradation to move in opposite directions. The results thus highlight tradeoffs that governments may have to confront in making policy choices. But the sensitivity of the results to economic structure, a point emphasized by Copeland and Taylor, underlines the pitfalls of over-generalization.

2 Model structure and assumptions

Our model captures some of the key stylized features of small developing economies, particularly those in tropical Asia, though its features are common to many other developing countries.[3] The economy comprises two sub-economies, manufacturing and agriculture. We make the following core assumptions:

1. Manufacturing (M) is a mini-Heckscher-Ohlin economy with mobile labor and capital, producing an import-competing, tariff protected good H, and an exportable X. X has a relatively high labor-to-capital ratio (ℓ). The low ℓ sector is pollution-intensive ('dirty'), while the other sector is 'clean'.[4] Industrial emissions, J, are produced in constant proportion to the output of H, i.e. $J = \beta y^H, \beta > 0$. The external costs of pollution are not internalized by dirty sector firms.
2. Agriculture (A) is a mini-Ricardo-Viner-Jones economy, in which the sectors are distinct sub-regions, 'upland' (U) and 'lowland' (F) with region-specific endowments of land, T in upland and N in lowland.[5] T and N differ due to variation in elevation, soil type, access to irrigation and other agro-climatic factors.[6] Labor is mobile between the two sectors. The lowland region produces import-competing 'food', whereas the upland, by assumption, produces plantation or 'tree crops' for export.[7]

3. The forest is an open-access resource that yields T through deforestation. To focus on the environmental benefits of forest we assumed it to produce only non-marketed outputs.[8] T is produced and maintained using labor L^T according to $T = L^T/\alpha$, where $\alpha > 0$□□□□□unit labor requirement. Thus the labor available for upland agricultural production is $L^U - \alpha T$.

We also assume that labor (L) is freely mobile among all activities and sectors; there are constant returns to scale, complete markets (except for environmental goods) and perfect competition in goods and factor markets. Consumers derive utility from consumption of marketed goods and environmental goods (standing forest and clean air). Environmental phenomena affect the economy only through consumer utility rather than through intersectoral effects on production costs.[9] Finally, to focus on the environmental stories we assume that tariff and tax revenues are redistributed to consumers in lump sum fashion.

By assumption, we have an economy with three sources of distortions: a tariff in the import-competing manufacturing sector, an absence of property rights in forests, and a missing market for pollution emitted by manufacturing sector firms. In principle, first best policies would imply moving to free trade while imposing Pigovian taxes on dirty sector firms, and enacting appropriate reforms to ensure that forest-related consumption externalities are fully internalized. But interesting policy issues arise precisely because in practice such first best policies are very difficult to implement. Hence it is useful to explore the effects of specific reforms in the continuing presence of one or more of these distortions.

Turning to the model, full employment of labor given competitive markets implies $L = L^U + L^F + L^M$. Prices (assumed exogenous) for each good are p^U and p^F for upland and lowland agriculture respectively, and p^H and p^X (= 1 by assumption) respectively for the import-competing (dirty) and exportable (clean) manufactures. The quantities of lowland land and manufacturing capital (K) are assumed exogenously fixed, but there is an endogenous supply of upland land. Using this notation we define revenue functions for each sector or region:

Lowland (food): $Q(L^F, N, p^F)$

Upland: $R(L^U - \alpha T, T, p^U)$

Manufacturing: $S(L - L^F - L^U, K, p^H)$.

These functions are non-decreasing and homogeneous of degree 1 in prices and endowments. By the envelope theorem their partial derivatives with respect to prices are sectoral outputs, and those with respect to factor endowments are shadow factor prices. Their sum is equal to total value added, I:

$$I = Q(L^F, N, p^F) + R(L^U - \alpha T, T, p^U) + S(L - L^F - L^U, K, p^H) \tag{1}$$

We capture consumer preferences and behavior with a conditional expenditure function, in which the quantities of industrial emissions and the amount of standing forest cleared for agriculture are assumed given. Letting **p** stand for the vector (p^F, p^U, p^H, 1):

$$E = E(\mathbf{p}, J, T, \upsilon) \tag{2}$$

This embodies all the information on the preferences of a utility-maximizing representative consumer with utility function $\upsilon(F, U, H, X; J, T)$, with $\upsilon_j > 0$ for all $j \in (F, U, H, X)$, $\upsilon_J \leq 0$, □□□ $\upsilon_T \leq 0$. To simplify the analysis we assume that utility is separable between marketed goods and environmental goods (bads).

By the properties of the revenue and expenditure functions and the envelope theorem, R_U is the supply of upland output, Q_N is the shadow value of lowland, E_H is domestic demand for import-competing manufactures, E_T is the negative of willingness to pay for standing forest, E_υ is the reciprocal of the marginal utility of income, and so on.[10] Finally, recall that the initial domestic price of H is increased by a tariff, given by $t^H = p^H - \overline{p}^H$, where a bar over a variable indicates the world price in domestic currency terms.

Given the optimizing behavior represented by the revenue and expenditure functions, the aggregate budget constraint of this economy is:

$$E = I + t^H(E_H - S_H) \tag{3}$$

There is full employment in equilibrium, so the usual marginal productivity condition for labor requires that the following conditions hold:

$$Q_L = R_L \tag{4}$$

$$R_L = S_L \tag{5}$$

$$R_T - \alpha R_L = 0 \tag{6}$$

Condition (6) ensures that in the upland sector, labor used in land clearing and in production are of equal value at the margin. It is thus a property of the model that since labor is the only input to land clearing, any shock that raises labor productivity in upland production also generates pressures for deforestation.[11] The solution to equations (3) to (6) yields equilibrium values of real income, L^F, L^U, and T, each as a function of ($\mathbf{p}$, t^H, L, N, K). From these we can calculate changes in L^M as well as sectoral and regional outputs, the wage, and industrial emissions. So long as the production of land from forest is a linear function of labor alone, however, we can obtain all the comparative static results of interest by solving (5) and (6) for L^F and L^U; this also gives L^M by the labor constraint and $T = L^U/\alpha$ by the production function for agricultural land in the uplands. For price changes, comparative static results are obtained by totally differentiating (4) and (5), holding all factor endowments except land constant, to yield:

$$\begin{bmatrix} Q_{LL} & -R_{LL} \\ S_{LL} & (R_{LL} + S_{LL}) \end{bmatrix} \begin{bmatrix} dL^F \\ dL^U \end{bmatrix} = \begin{bmatrix} -Q_{LF}dp^F + R_{LU}dp^U \\ S_{LH}dp^H - R_{LU}dp^U \end{bmatrix}, \tag{7}$$

in which the sign of $|\Delta|$, [illegible] is quickly established as $Q_{LL}(R_{LL} + S_{LL}) + R_{LL}S_{LL} > 0$. Comparative static results are obtained using Cramer's rule.

