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Trade and Tax Policy Reform and the Environment: The Economics of Soil Erosion in Developing Countries

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Increasing awareness of the importance of environmental factors for the sustainability of economic growth has focussed attention on the environmental consequences of policy reforms in developing countries. However, the analytical literature on the environmental impact of such changes is sparse (Cruz and Repetto 1992). In the presence of different levels of environmental externalities associated with different industries, simple economic policy reform prescriptions aimed at reducing relative price distortions can potentially aggravate environmental damages and, through both direct and indirect effects, hamper long term growth. In this paper we consider the environmental effects of policy reforms on the case of soil erosion in hilly lands, a major problem in many developing countries.

Most analyses of this problem argue that solutions must be sought in upland areas themselves, in new technologies, altered practices, reduced in-migration, more secure tenure institutions and stronger controls over resource use. While these direct approaches are undeniably important, they almost entirely overlook the potential role of relative price changes. This is surprising, given the large body of evidence showing that shifts in relative prices and profitability can induce substantial resource reallocation in agriculture, even in developing economies (Askari and Cummings 1976). Upland agricultural economies cannot be considered to exist in isolation from the rest of a developing economy, let alone from other agricultural regions and subsectors drawing on overlapping resource bases and producing similar goods. Moreover, the effects of upper watershed soil erosion on water quantity and quality directly impact on lowland agriculture, hydroelectric power generation, and availability of clean water.

In this paper we investigate the role played by intersectoral and interregional market links as conduits for relative price changes affecting upland agricultural resource use. Using a simple model we evaluate the likely impacts on upland resource allocation of some changes in commodity taxes and trade policies currently under discussion in developing countries.

We adopt a general equilibrium approach to the analysis, for two main reasons. First, environmental protection is not the only - or even the most pressing - issue confronted by the governments in developing countries. This means that policies aimed at reduced soil erosion are likely to be adopted only when the costs in terms of other, potentially overriding targets (most notably GNP growth, external balance, cheap wage goods and tolerable public sector deficits) are not too high. Our policy experiments constitute searches for "good" environmental policies that are also consistent with other economic policy goals. Such searches cannot satisfactorily be conducted in a partial equilibrium setting.

Second, in addition to problems of sustainability in upland agriculture, the nature of the soil erosion problem involves an externality, the deterioration of downstream land and water resources due to dam siltation, flooding and diminished water quality. Analyses of comparable situations suggest Pigovian taxes on upland farmers as first-best means to equate private and social rates of return on erosion-causing activities. The appropriate rate of a tax on a polluting activity would be sufficient to reduce its level without introducing distortions elsewhere in the economy. However, the Pigovian solution is infeasible in most developing countries, first because of the difficulty of associating particular quantities of pollution with particular farms (the non-point pollution problem), and second because of the practical difficulties in assessing and collecting taxes on small-scale, semi-subsistence farmers who are among the poorest groups in their country's economy.[1] In practice, developing country governments rely heavily on indirect taxes - primarily trade taxes - as relatively easily collected forms of revenue. Workable market-based solutions to upland soil erosion must perforce work with these second-best policy instruments. Trade taxes, unlike production taxes and subsidies, alter both producer and consumer prices even when there are no non-traded goods, so again we conclude that a single-sector analysis is inappropriate.

The analytical problem is compounded in developing countries by the presence of substantial existing price distortions, most notably in the form of existing tariff structures. There are therefore two sources of divergence between private and social rates of return to soil-eroding activities: price distortions and externalities. When externalities are present, the standard policy prescription of removing price distortions to correct incentives need not be an optimal one in a welfare sense.

In a companion paper (Coxhead and Jayasuriya 1994) we examine the effects of technical progress on the allocation of upland land among crops associated with different rates of soil erosion in a stylized two-region developing economy. In this paper we employ a structurally similar model to analyze the intersectoral effects of trade and tax policy changes on changes in upland agricultural resource allocation, and thus on rates of upland soil erosion.

In the following sections we first present the model (Section 2). We outline a stylized small, open developing economy with tariff-distorted prices and examine alternative policy changes for their likely effects on upland land allocation between crops, and therefore on the rate of erosion. For a range of policy changes we assess changes in real incomes, the price of food, and the allocation of upland land to food production. Subsequently, in Section 3 we present numerical simulations of policy changes and upland resource allocation. Section 4 concludes the paper with a brief discussion of our results and some suggested directions for policy-oriented extensions to this research.

2. The Model

In developing the model we focus on the issue of soil erosion in uplands,[2] and abstract from many dimensions of the soil degradation problem in order to highlight some key economy-wide relationships which come into play when trade or tax policies are altered. We also abstract from property rights issues. In our model upland land can be used to grow either an annual crop, food, or perennial tree crops, with the latter associated with markedly lower relative rates of soil erosion. This stylization summarizes empirical information from sloping uplands of developing countries showing typical annual per hectare soil losses from established perennials to be one or two orders of magnitude less than those for most annual crops.[3]

In the model, at a given level of measured national income a reallocation of upland land from annual food crops to perennial tree crops is considered to be welfare-improving, as the resulting land use pattern would generate lower soil erosion. To focus on changing profitability and its impact on land allocation among crops, we assume that cultivation of a particular crop is associated with a given rate of soil erosion which cannot be altered in the short run; in other words we abstract from the possibility that changes in relative crop profitability would lead to changes in the level of investments in land conservation rather than in the areas devoted to the competing crops.[4] On similar grounds we ignore the related and potentially important effect of changing land values on soil conservation investments and hence on overall soil degradation.[5] This is a complex problem and addressing it even in partial equilibrium would require a much more elaborate model.[6]

The model presents a representative developing economy in which three goods are produced and consumed: import-competing manufactures, exportable tree crops and non-traded food.[7] Food is produced in two sectors, one in the lowland region and one in the upland. The coexistence of two food production technologies is a stylized fact that fits very well with the fundamental differences between lowland irrigated and upland rainfed agriculture in developing countries. In *lowland*, monocrop agriculture produces food only, using labor and sector-specific land. Food is also produced in *upland*, where it competes for (upland) land with tree crops. Thus although only three goods are produced, the formal model has four *sectors*.[8] We begin by setting out and analyzing economic structure in upland and lowlands regions separately. Subsequently we introduce the food market clearing condition linking the regional economies.

Regional economies

Each sector uses two factors of production. Labor is used in all sectors, but due to short-run immobility upland and lowland labor cannot be substituted for one another (this dual labor market assumption is relaxed in simulation experiments in Section 3). Upland land and labor are freely mobile between upland food and tree crop production. Lowland land is specific to the lowland food sector. The manufacturing sector also uses a specific factor, capital. We assume competitive factor and commodity markets. Analytically, the upland region is a standard 2x2 Heckscher-Ohlin economy (Jones 1965). The lowland region is the familiar 2-good, 3-input specific factors economy (Jones 1971).