3 Welfare and environmental effects of trade policy reforms

Effects of manufacturing tariff liberalization

In this model, a price shock in one sector alters economy-wide resource allocations, and so affects the production of each type of environmental damage, with economy-wide labor mobility and capital mobility within manufacturing as the adjustment mechanisms. Consider first a tariff reform. A *ceteris paribus* tariff reduction in the capital-intensive manufacturing sector raises the return to labor and causes out-migration of workers from agriculture. From (7), with $dt^H < 0$:

$$dL^F = \frac{1}{\Delta} R_{LL} S_{LH} dt^H < 0 \tag{8}$$

$$dL^U = \frac{1}{\Delta} Q_{LL} S_{LH} dt^H < 0 \tag{9}$$

By substitution into the full employment constraint (with $dL = 0$) we also know:

$$dL^M = -\frac{1}{\Delta} S_{LH}\left(Q_{LL} + R_{LL}\right) dt^H > 0, \tag{10}$$

Tariff reduction, by raising labor productivity in manufacturing relative to that (measured at initial wages) in other sectors, results in labor migration to manufacturing from agriculture. This leads to the following proposition concerning environmental damages:

Proposition 1 (Tariff reform): Reducing the tariff on the polluting manufacturing sector, with labor mobile across all sectors and capital mobile within manufacturing, reduces both industrial pollution and deforestation, and raises consumer welfare.

Because H is capital-intensive, a reduction in its relative price causes X to expand, driving up wages. Output contraction in H results in a drop in emissions, i.e. $dJ < 0$. Labor moves out of agricultural sectors, and since $dT = \alpha dL^U$, upland deforestation diminishes. Thus reducing the tariff is an environmental win-win policy move— even with open access forest stocks.

The real income effect of a small change in the tariff is found by totally differentiating (3), using (2) and (1) and setting changes in the exogenous prices and quantities equal to zero. Defining net imports $Z_H = (E_H - S_H)$, and using (4) – (6) to eliminate some terms, we obtain:

$$\gamma d\upsilon + E_J dJ + E_T dT = t^H Z_{HH} dt^H - t^H S_{HL} dL^M \tag{11}$$

where $\gamma = E_\upsilon - t^H E_{H\upsilon} > 0$ and $dL^M = -(dL^F + dL^U)$. The first term on the left hand side provides a measure of change in the real income of the representative consumer; the second and third terms capture the utility effects of changes in each of the environmental variables. If we ignore environmental damages for a moment by setting $E_J = E_T = 0$, then (11) provides a measure of real income change due to the tariff change. The first term on the right hand side conveys the familiar deadweight loss of protection due to reallocation of resources within the manufacturing sector. Since $Z_{HH} = (E_{HH} - S_{HH}) < 0$, this term is positive for $dt^H < 0$. The second term captures an additional efficiency change due to the reallocation of labor between manufacturing and agriculture. For a tariff reduction this signed term is also positive. In sum, real income must increase when trade is liberalized. Finally, we know that both $dT < 0$ and $dJ < 0$ for a tariff reduction, so since $E_J \leq 0$ and $E_T \leq 0$, a broad measure of consumer welfare, consisting of the sum of all three terms on the left hand side of (11), is unambiguously increased by trade liberalization. [12]

In Appendix A we reinterpret (11) in proportional changes of variables, revealing that the magnitude of the environmental and welfare changes due to the tariff depends on the size of *H* in relation to overall income and expenditures, the tariff as a percentage of p^H, the capital-intensity of *H* relative to manufacturing as a whole, the elasticities of domestic excess demand for *H* with respect to own price, and the elasticity of the economy-wide wage with respect to p^H.

<u>Multilateral agricultural trade policy reforms</u>

The Doha round of world trade talks includes proposals for the major industrialized food exporters to reduce subsidies paid to their own farmers. These measures, if implemented, would raise world prices of most agricultural products, with a predicted price rise of 11% (Diao et al. 2001). Global trade reforms could thus impose potentially large terms of trade shocks on developing economies, with consequent impacts on domestic prices and resource allocation. This motivates our second and third experiments, in which for analytical purposes we divide the global price shock into a component affecting grain prices and another component affecting all other agricultural prices. What are the effects of this terms-of-trade shock?

By the same method as in the tariff change example, the labor market effects of an autonomous increase in the lowland agricultural price ($dp^F > 0$) are:

$$dL^F = -\frac{1}{\Delta}\big(Q_{LF}(R_{LL} + S_{LL})\big)dp^F > 0 \tag{12}$$

$$dL^U = \frac{1}{\Delta}Q_{LF}S_{LL}dp^F < 0 \tag{13}$$

$$dL^M = \frac{1}{\Delta}Q_{LF}R_{LL}dp^F < 0\,. \tag{14}$$

A rise in the lowland price causes labor to migrate out of uplands and manufacturing. In the latter sector, the labor market response causes an unambiguous drop in the output of the labor-intensive sector and a corresponding rise in that of the capital-intensive sector. In our model, lowland agriculture is a 'clean' industry producing import-competing goods. A first reaction would be to predict a loss in real income offset by gains from reduced environmental damage. The story, however, is not so neat.

Proposition 2 (food price rise): Raising the price of lowland agriculture, with labor mobile across all sectors and capital mobile within manufacturing, reduces real income and has indeterminate effects on aggregate environmental quality.

The labor market response shown in (12) to (14) is clear, and from this it can readily be deduced that the price shock results in a contraction of upland production, so $dT < 0$. The flow of labor from manufacturing, however, reduces output in the clean manufacturing sector and thus, with a fixed capital stock, raises it in the dirty sector, so $dJ > 0$. The total net environmental impact is ambiguous as different regions will experience contrasting effects.

The real income effect of the rise in p^F is given by:

$$\gamma d\upsilon + E_J dJ + E_T dT = -Z_F\, dp^F + t^H(E_{HF} dp^F - S_{HL} dL^M)$$

(15)

For t^H taking small values, a rise in p^F has a direct real income effect in which consumer losses are proportional to food imports. This first-order effect is modified by second-order terms capturing, respectively, higher tariff revenues due to substitution in consumption between *F* and *H*, and in manufacturing, an increase in tariff-related losses due to the expansion of *H* and contraction of *X*. The first of these effects increases real income; the second reduces it. Unless the first of these tariff-related effects dominates both the other and the first-order income effect, which is improbable, real consumer income must fall. Whether the broader definition of welfare, inclusive of environmental changes, rises or falls depends on the relative importance placed on damages from deforestation versus those from industrial pollution.

The second component of a global price shock concerns exportable agricultural products, which we assume to be grown in uplands only. For an increase in the upland food price ($dp^U > 0$) we have the following labor market responses:

$$dL^F = \frac{1}{\Delta} R_{LU} S_{LL} dp^U < 0 \qquad (16)$$

$$dL^U = -\frac{1}{\Delta} R_{LU} (Q_{LL} + S_{LL}) dp^U > 0 \qquad (17)$$

$$dL^M = \frac{1}{\Delta} R_{LU} Q_{LL} dp^F < 0. \qquad (18)$$

These results provide an indication of the likely direction of output changes, and motivate proposition 3.

Proposition 3 (Upland price rise): The welfare effect of an increase in the price of upland agriculture, with labor mobile across all sectors and capital mobile within manufacturing, is ambiguous as it increases real incomes but also increases both forms of environmental damage.

Raising the upland price produces a positive real income effect through the terms of trade, but unambiguously increases deforestation as upland agriculture expands through in-migration of labor. But this is only the direct environmental impact. Less obviously, this intersectoral migration also contributes to an increase in industrial pollution. At constant relative prices of manufactured goods, the lower labor endowment of manufacturing as a whole causes X to contract, drawing capital and labor into H; the dirty manufacturing sector thus expands and the clean sector contracts.

Taking the total differential of (3) with respect to p^U, holding the tariff, factor endowments and other product prices constant, gives:

$$\gamma d\upsilon + E_J dJ + E_T dT = -Z_U dp^U + t^H(E_{HU} dp^U - S_{HL} dL^M)$$

(19)

The symmetry with the lowland case is clear. For an exportable, domestic excess demand $Z_U <$ 0, so the first expression on the right hand side is a positive direct terms of trade effect. Indirectly, the price change causes both expenditure and M sector resources to switch toward H. As before, these have opposed signs, so their net effect must be small in relation to the first-order impact through Z^U. Hence real income should increase except in the most anomalous case. The environmental losses are clearer: dT is positive (i.e. deforestation increases), reflecting the higher value of upland agricultural land, and the transfer of M sector resources into H makes manufacturing more emissions-intensive, i.e. $dJ > 0$.

No additional calculations are necessary to see the joint effects of global price shocks affecting both categories of agricultural product. From the foregoing, real income may rise or fall, and pressures on forests may increase or decline. The only unambiguous result is that any and all reforms raising agricultural prices draw labor out of the manufacturing sector, with the result there that the labor-intensive clean industry contracts, and the capital-intensive polluting industry expands. (The same result is obtained if an identical product is produced in both agricultural regions.) In these cases, whether deforestation will rise or fall, will depend on the extent to which manufacturing releases labor as agricultural product wages rise. If labor supply from manufacturing is relatively elastic (inelastic), it is more (less) likely that higher agricultural prices will have a large land-clearing effect, as the wage effect of agricultural expansion in this case will be relatively small (large). In a nutshell, the environmental consequences of agricultural trade policy reforms at the global level will depend on initial economic structure.

<u>Home country agricultural trade reforms</u>

Many developing countries are net food importers and protect their domestic food sectors. Their accession to the WTO in the past decade has required them to relax this protection in some degree. With minor modifications to account for domestic tariff revenues, the terms of trade analysis just presented provides predictions of the effects of domestic agricultural policy reforms. Redefining the domestic price vector so $p = (\overline{p}^F + t^F, \overline{p}^U + t^U, \overline{p}^H + t^H, 1)$, the aggregate budget constraint is rewritten as $E = I + \mathbf{t'Z}$, where $\mathbf{t'Z}$ is the inner product of the tariff vector and the vector of excess demands for F, U and H. Then the effects of changes in t^F and/or t^U are found by total differentiation as before. The results differ from terms-of-trade shocks by the exclusion of first-order welfare effects a world price change, and inclusion of second-order terms capturing tariff distortions and the extent to which output in each sector responds to a change in labor endowment.

From (4) and (5), the labor market impacts of tariff reforms in agriculture follow by substitution of tariff changes for price changes. The aggregate budget constraint, ignoring variables held constant at their initial values, is:

$$E(\mathbf{t},J,T,\upsilon) = Q(L^F,t^F) + R(L^U,T,t^U) + S(L^M,t^H) + \mathbf{t'Z_j} \tag{20}$$

for $j \in (F,U,H)$. Taking the total differential with respect to the agricultural tariffs gives:

$$\begin{aligned} E_\upsilon(1-\mathbf{t'E_{j\upsilon}})d\upsilon + E_J dJ + E_T dT = \mathbf{t'Z}_{jj}dt^j &+ (t^H S_{LL} - t^F Q_{LF})dL^F \\ &+ (t^H S_{LL} - t^U R_{LU})dL^U \end{aligned} \tag{21}$$

In this expression, the first term on the right hand side is the standard welfare loss due to an increase in a tariff, and is negative (positive) for dt^j > (<) 0. The other two terms in parentheses are both non-positive, so the overall sign depends on changes in L^F and L^U. Solving for changes in labor demand due to tariff reductions, analogously to the procedure shown in (7) to (10), gives $dL^F/dt^F < 0, dL^U/dt^F > 0, dL^M/dt^F > 0,$ and $dL^F/dt^U > 0$, $dL^U/dt^U < 0, dL^M/dt^U > 0$. Hence the prediction of aggregate real income change (with $E_J = E_T = 0$) is indeterminate. By the same logic used earlier, the environmental consequences are $dT/dt^F > 0, dJ/dt^F < 0$ for a reduction in t^F, and $dT/dt^U < 0, dJ/dt^F < 0$ for a reduction in t^U. Lowering the tariff on lowland crops increases deforestation but reduces industrial pollution, while lowering that on upland crops reduces both. If the two occur together, industrial pollution will unambiguously diminish, but the deforestation rate may rise or fall. The following table summarizes these results:

	Tariff change		
	$dt^F < 0$	$dt^U < 0$	Both

dL^F	< 0	> 0	?
dL^U	> 0	< 0	?
dL^M	> 0	> 0	> 0
dJ	< 0	< 0	< 0
dT	> 0	< 0	?