Regional production and factor demands are shown as (1') - (6') in Table 1. Factor demand functions (1'), (2'), (4') and (5') are the first-order conditions of technology-constrained cost minimization by a representative producer in each sector. Zero profit conditions (3') and (6') state that after-tax revenues are exhausted in factor payments. Factor market clearing conditions (7') state that upland and lowland labor and upland land are all fully employed in the regions to which they belong. The other factors -- capital in manufacturing, and land in lowland agriculture -- are immobile in the short run; each is thus fully employed in a single sector. Commodity pricing conditions (8') relate the domestic price of each tradable commodity to world prices, modified by tariffs or export taxes. Lastly, we allow for food production to be taxed at different rates in each region. Equation (9') states that the producer price of food in each region is equal to the aggregate market-clearing food price less a region-specific production tax.

The model in Table 1 contains 19 equations and 31 variables. For our analysis we choose the following variables to be exogenous: regional labor endowments N^R, the upland land endowment K^U, lowland capital endowmentsK^j $(j = L, M)$; world market prices of tradables P^*_j; and tax and tariff rates s_r and t_j, a total of 11 variables. For the model to be exactly identified we must determine the value of one more variable, the economy-wide price of food, P_F. This price is determined by an aggregate food market clearing condition which will be discussed below (equation (15)). For the moment it is convenient to think of P_F as exogenous to producers in eitehr region.

Our interest lies in the impacts of tax and tariff changes on the allocation of upland land between food and tree crops, and by extension, on the rate of upland soil erosion. These can be approximated by expressing the model in terms of proportional changes of variables, then solving for changes in endogenous prices and quantities resulting from tax and tariff changes. As noted above, in this part of the analysis we assume labor to be immobile between upland and lowland regions. The correct short-run characterization of the labor market in any developing economy is an empirical question; however, some form of dual labor market assumption is maintained, explicitly or otherwise, in most current theorizing on agricultural land degradation and soil erosion.[9] In numerical simulations later in the paper we allow for migration to take place, i.e. for the labor market to clear across both regions. Given the structure of sectoral relative factor intensities, we find our results to be robust with respect to these two widely different labor mobility assumptions.

Let the proportional change in any variable X be denoted by a caret, so $\hat{X} \equiv dX/X$. The proportional change forms of (1') - (9') in Table 1 are given by (1) - (9) below. Because each sector uses only two factors there is just one free parameter in each, the elasticity of substitution σ_j. The share of factor i in the total costs of sector j is given by θ_{ij}. In (7), λ_{ij} denotes the share of sector j in employment of factor i. In (8), changes in domestic prices of the two tradable commodities are set by changes in world prices and in trade taxes, denoted by $\hat{T}_j = (1+t_j)$, where $j \in \{X,M\}$. Finally, in (9) the net change in the producer price of food grown in each region is equal to the sum of the change in the economy-wide food price and changes in sector-specific production taxes, given by $\hat{S}_r = (1-s_r)$, where $r \in \{U,L\}$.

$$\hat{N}_j = \hat{Y}_j - \theta_{Kj}\sigma_j(\hat{W} - \hat{R}) \qquad j \in \{U,X\} \tag{1}$$

$$\hat{K}_j = \hat{Y}_j + \theta_{Nj}\sigma_j(\hat{W} - \hat{R}) \tag{2}$$

$$\hat{P}_j = \theta_{Nj}\hat{W} + \theta_{Kj}\hat{R} \tag{3}$$

$$\hat{N}_h = \hat{Y}_h - \theta_{Kh}\sigma_h(\hat{V} - \hat{Q}_h) \qquad h \in \{L,M\} \tag{4}$$

$$\hat{K}^h = \hat{Y}_h + \theta_{Nh}\sigma_h(\hat{V} - \hat{Q}_h) \tag{5}$$

$$\hat{P}_h = \theta_{Nh}\hat{V} + \theta_{Kh}\hat{Q}_h \tag{6}$$

$$\lambda_{NU}\hat{N}_U + \lambda_{NX}\hat{N}_X = \hat{N}^U \tag{7.1}$$

$$\lambda_{NL}\hat{N}_L + \lambda_{NM}\hat{N}_M = \hat{N}^L \tag{7.2}$$

$$\lambda_{KU}\hat{K}_U + \lambda_{KX}\hat{K}_X = \hat{K}^U \tag{7.3}$$

$$\hat{P}_j = \hat{P}_j^* + \hat{T}_j \qquad j \in \{X,M\} \tag{8}$$

$$\hat{P}_j = \hat{P}_F + \hat{S}_j, \qquad j \in \{L,U\} \tag{9}$$

Equations (1) and (2) describe factor demand changes in each upland sector in terms of changes in commodity outputs and in the relative prices of upland land and labor. An equivalent analysis applies for lowland sectors in (4) - (6). By the Stolper-Samuelson theorem, changes in regional factor price ratios reflect shifts in relative producer prices (equations (3) and (6)). Producer price changes are in turn determined by changes in taxes, tariffs, world prices and, in the case of food, domestic supply and demand. We now consider the partial equilibrium impacts of changes in tariffs and taxes on resource allocation and factor pricing in the two regions. The analysis is partial equilibrium because for the moment we ignore endogenous food price changes caused by adjustments in aggregate demand and regional supplies. In order to focus on policy changes we assume zero growth in factor endowments, setting $\hat{N}^U$, $\hat{N}^L$, $\hat{R}^U$, $\hat{R}^L$, and $\hat{R}^M$ equal to zero. For brevity we concentrate on expressions relevant to land allocation in uplands, since by assumption these bear directly on the erosion rate.

Using (1) - (7) we obtain reduced form expressions for proportional changes in sectoral outputs and relative factor prices in terms of exogenous changes in taxes, tariffs, world prices of tradables, and the price of food. Taking the difference between the two upland sector zero profit conditions (3) we find that relative factor price changes in upland are directly related to relative commodity price changes, modified by any commodity taxes:

$$(\hat{W} - \hat{R}) = \frac{1}{\theta}(\hat{P}_F - \hat{P}_X + \hat{S}_U - \hat{T}_X), \tag{10}$$

where $\theta = (\theta_{NU} - \theta_{NX}) > 0$ if upland food production is labor-intensive relative to treecrop production (Jones 1965). A rise in the price of tree crops relative to food reduces wages relative to land rents; an identical effect is obtained by an increase in the tree crop export subsidy ($\hat{T}_X > 0$) or an upland food production tax ($\hat{S}_U < 0$).

Next, using (8) and (9) we solve for output changes in upland sectors as:

$$\hat{Y}_U = \varepsilon^U_{FF}(\hat{P}_F - \hat{P}_X + \hat{S}_U - \hat{T}_X) \tag{11}$$

$$\hat{Y}_X = -\varepsilon_{XX}(\hat{P}_F - \hat{P}_X + \hat{S}_U - \hat{T}_X), \tag{12}$$

where $\varepsilon^U_{FF} > 0$ and $\varepsilon_{XX} > 0$ are own-price supply elasticities of upland food and treecrops. A rise in the relative price of tree crops reduces food production and increase tree crop production. At constant prices the same output changes are achieved by increasing the rate of the export subsidy relative to that of the food production tax.