Tariff reduction in upland agriculture yields conventional real income gains, and reduces both forms of environmental damage—a win-win outcome. Lowland tariff reduction may increase deforestation but is otherwise economically and environmentally desirable.[13]

Geometric illustration

The intuition underlying the above analyses can be presented geometrically. In Figure 1 the central panel (b) shows the economy-wide labor market. The width of the panel denotes the economy's total labor endowment; employment in agriculture is measured to the right from 0_A, and that in manufacturing to the left from 0_M. Labor demand curves for the *M* and *A* sub-economies are constructed by horizontal addition of those for the respective sectors, as shown. In the initial equilibrium, the economy-wide wage (w) is given by the intersection of L_A and L_M.

The right-hand panel (c) shows unit cost (i.e. zero profit) curves for each manufacturing sector in factor price space (Mussa 1979). Note that the wage is set economy-wide, rather than purely within the manufacturing sector. Product prices and the wage determine the set of feasible manufacturing industries and the location of their unit cost curves. The (negative of the) aggregate capital-labor ratio in manufacturing is shown by the line $\ell\ell'$; an increase in the ratio increases the slope of this line, and a ratio higher than the slope of a line tangent to c_H at the intersection of the unit cost curves (point *G*) implies specialization in capital-intensive production.[14] For given wage and prices, with both goods being produced, we can read off the equilibrium return to *M* sector capital, r_M, on the horizontal axis.

In the left-hand panel (a) we show the analogous curves for the two agricultural sectors. The horizontal axis shows unit returns to land in each agricultural region, r_U and r_F. These are not required to be equal, though for convenience we have chosen units of land so as to equate them in the initial equilibrium.

Absence of property rights in upland land means that profit-maximizing upland producers use upland land up to the point at which its <u>average</u> product is equal to average cost (Gordon 1954). We can capture this in the figure, by interpreting the curve L_A in panel (b) as the horizontal sum of labor demands in lowland and upland agriculture, noting that under open access to forests, upland labor demand exceeds the quantity that would be observed if property rights were enforced. In the initial equilibrium, open access means that there is overuse of labor in upland; were property rights enforced, the total labor demand curve in agriculture would lie to the left of L_A.

In manufacturing, because we assume that producers in the dirty industry are not penalized for emissions, free disposal of air and water pollutants leaves producers on their marginal curves, while producing a negative social externality.

To illustrate the working of the model, let the labor-intensive manufacture, *X*, be the numéraire good and set $p^X = 1$. Consider an increase in the price of upland agriculture, p^U. As shown in panel (b) of Figure 2, this displaces the demand for upland labor vertically upwards by the amount of the price rise, and aggregate agricultural labor demand curve is increased by the price change times the upland share of agricultural labor. With no change in manufacturing prices, the aggregate labor market response is clear: labor is withdrawn from manufacturing and moves into agriculture; within agriculture, it is reallocated from lowland to upland production.

As a result of the price change, production in upland agriculture rises and that in lowland falls. For the lowland, where the quantity of land is fixed, the output change is proportional to the reduction in labor use at the new, higher wage. For the upland, we suppose that new land may be brought into production; however, as long as the labor required for forest conversion is directly proportional to that required for upland production, the change is still proportional to the corresponding labor demand shift. Returns to land in each agricultural region are altered, as seen in panel (a); that in upland must rise, and that in lowland fall.

At the original wage and price levels, the withdrawal of labor from *M* has predictable resource allocation effects. The aggregate labor-capital ratio in manufacturing falls (in terms of Figure 1, the line $\ell\ell'$ becomes steeper) and the labor-intensive sector contracts, while *H* expands. This is not an equilibrium, however, as the increase in upland labor demand also exerts upward pressure on the wage. With constant output prices, the productivity of labor in *M* must rise to match the wage increase. As a consequence of the wage increase the *M* sector's aggregate labor demand falls and the L_M curve in panel (b) moves to the right. The final labor market equilibrium, depending on the extent to which the *M* industries in aggregate release labor, will be an economy-wide labor allocation lying between L^1 and L^2, with a wage between w^0 and w^1. In manufacturing, both the quantity and price effects of the economy-wide labor market adjustment will reduce the output of the labor-intensive sector; the output of the capital-intensive sector may rise or fall. The return on *M* sector capital must also fall.

The environmental effects of the agricultural price increase can be inferred from the diagram. In manufacturing, dirty output has expanded relative to clean, so the overall emissions-intensity of manufacturing has risen. Whether *total* emissions rise or fall depends on whether or not the dirty sector has expanded in absolute terms. The price rise for upland raises the return to labor used in clearing forest along with that of labor used in production. Looking across the economy as a whole, the price rise is an environmental lose-lose outcome (more deforestation, more emissions) if *H* expands, or a lose-win outcome if *H* contracts.

Thus when there is more than one source of environmental damage, and when these are associated with activities in distinct sectors of the economy, the net effects of a policy or price shock may differ from its direct effect. It may confer an environmental benefit in the directly affected sector but may indirectly confer a benefit or a loss another sector. This point is not captured in models where 'environmental damage' refers to a single phenomenon such as forest loss or industrial pollution.

In summary, this analysis indicates that under some circumstances trade liberalization – specifically, the reduction of import tariffs on polluting industries, or of protection for agricultural industries operating at the forest frontier – is capable of generating a win-win-win outcome of reduced deforestation, reduced intensity of industrial emissions, and increased consumer welfare. These predictions are robust for the structure of the economy as we have assumed it; the magnitudes of these effects will of course depend on the extent to which factor demand in each sector is responsive to changes in the economy-wide wage.

Reform of property rights

The open access nature of property rights in the forest sector leads to overexploitation of forests and establishment of well-defined property rights is considered an important component of the institutional reform agenda in developing countries. Recall from the discussion of Figure 1 that because there is open access to forests for conversion to upland land, the privately optimal labor allocation in upland agriculture equates average, rather than marginal costs and returns. Thus the curve L_A in panel (b) of the figure is equal to the horizontal sum of labor's value marginal product in lowland agriculture and its *average* product in upland. It follows that enforcing property rights in forests, which reduces the rents earned from land-clearing, displaces the L_A curve to the left—in the limiting case, to the point at which it is simply the sum of the upland and lowland *marginal* (i.e. labor demand) curves, and property rights in forest are fully enforced. In panel (c), an increased labor endowment and lower economy-wide wage will once more reduce the overall emissions-intensity of manufacturing production, and — if these effects are large enough that *H* output contracts absolutely— even reduce it in absolute terms. Thus the establishment of property rights in forestland will tend to reduce both deforestation *and* urban pollution in this case, even though forestlands will continue to remain undervalued as long as their full environmental benefits are not reflected in their land values.

4 Economic structure and environment: some stylized Asian economies

The core model outlined in section 2 is capable of a number of permutations, each reflecting a different economic structure and set of policies. It can be easily adapted, for example, to model a range of economic structures seen in developing Asia, where recent developments in resource-rich countries such as Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and increasingly, Vietnam provide a laboratory of sorts for the comparative study of the interaction of growth, trade, policy reforms, and environment. Though these economies shared many similarities in resource and factor endowments and economic structure in the past, they differ markedly today in terms of their state of development and economic structure (Table 1). Some, for example, are important food exporters (Thailand and Vietnam) while others are net importers (who typically protect their food sectors); some continue to have extensive (though rapidly diminishing) forests

(Indonesia, Malaysia) while others (Thailand, Philippines) have almost entirely destroyed their forests. However, they all face common problems in terms of rising industrial pollution, deforestation and other forms of natural resource degradation. In this section we briefly sketch how the model can be used to provide insights into the interaction between trade, resource degradation and industrial pollution in different structural and policy settings.

The differences in economic structure among Asian developing countries can be attributed in part to past differences in policy regimes. Historically, all countries taxed agriculture, particularly export agriculture, to finance industrialization (though import-competing food agriculture received some protection). But the net price-increasing effects of food import restrictions and related interventions were insufficient to offset the prevailing anti-agriculture bias of industrial promotion policies (Krueger et al 1988). These policies have changed greatly over time, though the pace and scope of changes has varied widely among countries. In a very significant shift, however, this policy bias was inverted almost universally in the 1990s, as significant progress was made in the liberalization of manufacturing but not agricultural import trade restrictions. Current WTO rules bind import tariffs for manufactures, but are considerably more lenient where developing country agricultural imports are concerned. As a result, very high levels of protection for cereals have persisted in Asia even after major trade reforms in other sectors and rice, corn, and other staples are now among the region's most heavily protected commodities (WTO 1998-2001).[15]

There has also been massive expansion of industrial plantations in many parts of tropical Asia, stimulated by liberalization of trade and investment. In Southeast Asia, the area planted to coffee has risen by more than 300% since 1980, while for oil palm the increase is more than 500%.[16] New land for expanding crops has been obtained primarily through the conversion of forests, where enforcement of property rights remains costly and controversial (Gérard and Ruf 2001; Vincent et al. 1997). Deforestation rates in tropical Asia are the world's highest (Table 2).

One adaptation of the model in section 2 is to the case of an economy producing import-competing food in both agricultural regions, in addition to the two types of manufacturing industry, capital-intensive ISI and labor-intensive exportables. This configuration is a stylization of many developing Asian economies, of which the Philippines is an excellent example. In this type of economy, a tariff on capital-intensive manufactures increases the relative profitability of ISI production, and labor and capital are transferred to the protected sector; its output goes up, and the manufacturing sector as a whole becomes more emissions-intensive. Within manufacturing, however, the tariff raises the return to capital and lowers that to labor in the usual Stolper-Samuelson fashion. With a constant food price, labor is drawn into agriculture with lower wages. The cost of land-clearing for upland agriculture falls, so the tariff also increases deforestation pressures. Net migration of labor into uplands, as a response to declining productivity and earnings potential in manufacturing, is a well-documented feature of ISI regimes (e.g. Cruz and Francisco 1993); the tariff is one factor contributing to the increased population pressure on upland resources that is often identified as a cause of deforestation.

This type of economy usually exhibits agricultural protectionism, often rationalized by concerns about food security. Higher food sector protection draws labor out of manufacturing, and the model tells us that the labor-intensive, export-oriented manufacturing industry will experience the largest relative output decline. Both upland and lowland agriculture will expand. Lowland, however, is constrained by a fixed land endowment; in uplands, the higher food price increases the return to forest clearing to create new lands. In Asia, high and increasing rates of protection for corn and other cereals grown largely in uplands and non-irrigated areas has been associated with agricultural expansion at the forest margin (Coxhead, Shively and Shuai 2002; Coxhead 2000). Thus the protection for food producers increases deforestation and reduces the output of labor-intensive manufactures. The emissions-intensity of manufactures rises, but overall industrial pollution may rise or fall since the sector as a whole will contract.

The combination of industrial protection and agricultural protection in this type of economy thus favors both emissions-intensive industrial development and deforestation at the upland agricultural margin.

A variant is the tropical economy in which upland agriculture produces primarily industrial crops for export (Indonesia is an example of such an economic type). As in the earlier case, the land frontier is open in the sense that forest can be freely converted for agricultural expansion, in spite of negative externalities generated by forest clearing.[17]

With tree crops exportable, manufacturing protection in this economy again releases labor to both agricultural sectors.[18] Protection for lowland agriculture (food), in this economy, causes the lowland region to expand, raising labor demand; this promotes down-slope migration and discourages deforestation at the upland frontier. As before, the protection for food producers also draws labor out of the manufacturing sector, reducing the relative size of the exportable goods sector and increasing emissions-intensity. By comparison with the first example, in this case agricultural protectionism tends to diminish pressures on forests.