Using (10) - (12) we can solve (1) and (2) for upland factor demands in terms of changes in commodity prices and fiscal instruments. In the case of the change in demand for land in upland food production, for example, this substitution yields:

$$\hat{N}_U = \varepsilon_{NU}(\hat{P}_F - \hat{P}_X + \hat{S}_U - \hat{T}_X), \tag{13}$$

where $\varepsilon_{NU} = \varepsilon^{U}_{FF} + (\sigma_U \theta_{NU}/\theta) > 0$.[10] Other things equal, the area of upland land devoted to food crops is reduced by a relative food price decline. At constant prices, increasing the export subsidy relative to the food tax will also result in a reduction in food land demand. Expression (13) shows how *direct* sectoral instruments -- upland food production taxes or tree crop export subsidies -- can reduce the use of upland land for food production by increasing the relative profitability of tree crops. Moreover, if the upland and lowland economies were independent, these would be the *only* price policies available as instruments of environmental policy in uplands.

We now relax the requirement that the price of food remain constant. As we will show below, this price responds endogenously to tax and tariff shifts, so signs and magnitudes of factor demand responses to policy changes depend greatly on the response of the food price to the same changes. Suppose, for example, that the treecrop export subsidy were increased by 1%, so $\hat{T}_X = 1$. From (13), with no change in world prices or the other policy variables, the change in upland land demand with respect to the subsidy would be:

$$\frac{\hat{N}_U}{\hat{T}_X} = \varepsilon_{NU}\left(\frac{\hat{P}_F}{\hat{T}_X} - 1\right).$$

Similar expressions can of course be obtained for the other policy changes; all reveal that in order to predict the impact of a policy change on the use of upland land for food production it is necessary first to know the effect of the same change on the price of food.

The food market

For political economy reasons most developing country governments insulate domestic markets for staple foods from international price movements. To reflect this we now suppose that food is not traded internationally; accordingly, the food price P_F is determined entirely in domestic markets. This food pricing rule is critical to the results obtained in the analysis, since it is through endogenous adjustments in the food price relative to prices of tradables that policy changes in one region affect resource allocation, production and input prices in *both* regions. The food market thus provides a conduit through which changes in taxes and tariffs levied on lowland sectors affect upland land allocation. This regional link expands the set of economic policy instruments having the potential to affect upland resource allocation. It also creates the possibility that, through indirect impacts on upland commodity and factor prices, price policy reforms apparently unrelated to the upland region might produce "unexpected" environmental consequences.

The general equilibrium change in the price of food depends on supply changes in both regions as well as on changes in food demand, which itself depends on changes in commodity prices as well as in the incomes of consumers. For simplicity we assume food to be homogeneous, so consumers make no distinction by the region in which it is produced.

Income-constrained utility maximization by a representative consumer (or several consumers having identical homothetic preferences) is summarized by an expenditure function $E(P,U)$ in the vector of commodity prices P and utility, where $U = U(C)$. Total income in each region is summarized by a revenue function $G^r(P^r)$, where $r = \{U,L\}$; each P^r, a subset of P, contains the prices of goods produced in region r (e.g. $P^L = (P_M, P_F)$). Since we suppose tariffs to be non-zero in initial equilibrium, additional income is generated from tariff revenues. If these are returned to consumers then the aggregate budget constraint can be written as the equality of expenditures and disposable income:

$$E(P,U) = G^L(P^L) + G^U(P^U) + t_M P_M^* (E_M - G_M^L) \tag{14}$$

where subscripts on E and G indicate partial derivatives of these functions with respect to the subscripted prices. By Shephard's lemma $E_j = C_j$ is consumer demand for j, and $G_j^r = Y_j$ is production of commodity j in region r. We can now write the market clearing for food in terms of the derivatives of the revenue and expenditure functions:

$$E_F(P,U) = G_F^U(P^U) + G_F^L(P^L). \tag{15}$$

Equations (14) and (15), with (1') - (9'), form an exactly identified general equilibrium system solving for endogenous factor demands and prices, commodity supplies and domestic prices, and the utility level of the representative consumer. Market-clearing conditions (7.1')-(7.3') ensure full employment of factors; (14) ensures equality of aggregate expenditure and income, and (15) requires that the food market is in equilibrium. By Walras' law, when these conditions are satisfied trade is also in balance. In proportional changes of variables, the same exactly identified system is given by (1)-(9) and (depending on which policy is being changed) either (19), (24), (29) or (34) below.

The general equilibrium impact of a small change in a tariff or tax on real income and food price is found by totally differentiating (14) and (15), using the price definitions in (8) and (9). The effect of each policy change on upland land demand is then found by substituting the general equilibrium change in the price of food with respect to that policy into (13). We explore four policy changes: a tariff increase, an export subsidy on tree crops, a food production tax in uplands, and a lowland food production subsidy.

Tariff Increase

To study the *ceteris paribus* effect of a tariff change we take the total differentials of (14) and (15), holding constant all policies other than the tariff. We define the change in real income as $dY = E_U dU$, where E_U is the inverse of the marginal utility of income. We denote excess demand for each commodity -- that is, net imports $(E_j - G_j)$ -- by Z_j. We further note that $E_{FU} = C_F E_U$ and $E_{MU} = C_M E_U$. Lastly, in order to focus on the policy change we let the prices of tradables be fixed and choose units so that initially $Y = P_F = P_X^* = P_M^* = 1$. This implies that quantities in each sector are equal to their GNP shares. It also follows from this choice of units that $P_M = 1 + t_M$. Real income and food price changes in response to a tariff increase are then found from the solution to the simultaneous equation problem:

$$\begin{bmatrix} 1 - t_M C_M & -t_M Z_{MF} \\ C_F & Z_{FF} \end{bmatrix} \begin{bmatrix} dY \\ dP_F \end{bmatrix} = \begin{bmatrix} t_M Z_{MM} d(1+t_M) \\ -Z_{FM} d(1+t_M) \end{bmatrix} \qquad (16)$$

The determinant of the coefficient matrix is $|A| = (1 - t_M C_M) Z_{FF} + t_M C_F Z_{MF} < 0$ in stable models (Dixit and Norman 1980)[11], so when the tariff rate is increased:

$$dY = |A|^{-1} t_M \{ Z_{MM} Z_{FF} - Z_{MF} Z_{FM} \} d(1+t_M) < 0 \tag{17}$$

and

$$dP_F = -|A|^{-1} \{ (1-t_M C_M) Z_{FM} + t_M C_F Z_{MM} \} d(1+t_M) \gtrless 0. \tag{18}$$

In an economy with existing tariff distortions, raising the tariff unambiguously reduces real income.[12] The tariff rise has two contradictory effects on food prices. First, it induces substitution between food and importables in consumption and production; this effect, captured by Z_{FM} in (18), is positive as long as F and M are net substitutes. The tariff increase also causes real income to decline, which reduces food demand; this effect is captured by the second term in (18), and is larger for a higher initial tariff rate. However, unless the income effect is so large as to outweigh the substitution effect, increasing the tariff will raise the relative price of the nontraded good, food (Dornbusch 1974; Edwards and van Wijnbergen 1987).