A third variant is that in which lowland agriculture produces an export rather than an import-competing product. This is the case with Thailand and Vietnam. In both economies, industrial protectionism has the same effects as already described. Additions to the labor force must find employment in agriculture rather than industry, and with an open land frontier, this leads to deforestation, and this is precisely what has been observed in both countries. This process ended in Thailand in the 1990s, after several decades of unfettered harvesting of forests both for timber and agricultural land, during which time forest cover diminished dramatically. In Vietnam, 'push' migration of this kind was apparent in the 1980s and early 1990s.

In both economies, trade and related policy reforms have seen huge increases in manufacturing sector activity, especially in the most labor-intensive industries. In the Thai case, with expansion concentrated in the labor intensive manufacturing sector, this has been accompanied by extraordinary rates of outmigration from the countryside, and especially from the forest frontier areas, with the total agricultural area diminishing by more than 10% between 1989 and 1996 (Coxhead and Plangpraphan 1999). In Vietnam, however, where trade liberalization raised incentives for both labor intensive manufacturing, but perhaps even more so for export agriculture (given further stimulus by an international coffee price boom), the opening of the economy caused a land race at the forest frontier. Between 1989 and 2000, Vietnam's harvested coffee area increased by a factor of more than one hundred, from 42,000 ha to 477,000 ha[19] as the country became the world's second-largest coffee exporter, and other crops such as mulberry and tea have also experienced rapid area growth (Ha 2001).

These sketches, although obviously incomplete, nevertheless indicate ways in which apparently minor variations in economic structure can be associated with very substantial differences in the influences that similar policy reforms exert on the use of environmental and natural resources. If nothing else, they do indicate clearly that even within a relatively homogeneous subset of developing resource-rich economies, there are no grounds for supposing the existence of a common set of environmental and natural resource depletion trends in the course of economic growth. They also suggest some tentative conclusions concerning development with incomplete property rights in natural resources. Open access to forest is a more severe problem when other labor-intensive sectors in the economy fail to grow. A capital-intensive industrialization strategy may induce composition effects that increase not only industrial emissions, but also deforestation. Pro-environment development strategies inherently address more than one target, and as such must involve more than one instrument.

5 Concluding remarks

Debate on the environmental effects of trade liberalization in developing countries remains intense, but theorizing on the underlying economic forces at work lags behind the empirical literature. The model in this paper is a tool for understanding the multi-dimensional environmental consequences of such policy changes. These can have intersectoral effects, whose signs and magnitudes are determined by the initial structure of the economy being examined. The same policy shock could well have opposed environmental effects in two different economic types. This finding undermines analyses of the trade-growth-environment relationship that rely on generic characterizations of economic structure. A second finding is that different types of environmental damage—in our example, industrial emissions and deforestation—respond in different ways to economic shocks. A third point is that when environmental externalities coexist with policy-induced distortions, partial policy liberalization may have negative effects on aggregate welfare or on environmental problems.

None of these findings are novel to trade theorists, but they have yet to emerge as clearly understood facets of economy-environment relationships in developing economies. These analytical results can also play an important role in highlighting the limitations of reliance on oversimplified models in the trade-environment literature— for example Deacon (1995), which suggests that trade liberalization will necessarily be anti-environment.

The model we have presented can be extended in a number of areas to address several other important issues, such as the impact of opening economies to international capital flows. The model can also more explicitly incorporate various types of intersectoral production externalities and issues related to internal market segmentation in factor and goods markets. Most importantly the insights from this model can be utilized in evaluating the environmental outcomes of various exogenous shocks and policies in more richly specified applied general equilibrium models.

Appendix A

Equation (11) in elasticity form

Ignoring the two environmental terms on the left hand side, equation (11) relates changes in consumer real income directly to changes in the tariff, and indirectly to intersectoral labor flows induced by the tariff change. Of these, the direct term is negative; the indirect term is of indeterminate sign. The magnitudes of both are of interest when we consider the tariff experiment across economies with different initial structure (relative size of sectors, etc). Converting from absolute to relative changes of variables yields expressions whose parameters are readily given economic interpretation. Taking the direct tariff term first, we have

$$t^H Z_{HH} dt^H = t^H \frac{\partial Z_H}{\partial p^H} dt^H$$

$$= t^H \cdot \varepsilon^H \frac{Z_H}{p^H} dt^H$$

where ε^H is the elasticity of excess demand for H w.r.t. own price. Dividing (11) by initial total expenditure E gives, for the direct tariff term:

$$\varepsilon^H \cdot \frac{Z_H}{E} \cdot \frac{t^H}{p^H} \cdot dt^H, \tag{A.1}$$

which is the elasticity of excess demand (< 0) times excess demand as a fraction of total expenditures, times the tariff as a fraction of domestic price, times the tariff change. The direct tariff effect will be larger, the greater in absolute value is each of these terms.

The indirect term can be similarly reinterpreted:

$$t^H S_{HL} dL^M = t^H \frac{\partial S_H}{\partial L^M} dL^M,$$

then using Hotelling's lemma to obtain $S_H = y^H$, the output of sector H, and Young's theorem we have:

$$t^H \frac{\partial y^H}{\partial L^M} dL^M = t^H \frac{\partial w}{\partial p^H} dL^M$$

or, after dividing through by E and some minor manipulation,

$$\frac{t^H}{p^H} \cdot \varphi^{LH} \cdot \frac{wL^H}{E} \cdot \lambda_{LH}^{-1} \frac{dL^M}{L^M}, \tag{A.2}$$

where $\varphi^{LH} < 0$ is the elasticity of the wage with respect to p^H, and λ_{LH} is the share of H sector in total manufacturing employment. The sign of dL^M/L^M is determined in general equilibrium by the simultaneous solution to equations (3) to (6), and will depend on the relative magnitudes of the tariff-induced changes in relative prices and wages. If $dL^M/L^M > 0$, the migration of additional labor into manufacturing as the result of the tariff exacerbates the existing misallocation of resources in the economy, and thus further reduces real income. Expression (A.2) says that the welfare loss from labor transfers due to the tariff is greater, the higher is the tariff in relation to domestic price, the greater is the (absolute value of the) wage elasticity, and the larger is the wage bill in H in relation to total income. The effect is diminished in proportion to share of H sector employment in total manufacturing employment. For E_J and $E_T \neq 0$, the overall welfare effect of the tariff depends on these direct and indirect real income effects as well as endogenous changes in J and T.

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Table 1: GDP growth rates and shares (%) of major sectors, selected Asian countries

Country	GDP growth[a]	Years	Agric.	Industry	(*Mfg*)	Services
Indonesia	3.97	1960-80	42	23	*10*	35
		1981-90	22	37	*16*	40
		1991-00	18	43	*24*	40
Malaysia	4.12	1960-80	29	30	*14*	41
		1981-90	20	39	*21*	41
		1991-00	13	42	*27*	45
Philippines	1.04	1960-80	28	31	*23*	41
		1981-90	24	36	*25*	40
		1991-00	20	32	*23*	48
Thailand	4.34	1960-80	29	25	*17*	46
		1981-90	17	33	*24*	50
		1991-00	11	39	*29*	50
Vietnam	5.37[b]	1960-80	..	..	..	..
		1981-90	40	29	*26*	32
		1991-00	29	30	*20*	41
Sri Lanka	2.99	1960-80	30	24	*17*	47
		1981-90	27	27	*15*	46
		1991-00	23	26	*16*	50

a. Real per capita income (1995 US$), annual average 1970-2000. b. 1991-2000.
.. = not available. Source: World Bank: *World Development Indicators 2001*

Table 2: Estimated changes in natural forest and plantation cover

Region	1990 ('000 ha)		2000 ('000 ha)		Average annual change of natural forest	
	Nat. forest	Plantation	Nat. forest	Plantation	'000 ha	Per cent
Africa	697,882	4,415	641,828	8,038	-5,589	-0.8
Oceania	36,201	149	34,869	263	-133	-0.4
S. America	903,199	7,279	863,739	10,455	-3,946	-0.4
Asia	495,340	56,117	431,422	115,873	-6,392	-1.3
—Tropical	289,820	22,486	233,448	54,624	-5,637	-1.9
—Temperate	205,520	33,631	197,974	61,249	-755	-0.4

Source: World Resources Institute calculations from FAO data (Matthews 2001).