Returning to the effects of the tariff change on regional economies, it is clear that a higher tariff rate will reduce food production in lowlands, where manufacturing and agriculture compete for lowland labor. What will happen to food production and land demand in uplands? To find out, we express (18) in proportional changes of variables and substitute the resulting expression for the general equilibrium food price change (19) into (13), the change in upland land allocated to food production. Expressed in proportional changes, (18) becomes:

$$\hat{P}_F = -|A|^{-1} \{ \zeta(\beta_{FM} - \delta_L \varepsilon_{LM}) + t_M(\rho_M \beta_{MM} - \gamma_M \varepsilon_{MM}) \} \hat{T}_M \, , \tag{19}$$

where : $$|A| = \frac{C_F Y}{P_F} \left\{ \zeta(\beta_{FF} - \sum_r \delta_r \varepsilon_{rF}) - t_M(\rho_M \beta_{MF} - \gamma_M \varepsilon_{MF}) \right\} < 0 \qquad (r = L, U)$$

$\beta_{ij} = (\partial C_i / \partial P_j)(P_j / C_i)$ is the elasticity of demand for good i w.r.t price j;

$\varepsilon_{ij} = (\partial Y_i / \partial P_j)(P_j / Y_i)$ is the elasticity of supply of good i w.r.t price j;

$\delta_r = Y_r / (Y_L + Y_U)$ is the share of region r in total food production;

$\rho_M = C_M / Y$ is consumption of importables as a share of total expenditure;

$\gamma_M = Y_M / Y$ is domestic production of importables as a share of GNP; and

$\zeta = (1 - t_M \rho_M) > 0.$

As before, the first term on the r.h.s of (19) is the price effect of a shift in the excess demand curve for food; the second term is the real income impact of the tariff change. Substituting (19) into (13) gives the general equilibrium change in upland food land allocation:

$$\frac{\hat{N}_U}{\hat{T}_M} = \varepsilon_{NU}\frac{\hat{P}_F}{\hat{T}_M} \gtrless 0. \tag{20}$$

Evaluating (19) and (20) together it can be seen that raising tariffs tends to increase upland food land area through substitution effects in consumption ($\beta_{FM}>0$) and in lowland production ($\varepsilon^{L}_{FM}>0$), since manufacturing protection draws labor out of lowland food and reduces its supply. This effect has a greater food price impact if a large fraction of total food supply comes from lowland ($\delta_L \rightarrow 1$). The positive substitution effect is diminished by a negative income effect, the size of which is governed by the initial degree of trade distortion (t_M), the elasticities of excess demand for importables, and the size of the importables sector in relation to GNP. Both substitution and income effects are scaled by the upland food supply elasticity ε_{NU}, which describes the extent to which resources are transferable between *upland* sectors. If we accept the presumption that substitution effects dominate in (19) then the tariff will raise food prices and cause upland land to shift into food production.

Treecrop Export Subsidy

The second example, an export subsidy for the tree crop sector, provides an incentive for producers to switch resources from food to tree crop production. The subsidy is initially zero, so unlike the tariff it generates deadweight losses and fiscal costs only at the margin. The incremental fiscal cost of the subsidy, and of distortions associated with its effects on relative prices, will thus be negligible and can reasonably be ignored in order to simplify the analysis. Taking the total differential of (14) and (15), with all policy instruments except the export subsidy held constant, yields:

$$\begin{bmatrix} 1-t_M C_M & -t_M Z_{MF} \\ C_F & Z_{FF} \end{bmatrix} \begin{bmatrix} \mathrm{d}Y \\ \mathrm{d}P_F \end{bmatrix} = \begin{bmatrix} -(Z_{XX} - t_M E_{MX})\mathrm{d}(1+t_X) \\ -Z_{FX}\mathrm{d}(1+t_M) \end{bmatrix} \tag{21}$$

from which we obtain solutions for real income and food price changes:

$$\mathrm{d}Y = -|A|^{-1}\{Z_{FF}(Z_{XX} - t_M E_{MX}) + t_M Z_{MF} Z_{FX}\}\mathrm{d}(1+t_X) > 0 \tag{22}$$

and

$$dP_F = -|A|^{-1}\{(1-t_M C_M)Z_{FX} - C_F(Z_{XX} - t_M E_{MX})\}d(1+t_X) > 0. \tag{23}$$

Equation (22) shows that the subsidy unambiguously increases aggregate real income, so long as we ignore its fiscal cost.[13] The income effect in (23) is thus positive; moreover, the subsidy causes resources to be drawn out of upland food production. Both effects raise the food price. To find the effect on upland land demand we once again write (23) in proportional changes:

$$\hat{P}_F = -|A|^{-1}\{\, \zeta(\beta_{FX} - \delta_U \overset{U}{\epsilon}_{FX}) - (\rho_X\beta_{XX} - \gamma_X\varepsilon_{XX} - t_M\rho_M\beta_{MX})\}\hat{T}_X ; \tag{24}$$

substituting this into (13) we find:

$$\frac{\hat{N}_U}{\hat{T}_X} = \varepsilon_{NU}\left(\frac{\hat{P}_F}{\hat{T}_X} - 1\right) \gtrless 0. \tag{25}$$

With no change in the price of food the subsidy reduces $\hat{N}_U$. However, the possibility exists for a paradoxical result in which the export subsidy increases the food price by so much that upland food area actually *increases*. The likelihood of this outcome is small and depends on a high income elasticity of food demand and a large food supply contraction; nevertheless it is clear that the export subsidy will not have the full effect intended as long as it engenders increases in both aggregate income and the food price.

Food Sector Policies

We next consider the impacts of direct taxes or subsidies on food production sectors. Food taxes reduce aggregate real income and, in addition, raise the price of food by causing food sector output in the region to which they are applied to decline. Subsidies achieve the opposite price and production outcomes, but their effects on real income are ambiguous since subsidies alter tariff revenue through cross-price effects in production. As in the export subsidy case considered above, we assume that when the only initial distortion is the tariff, the direct net revenue effects of the production taxes or subsidies will be negligible and may be ignored.

Upland production tax The appropriate rate of a tax on upland food production could in principle reduce erosion to a socially acceptable rate by aligning private and social profitability in that sector. However, a production tax on upland food would not unambiguously reduce upland food area. Its effect on upland land use would depend on the extent to which the tax caused the economy-wide food price to increase, and on the consequent lowland supply response. If we consider $d(1-s_U)$ in the total differentials of (14) and (15), holding world prices and other policies constant, we obtain:

$$\begin{bmatrix} 1-t_M C_M & -t_M Z_{MF} \\ C_F & Z_{FF} \end{bmatrix} \begin{bmatrix} dY \\ dP_F \end{bmatrix} = \begin{bmatrix} G_F^U P_F d(1-s_U) \\ G_{FF}^U P_F d(1-s_U) \end{bmatrix} \tag{26}$$

from which:

$$dY = |A|^{-1}\{Y_U P_F Z_{FF} + G_{FF}^U t_M P_F Z_{MF}\} d(1-s_U) \gtrless 0 \tag{27}$$

A food production tax imposed in uplands ($d(1-s_U) < 0$) reduces aggregate welfare by deadweight losses associated with the tax, as shown by the first term in braces in (27). However, the tax causes imports imports to increase, both because the lowland food sector expands, causing labor to flow out of manufacturing, and because consumer demand switches toward manufactures. Both effects are summarized in the net excess demand parameter Z_{MF}.

The effect of the upland food tax on food prices is also ambiguous:

$$dP_F = |A|^{-1}\left\{(1-t_M C_M) G_{FF}^U - C_F G_F^U\right\} P_F d(1-s_U) \gtrless 0. \tag{28}$$

As with the tariff change, the upland food tax has two contradictory effects on food price. The upland food sector contracts (the first term in braces) which increases P_F, and aggregate income declines, which reduces it. To observe the effects on upland land we once again convert (28) into proportional changes and substitute into (13), to obtain:

$$\hat{P}_F = |A|^{-1}\{\zeta \varepsilon_{UF} - \rho_F\} \delta_U \hat{S}_U , \tag{29}$$

$$\frac{\hat{N}_U}{\hat{S}_U} = \varepsilon_{NL}\left(\frac{\hat{P}_F}{\hat{S}_U} - 1\right) \gtrless 0. \tag{30}$$

As (30) shows, taxing upland food production will reduce upland food land area, except in the event that the food price increase it causes is very large. At best the impact of the tax will be less than would be predicted by a partial equilibrium policy analysis in which food prices were assumed to be unaffected by changes in upland production.

Lowland food production subsidy The distribution of public expenditures for irrigation, infrastructure, extension, R&D and input subsidies is substantially biased towards lowland agriculture in nearly every developing country. In recent decades, productivity gains from "green revolution" high-yielding cereal varieties were captured almost entirely by lowland farmers, particularly those with access to irrigation. The supply effect of this technical progress caused cereal prices to fall; profits on the technologically lagging upland farms declined as a result. The green revolution thus contributed to a slowing in the rate of expansion of annual food crops in uplands (Coxhead and Jayasuriya 1994). To a profit-maximizing producer, technical progress is equivalent to a price rise. In our final experiment, therefore, we consider a subsidy on lowland food production. Totally differentiating (14) and (15) as before, with $d(1-s_L) > 0$ and holding world prices and other policies constant, we obtain:

$$\begin{bmatrix} 1-t_M C_M & -t_M Z_{MF} \\ C_F & Z_{FF} \end{bmatrix} \begin{bmatrix} dY \\ dP_F \end{bmatrix} = \begin{bmatrix} (G_F^L - t_M G_{MF}^L) P_F d(1-s_L) \\ G_{FF}^L P_F d(1-s_L) \end{bmatrix} \tag{31}$$

from which:

$$dY = |A|^{-1}\{Y_L Z_{FF} - t_M(G_{MF}^L Z_{FF} - G_{FF}^L Z_{MF})\} P_F d(1-s_L) \gtrless 0, \tag{32}$$

$$dP_F = |A|^{-1}\{(1-t_M C_M) G_{FF}^L - C_F(G_F^L - t_M G_{MF}^L)\} P_F d(1-s_L) \gtrless 0. \tag{33}$$

Deadweight losses from the subsidy reduce real income; however the expansion of lowland agriculture causes manufacturing production to contract so tariff revenues increase. Once again, therefore, the net welfare gain is probably negative, but not unambiguously so. To find the effect of the subsidy on upland land allocation we again convert (33) into proportional changes:

$$\hat{P}_F = |A|^{-1}\{\zeta \delta_L \varepsilon_{LF} - \delta_L \rho_F + t_M \gamma_M \varepsilon_{MF}\} \hat{S}_L , \tag{34}$$

and substitute into (13):

$$\frac{\hat{N}_U}{\hat{S}_L} = \varepsilon_{NU}\left(\frac{\hat{P}_F}{\hat{S}_L}\right) \gtrless 0. \tag{35}$$

A positive lowland supply response to the subsidy reduces the price of food, but this reduction may be offset if the tariff revenue increase is large. Unless this income effect dominates the food price change, the lowland subsidy will cause upland land to shift out of food. The shift, however, is unlikely to be as great as that spurred by the upland tax or export subsidy (compare (35) with (25) and (30)).

The four policy experiments just conducted reveal two important points. First, general equilibrium feedback may alter or even overturn the intended effects of a changes in a given policy. Second, a reduction in upland food area could under some circumstances be achieved equally successfully by indirect means -- a subsidy on lowland food production, or a tariff reduction (the opposite of the case analyzed by us) -- as by the more conventional direct interventions.

There are good political and economic reasons to consider the effects of lowland policy interventions on upland resource allocation. First, food self-sufficiency goals continue to motivate governments to seek supply gains from technologically more advanced lowland areas. Second, ease of collection and a relatively diffuse impact means that trade taxes continue to be important fiscal policy instruments in many developing countries. Third, structural adjustment programs for developing countries invariably stress tariff reduction as one component of an overall strategy of reducing allocative inefficiency. Our analysis suggests that reducing existing tariff distortions, or even countering them with new distortions such as treecrop export subsidies, may also reduce the rate of upland land degradation. If so, the long-run economic gains from reduced erosion and land degradation should be offset against new fiscal costs, tariff revenue reductions and other more visible economic and political costs of tariff reform.

It might be argued that the "disprotection" of the manufacturing sector implicit in either of the policy changes just discussed - a subsidy on tree crop production, or on lowland food - is undesirable when industrialization is obviously an important policy goal in its own right. However, in an economy in which policy distortions already confer considerable benefits on the manufacturing sector, the agricultural subsidies would merely counterbalance some of the existing anti-agriculture bias of development policy. This point serves to reinforce the observation that in a policy-distorted economy there frequently exists a "mandate for regulation" (Vasavada 1992:597).

Our analysis with this simple model exposes important general equilibrium mechanisms linking regions as well as sectors. A partial equilibrium analysis ignoring regional market linkages would observe the symmetry between taxing upland food production and subsidizing treecrop exports. However, it would fail to capture indirect effects on the relative profitability of upland crops, and consequent shifts in the allocation of upland resources, arising from interventions in lowland sectors and transmitted to uplands through key commodity markets such as those for staple foods. Some prescriptions for reduced environmental degradation in uplands of developing countries predict that reductions in trade taxes will lead to increased rates of resource depletion in developing countries.[14] Our general equilibrium analysis contradicts such predictions in the case of annual crops grown in uplands.

Comparative statics predictions such as those we have presented help identify which technical and market parameters are likely to be important determinants of the outcome of a policy change. However, comparative static results can typically be definitively signed only in models of minimal dimensions. Even in the simple model above we can make few firm predictions about the signs of changes in real income, the price of food, and the demand for land for upland food production even with only a single market link between upland and lowland regions. When changes in endogenous variables cannot be predicted *a priori*, numerical simulation provides an appropriate alternative method.