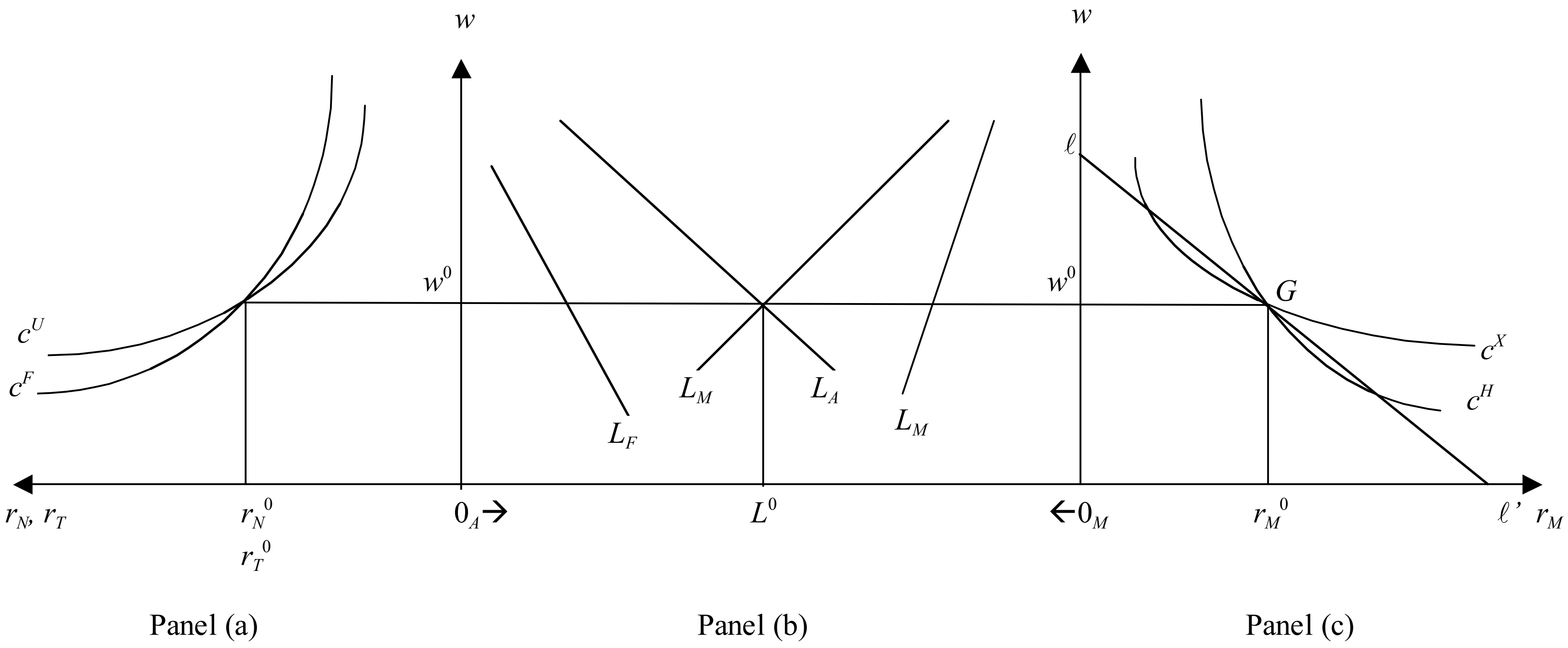

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FIGURE 1

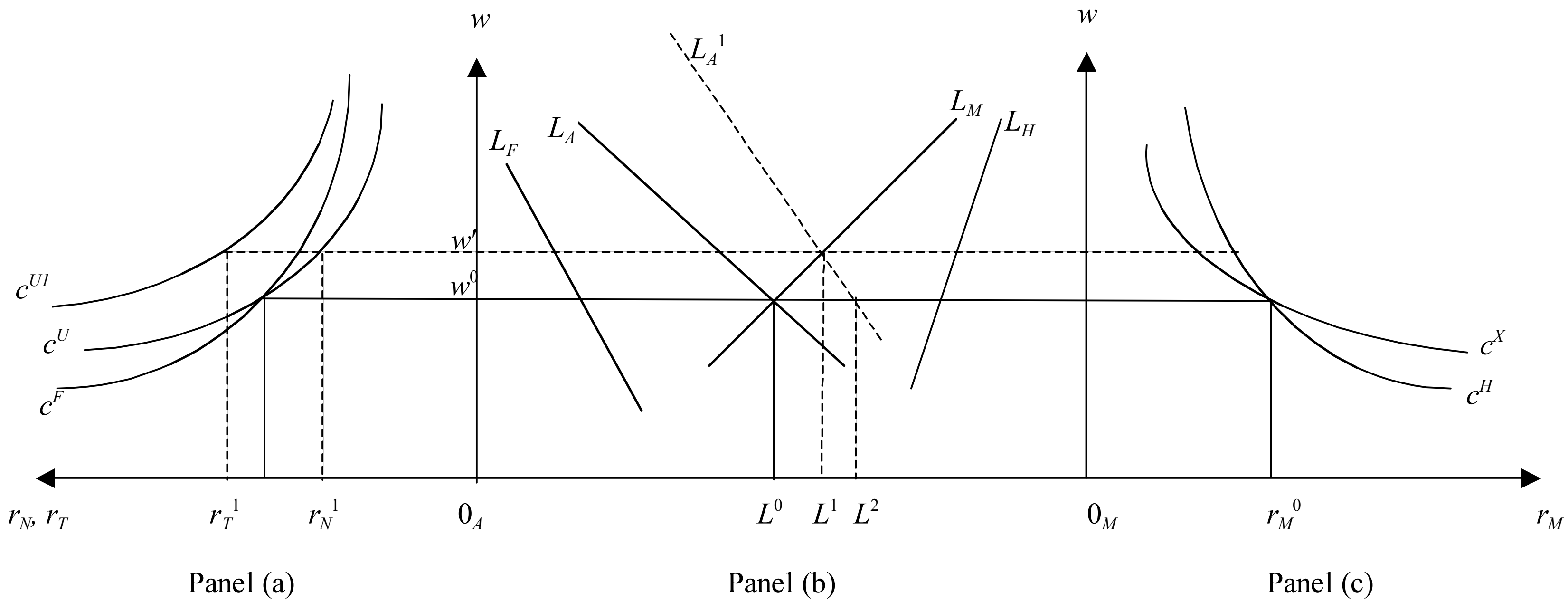

FIGURE 2: INCREASE IN UPLAND AGRICULTURAL PRICE

Notes

[1] "One large omission from our review is any explicit discussion of renewable or non-renewable use of resource use or sustainability... but an analysis of trade's impact on resource use will take us too far afield". (Copeland and Taylor, 2003:5).

[2] See Copeland and Taylor (1999) for a model in which industrial emissions degrade the natural resource base, and Bandara and Coxhead (1999) for analysis of the effects of soil erosion on industrial production costs through impacts on hydro power production.

[3] The model and analysis in this section is a substantive variation on that in Coxhead and Jayasuriya (2003). Some of its features, notably the modeling of forest clearing in upland, are drawn from Lopez and Niklitschek (1991).

[4] This assumption that protected capital-intensive industries in developing countries is more pollution intensive is consistent with evidence from several developing countries, such as Philippines and Thailand (see Coxhead 2000b).

[5] The spatial separation of upland and lowland can be exploited to yield richer model specifications that generate insights into impact of enhanced domestic market integration in previously segmented labor and goods markets.

[6] In most Asian countries, rice, the main food staple, is grown primarily in low lying, fully or partially submerged land (that is often irrigated), while 'uplands' or 'dry lands' are cultivated to perennials— often tree crops like tea, rubber and oil palm— as well as to food crops under rain-fed conditions. Conversion of 'uplands' to 'lowlands' is technically feasible but costly, sometimes prohibitively so, and even when converted differences in key agro-climatic factors result in continuing productivity differences that justify treating these as essentially two different land types.

[7] These products, especially in the Asian tropics, include beverages such as tea, coffee and cacao, oil palm, and other industrial crops. Later in the analysis we assume instead that the two regions may both produce the same good ('food'), in which case an identical product is produced in two technologically distinct sectors.

[8] We do not address the widely analyzed case of the impact of higher timber prices on forests. Our key point is that any reduction of virgin forest leads to environmental losses.

[9] This can be easily relaxed; see Copeland and Taylor (1999). Coxhead and Jayasuriya (2003) also explore intersectoral production externalities in a similar model.

[10] As a notational convention we write the derivatives of *Q, R, S* and *E* with respect to prices using the symbols for each sector, for example $E_M = \partial E/\partial p^H$, $E_{HF} = \partial^2 E/\partial p^H \partial p^F$, and so on. Derivatives with respect to factors or output prices are written (for example) $R_T = \partial R/\partial T$.

[11] This assumption is made for convenience only, and an extension to the model could provide for labor-land substitution in upland. Coxhead and Jayasuriya (2003) model upland production with more than one output and different factor proportions.

[12] If there were non-traded final goods in the economy, there would be additional substitution terms in (6) due to endogenous price changes. These are explored in Coxhead and Jayasuriya (2003, Chapter 4).

[13] In countries with *diversified* upland sectors—producing both food and export crops—tariff reduction could have a pro-forest effect as well, if export crops are less land-intensive and do not produce other forms of environmental damage (see Coxhead and Jayasuriya 2003).

[14] Output in each of the *M* sectors can also be computed from the diagram, by drawing lines tangential to each unit cost curve at the point of intersection and calculating sectoral employment shares of capital and labor along each axis. See Mussa (1979).

[15] For example, in the Philippines the effective manufacturing protection rate declined from 32% to 15% between 1990 and 2000, whereas that for agriculture fell only from 32% to 24%. In 2000, the Philippines' implicit tariff on rice and corn was 43% while the median value for manufactures other than food processing was under 10% (Aldaba and Cororaton 2003).

[16] Source: FAO data accessed at www.fao.org/faostat, January 17 2003.

[17] Such negative externalities with transboundary dimensions are especially pertinent in the Indonesian case, where widespread forest burning to establish oil palm and other plantations since the late 1990s has generated significant pollution in the form of smoke, or 'haze' in neighboring countries as well as through much of Indonesia itself.

[18] The rate of expansion at the frontier depends on tree-cutting technology and in a more sophisticated model, it would matter whether the forests had previously been logged, and thus made more readily accessible to colonizing farmers; see Angelsen (1995).

[19] Source: FAO data accessed at www.fao.org/faostat, January 17 2003.