3. Some illustrative experiments

Model Structure

In this section we investigate the effects of the tax and tariff changes considered above in a computable model using synthetic data intended to be broadly representative of the structure of a developing economy.[15] These data are presented in Table 2. Item 3 in the table indicates that the two lowland sectors together account for nearly four-fifths (77%) of GNP, while treecrops contribute 14% and upland food 9%. Upland sectors, however, account for half of total employment (item 1). Of the four sectors, manufacturing is the least and upland food the most labor-intensive, with the other two sectors holding intermediate positions (item 2). Because lowland production technologies are in general more advanced, we assume short-run Allen elasticities of substitution of 0.2 in upland sectors and 0.5 in lowland sectors. Food accounts for a little over half (56%) of consumer expenditures, manufactured goods 40% and treecrops 4% (item 5). In the absence of better information we rule out cross-price effects in consumption and impose unitary income and own-price elasticities of consumer demand for each good.

The core structure of the model used in our simulation analyses is as presented in Section 2. We extend the model to include measures of changes in trade volumes and values, government revenues and expenditures. We also add one initial distortion, a subsidy on lowland agricultural production.[16] This subsidy reflects the prevailing bias of developing country government spending on irrigation, transport and marketing infrastructure, research and development, and agricultural inputs in favor of irrigated lowland cereal agriculture relative to upland areas and exportable crop sectors. The resulting sectoral protection structure reflects a remarkably uniform pattern observed across developing economies, in which sector-specific policies confer direct protection on import-competing manufactures and staple food production relative to agricultural exportables, while the indirect effects of trade and macreconomic policies penalize all agricultural sectors relative to manufacturing (Krueger, Schiff and Valdes 1988).

Our analysis concerns short-run changes in prices, resource allocation and income. In this length of run some factors are specific to sectors, and the mobility of labor across regions is restricted. Therefore, consistent with the short-run scope of the model, rather than impose *ex post* balance on the budget and on the current account, in our simulations we permit both to move into deficit or surplus. Permitting the budget and trade accounts to display temporary disequilibria is not merely appropriate for a short-run simulation; it also serves to reveal the kinds of macroeconomic stresses to which a government contemplating a policy change is likely to pay close attention. By this means our analyses reveal not only the environmental outcome of each policy change, but also some of its key economy-wide and macroeconomic implications.

Finally, for each policy change we present two sets of simulation results. In the first we maintain the dual labor market assumption of Section 2. In the second set we relax this condition and permit migration between uplands and lowlands. Allowing free labor mobility among all sectors adds a new economic link between upland and lowland regions.

Simulation Results

In Tables 3-5 we report the effects of four policy changes, each having the effect of reducing the upland land area devoted to food production.[17] The changes are: an export subsidy on treecrop production; tariff reduction in manufacturing; a Pigovian production tax on soil-eroding upland food production, and a subsidy on lowland food production. Each policy instrument is altered by a uniform rate of 10%. Effects on production, factor demand, and the price of food are consistent with those found in the analysis of Section 2.

As expected, the interventions that affect upland sectors directly -- the Pigovian tax and the treecrop export subsidy -- have relatively greater impacts on upland resource allocation. The upland food production tax, for example, reduces land demand in that sector by 33% in the dual labor market case, and by 73% when labor is regionally mobile (Table 3, third column). The tree crop export subsidy (Table 3, first column) reduces upland food land area by 13% and 21% respectively for the same two labor market closures. However, tariff reduction and the lowland subsidy also contribute to reductions in upland food land area, albeit by smaller amounts: 10% and 16% for the tariff reduction, and 12% and 32% for the lowland food subsidy. In the single labor market case, reductions in upland food labor demand due to each of the lowland interventions are not matched by employment expansion in the more land-intensive treecrop sector. The lowland policy changes thus promote outward migration from uplands.

From a purely environmental viewpoint the results in Table 3 indicate that direct policies are relatively more effective in reducing upland food land area, and should therefore reduce erosion rates faster in the short run. However, the current account, budget and real income changes reported in Table 4 reveal considerable asymmetry in the macroeconomic impacts of the four policies. Both trade tax changes increase real income, while the food sector interventions reduce it . Moreover, the fiscal costs of food sector taxes are seen to be substantially greater than those of trade tax reforms. The food sector instruments and the export subsidy are all sources of new deadweight losses which, other things being equal, will reduce real income. With the food taxes these losses are accompanied by reduced imports, and therefore by declining tariff revenues. The export subsidy, by contrast, has the effect of moving the domestic price ratio of tradables closer to their world price ratio, and the gains from this shift are sufficient to offset any new resource misallocation costs created by the subsidy.[18]

The policy changes alter factor incomes in different ways, producing a range of income distributional outcomes. Factor price movements caused by the policy changes are reported in Table 5. The treecrop sector is land-intensive relative to upland food, and each policy change causes the former sector to expand and the latter to contract. In the dual labor market experiments, returns to upland land increase relative to upland wages, which decline by as much as 29%. These factor price effects are of course moderated when labor is mobile across regions. The tree crop export subsidy, for example, promotes expansion of the large and labor-intensive lowland food sector, and so bids up both wages and upland land returns. By contrast, the distribution of gains from the upland food tax is concentrated in increased returns to lowland land.

In sum, the *environmental* benefits from a Pigovian solution to upland erosion must be weighed against questions about its *economic* sustainability in terms both of narrowly defined macroeconomic targets and broader social equity goals. First, policies which require developing country governments to incur budget deficits are unlikely to be considered desirable in an era of tight fiscal constraints. Second, policies that bid up the prices of consumer staples like food are likely to be politically marginal. Third, policy changes that reduce aggregate real income and the earnings of upland labor can thereby be expected to increase absolute poverty, and in particular poverty among the most vulnerable groups in the economy, upland farmers. Since members of the same groups are primarily responsible for land use decisions leading to changes in erosion rates, in the longer run the upland food tax could conceivably cause erosion rates to *increase*, by reducing the terms of trade of upland farmers.

Fourth, the analysis begs questions about the administrative and political costs of alternative policies. Practical and political considerations virtually rule out the possibility of imposing direct production taxes on upland food producers. Not only would the administrative costs of assessing such a tax be prohibitive, but in addition, the tax would reduce the relative incomes of groups known to occupy the lowest position in developing country income distributions. Ruling out direct taxes on upland food producers and subsidies to their competitors in factor or product markets leaves the trade tax options: a subsidy on treecrop production, or a reduction in manufacturing sector tariff protection. The political costs of these policies should not be minimized: in particular, import-substituting industrial capitalists are frequently the best-placed to influence policy. Nevertheless, in addition to its indirect environmental benefits, tariff reduction has the advantage of being consistent with many other long-run policy goals in developing countries.

4. Conclusions

We have presented a small general equilibrium model illustrating market-based interactions between upland and lowland agricultural economic systems and exploring implications of some public policy changes in different sectors for upland soil erosion rates, as implied by reallocation of land in the upland region between more erosive food crops and less erosive tree crops.

In our model Pigovian pollution taxes are superior instruments for reducing upland food area (and by extension, erosion); however, they and some other measures are inconsistent with

.other likely goals of policy, notably reduced budget deficits and improved welfare of poor households. By extension, subsidies or price rises for upland food producers -- sometimes recommended as palliatives for land degradation problems -- would almost certainly have the effect of increasing upland food land area. Because of interregional and intersectoral linkages through food and labor markets and through trade, tax and tariff policies having no *direct* relationships to upland agricultural production could well prove effective in reducing erosion-producing activity. Such instruments should be included in the set of possible interventions aimed at achieving reductions in upland erosion.

Our results from this simple exercise are intended to be illustrative only. We have ignored the effects of changing land values on the potential adoption of land-conserving technologies and infrastructural investments. We have also avoided explicit specification of a damage function relating upland erosion rates to the productivity of lowland agriculture. This relationship is as yet poorly understood; parameters governing the rate of lowland land degradation due to upland soil erosion have not been empirically established.

Our findings highlight the need for policies addressing upland soil degradation to recognise potential *upland* impacts of trade and taxation policies addressed mainly to *lowland* agriculture and non-agricultural (e.g. manufacturing) sectors. In developing countries, real wages and agricultural earnings continue to be paramount determinants of economic welfare, and changes in the price of food continue to be the major determinants of changes in real wages and agricultural incomes. There is every reason to expect that a change in relative wages or agricultural earning opportunities between lowlands and upland will induce migration and/or resource reallocation responses such as those we have attempted to capture. Policies aimed at slowing upland land degradation must take account of economic links among regions.

Developing country governments considering adoption of policies intended to reduce land degradation are justifiably concerned about the implications of environmental policies for economic goals they frequently regard as more pressing. Our analysis makes possible explicit *ex ante* comparisons of the effects of alternative policy changes in relation to multiple objectives.

The results in this paper suggest a positive relationship between manufacturing tariff reduction and moves away from erosion-increasing upland resource use patterns. If these results remain true in larger, more richly specified models, then some common fears that environmental goals might be achievable only at the expense of economic growth might be allayed.

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Table 1: Regional economic structure

Production and factor demand in upland sectors:

$$N_j = N_j(Y_j, W, R) \qquad j = U,X \qquad (1')$$

$$K_j = K_j(Y_j, W, R) \qquad (2')$$

$$P_jY_j = WN_j + RK_j \qquad (3')$$

Production and factor demand in lowland sectors:

$$N_j = N_j(Y_j, V, Q_j) \qquad j = L,M \qquad (4')$$

$$K_j = K_j(Y_j, V, Q_j) \qquad (5')$$

$$P_jY_j = VN_j + Q_jK_j \qquad (6')$$

Regional factor markets

$$N_U + N_X = N^U \qquad (7.1')$$

$$N_L + N_M = N^L \qquad (7.2')$$

$$K_U + K_X = K^U \qquad (7.3')$$

Domestic prices of tradables

$$P_j = P_j^*(1 + t_j) \qquad j = M,X \qquad (8')$$

Regional producer prices of food

$$P_r = P_F(1 - s_j) \qquad r = U,L \qquad (9')$$

Variable definitions:

N_j	Labor use in sector *j*	K_j	Land/capital use in sector *j*
Y_j	Output of sector *j*	W	Upland wage
R	Upland land price	V	Lowland wage
Q_j	Lowland land/capital price ($j = L,M$)	N^R	Labor endowment in region *R*
K^U	Land endowment in upland region		
P_j	Domestic price of commodity *j*	P_j^*	World market price of *j* ($j = M,X$)
s_r	Production tax on food produced in region *r* ($r=U,L$)	t_j	Tariff (or export tax) rate on traded good *j* ($j = M,X$)

Subscripts:

U	Upland food
L	Lowland food
M	Manufactured good (importable, produced in lowlands)
X	Treecrops (exportable, produced in uplands)

Table 2: Data base for simulation experiments

	Sector				
	Upland food	Lowland food	Tree crops	Manuf.	Total
1. Sector shares in factor demand (λ_{ij})					
Upland land	0.31	0	0.69	0	1.00
Upland labor	0.50	0	0.50	0	1.00
Lowland labor	0	0.66	0	0.34	1.00
Lowland land	0	1.00	0	0	1.00
Mfg. capital	0	0	0	1.00	1.00
2. Factor shares in total cost (θ_{ij})					
Upland land	0.44	0	0.64	0	
Upland labor	0.56	0	0.36	0	
Lowland labor	0	0.40	0	0.33	
Lowland land	0	0.60	0	0	
Mfg. capital	0	0	0	0.67	
Total	1.00	1.00	1.00	1.00	
3. Sector shares in GNP (γ_j)					
	0.09	0.47	0.14	0.30	1.00
4. Budget shares of goods (μ_j)					
	0.56		0.04	0.40	1.00
5. Allen elasticities of factor substitution (σ_j)					
	0.2	0.50	0.2	0.50	
6. Initial subsidy and tariff rates					
	0	0.07	0	0.30	

Table 3: Production and factor demand effects of 10% tax changes.

Endogenous Variable	Export subsidy on tree crops	Tariff reduction in m'facturing	Upland food production tax	Lowland food prodn subsidy
Dual Labor Market	Percentage changes			
Output				
Upland food	−11.2	−8.6	−27.8	−10.2
Lowland food	0.7	0.5	0.1	0.7
Treecrops	7.1	5.5	18.9	6.5
Manufacturing	−1.1	−0.8	−0.2	−1.0
Labor Demand				
Upland food	−9.5	−7.3	−23.7	−8.7
Lowland food	1.7	1.3	0.2	1.6
Treecrops	9.5	7.3	23.7	8.7
Manufacturing	−3.2	−2.5	−0.5	−3.1
Land Allocation				
Upland food	−13.2	−10.1	−32.9	−12.0
Treecrops	5.9	4.5	14.6	5.3
Single Labor Market				
Output				
Upland food	−20.0	−15.6	−72.4	−32.3
Lowland food	1.5	1.1	3.9	2.5
Treecrops	10.2	7.8	32.6	13.8
Manufacturing	−0.9	−0.7	0.5	−0.7
Labor Demand				
Upland food	−19.4	−14.9	−72.1	−32.7
Lowland food	3.6	2.8	9.5	6.2
Treecrops	11.4	8.8	32.9	13.2
Manufacturing	−2.8	−2.2	1.5	−2.1
Land Allocation				
Upland food	−21.3	−16.4	−72.7	−31.8
Treecrops	9.5	7.3	32.3	14.1

Table 4: Effects of 10% tax changes on prices, trade, budget and real GNP

Endogenous Variable	Export subsidy on tree crops	Tariff reduction in m'facturing	Upland food production tax	Lowland food prodn subsidy
Dual Labor Market		Percentage changes		
Producer Prices:				
Upland food	6.4	-2.8	-9.1	-3.3
Lowland food	6.4	-2.8	0.9	6.1
Treecrops	10.0	0.0	0.0	0.0
Manufacturing	0.0	-7.7	0.0	0.0
Consumer Price of Food	6.4	-2.8	0.9	-3.3
Exports (volume)	12.0	9.2	26.4	10.9
Imports	23.9	18.3	-13.3	-14.5
Current Account (% of GNP)	-1.2	-0.9	4.0	2.5
Gov. Revenue (% of GNP)	0.7	-0.5	-1.3	-0.4
Gov. Expenditure (% of GNP)	1.2	-0.1	0.0	4.6
Budget (% of GNP)	-0.5	-0.4	-1.3	-5.1
Real ~~income~~ absorption (% of GNP)	1.2	0.9	-4.0	-2.5
Single Labor Market				
Producer Prices:				
Upland food	8.1	-1.5	-0.6	0.9
Lowland food	8.1	-1.5	9.4	10.3
Treecrops	10.0	0.0	0.0	0.0
Manufacturing	0.0	-7.7	0.0	0.0
Consumer Price of Food	8.1	-1.5	9.4	0.9
Exports (volume)	15.8	12.2	45.2	20.2
Imports	27.1	20.8	2.5	-6.6
Current Account (% of GNP)	-1.1	-0.9	4.3	2.7
Gov. Revenue (% of GNP)	0.8	-0.4	-0.8	-0.2
Gov. Expenditure (% of GNP)	1.3	-0.0	0.4	4.8
Budget (% of GNP)	-0.5	-0.4	-1.2	-5.0
Real ~~GNP~~ absorption (% of GNP)	1.1	0.9	-4.3	-2.7

Table 5: Factor price effects of 10% tax changes.

Endogenous Variable	Export subsidy on tree crops	Tariff reduction in m'facturing	Upland food production tax	Lowland food prodn subsidy
Dual Labor Market	Percentage changes			
Factor Prices				
Upland land	16.5	5.0	16.3	5.9
Upland labor	−1.8	−9.1	−29.4	−10.7
Lowland labor	4.3	−4.4	0.6	4.1
Lowland land	7.7	−1.7	1.1	7.4
Manuf. capital	−2.2	−9.1	−0.3	−2.1
Single Labor Market				
Factor Prices				
Upland land	13.4	2.7	1.1	−16.0
Labor	3.8	−4.8	−2.0	2.8
Lowland land	11.0	0.8	17.1	15.3
Manuf. capital	−1.9	−9.2	1.0	−14.0

Endnotes

[1] The public good characteristics of non-point pollution also render infeasible most Coasian bargaining solutions, although these are occassionally observed in transactions between individual farmers with adjoining properties.

[2] Problems of soil erosion and degradation are not confined to uplands, although it appears at present that most acute problems are associated with upland land use patterns.

[3] The difference between perennial and annual crops dominates most comparisons of erosion rates for a given set of physical conditions. The following measured rates of soil loss for a major Philippine watershed are typical:

Land use	Area(%)	Ave. soil loss (t/ha/yr)	Proportion of total soil loss (%)
Primary and secondary forest	40.3	2.15	1
Lowland and irrigated rice[a]	7.2	0.28	--
Grassland/savannah[b]	38.9	197.80	81
Swidden/diversified cropland	3.2	428.59	17
Other/non-agricultural	10.4	--	--

[a] Nearly all in areas of low or no slope.
[b] Mainly short fallows forming part of the swidden/annual crop land base.

Source: W. Cruz, H. Francisco and Z. Conway (1988): "The On-Site and Downstream Costs of Soil Erosion in the Magat and Pantabangan Watersheds", *Journal of Philippine Development* XV(1).

[4] In most developing countries the impact of new upland annual crop production technologies designed to minimize land degradation and erosion remains limited, mainly to "project" sites.

[5] The economic importance of off-site land degradation effects typically exceeds that of on-site effects (e.g. Cruz, Fancisco and Conway, *op. cit.*).

[6] Given the paucity of data on the relevant physical parameters, we do not explicitly incorporate national income losses due to lower on-site productivity and off-site damages. Accordingly, in our model the definition of real income excludes the economic costs of on-site soil degradation

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and off-site damages. As our discussion of this point later in the paper makes clear, ignoring these economic costs of erosion introduces ambiguity over the *true* welfare impacts of policy changes that both reduce erosion and cause measured real income to decline. Conversely, if a given policy change reduces erosion but increases measured real income, the change must be welfare-increasing.

[7] Developing country food markets are typically governed by government regulations involving quantitative restrictions which insulate domestic food markets from international price movements. These measures effectively convert food into a non-traded good.

[8] See Coxhead and Warr (1991) for a model built along similar lines where a traded good with exogenously given price is produced with two different specific factors; the model presented here extends the earlier analysis to the case where the output price is endogenously determined.

[9] For example: "[Interventions in agriculture have] a tendency to bias the public allocation of resources toward the modern farm-household subsector relative to the traditional and typically labor-surplus subsector of the rural economy" (Pardey and Roe 1991: 8).

[10] Proofs are given in Coxhead and Jayasuriya (1994), and may be obtained from the authors.

[11] In Dixit and Norman (and in Edwards and van Wijnbergen 1987) the determinant of this matrix has a positive sign. Their definition is analogous to $|A|(E_{FF} - G_{UF} - G_{LF}) > 0$ in our model.

[12] The proof relies on the fact that the matrix Z of second partial derivatives of the expenditure relation is negative semidefinite The term inside braces in the expression for dY is the second principal minor of this matrix and is therefore positive.

[13] The theory of the second-best predicts that in a distorted economy real income may in some circumstances be increased by introducing a new distortion. In the present example importables are overproduced and underconsumed relative to their free trade prices, and the initial level of real income is less than it would be under free trade. The export subsidy brings the domestic price ratio of tradables more closely into line with world prices and thus reduces resource misallocation

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(deadweight losses) caused by the tariff. The positive change in (22) is measured relative to its initial, tariff-distorted level. As noted in the text, we ignore the fiscal cost of the subsidy; if this were very large it could reverse the sign of (22).

[14] For example: "The ultimate impact of trade taxes in general is to reduce the rate of resource depletion since they worsen the terms of trade faced by developing countries" (Lamberte *et al* 1992:35).

[15] Most of the data - notably those for employment, factor intensity and consumer budget shares -- are drawn from Philippine economic statistics (NSCB 1992).

[16] The government budget (B) consists of revenues from tariffs and the upland food production tax, and expenditures on subsidies applied to treecrop exports and lowland food production:

$$B = T_M P^*_M M - S_L P_F Y_L - T_X P^*_X X + S_U P_F Y_L$$

where M and X are import and export volumes. These net revenues accrue to the model's representative consumer. We assume initial rates of the tariff and of the lowland agricultural subsidy to be 30% and 7.1% respectively: at these rates tariff revenues are exactly matched by the cost of the subsidy, so the budget is initially in balance. Since the other two policies S_U and T_X are initially zero, when all policies change, the change in the budget is given by:

$$\mathrm{d}B = T_M P^*_M M (\hat{P}^*_M + \hat{M} + \frac{1}{T_M}\mathrm{d}T_M) - S_L P_F Y_L (\hat{P}_F + \hat{Y}_L + \frac{1}{S_L}\mathrm{d}S_L) - P^*_X X \mathrm{d}T_X + P_F Y_U \mathrm{d}S_U.$$

A budget deficit or surplus resulting from changes in tax or trade policies is met by increasing or reducing the taxation of households' factor incomes.

[17] The simulation software used was GEMPACK v.4.2 (Codsi and Pearson 1988).

[18] The welfare gain from the export subsidy is a demonstration of the well-lnown principle that in an economy with existing distortions welfare may be increased by adding a new distortion. See footnote 11.