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TAX AND TRADE POLICIES, EROSION AND ECONOMIC WELFARE IN DEVELOPING COUNTRIES

By

Ian Coxhead*
University of Wisconsin-Madison
and
Sisira Jayasuriya*
La Trobe University

* Ian Coxhead is in the Department of Agricultural Economics, University of Wisconsin-Madison and Sisira Jayasuriya is in the Department of Economics, La Trobe University, Bundoora, Victoria, Australia.

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Ian A. Coxhead* and Sisira Jayasuriya**

Most analyses of the erosion problem in developing countries are based on restrictive assumptions about the economic links between upland agriculture and the rest of the economy. Ignoring these links may produce misleading policy advice. We present an analytical model that traces the impacts of environmental and economic policy changes not only on upland resource allocation and erosion, but also on trade, the public sector budget, income distribution and aggregate real income. Simulation experiments highlight the role of domestic market linkages as conduits between lowland and upland economies. The results indicate that once economy-wide, trade, and fiscal effects are taken into account, indirect policies such as trade tax reforms may provide better means for reducing upland erosion than would direct environmental policies.

* Department of Agricultural Economics, University of Wisconsin-Madison, Madison, Wisconsin, U.S.A., and **Department of Economics, La Trobe University, Bundoora, Victoria, Australia.
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Most analyses of upland soil erosion problems in developing countries argue that solutions to soil mining and runoff must be sought in the uplands themselves, in new technologies, altered practices, reduced in-migration, more secure tenure institutions and stronger controls over resource use. These direct approaches are important, and without them the long-run prospects for sustainable agricultural development in sloping uplands appear remote. However, substantial investment of fiscal, human and/or political resources is inherent in each of these approaches, and moreover their lead times are long and results uncertain. Relative price changes, by contrast, are known to produce substantial shifts in developing country agricultural resource allocation even in the short run (Askari and Cummings 1976). Relative price shifts in agriculture may have very indirect causes; however, upland agricultural economies cannot be considered to exist in isolation from the rest of a developing economy, let alone from the rest of agriculture, their geographical remoteness notwithstanding. In this paper we investigate intersectoral and interregional market linkages and their roles as conduits for relative price changes affecting upland 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.

In our model upland land can be used to grow either food, an annual crop, 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. Thus the link between relative food prices and the rate of land degradation lies at the core of our model: other things equal, a higher relative food price creates incentives to grow food rather than tree crops in uplands, which increases the allocation of land to upland food and thereby raises the erosion rate.

A general equilibrium approach is necessary 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, balanced trade, 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 public policy goals. Such searches cannot satisfactorily be conducted in a partial equilibrium setting.

Second, in addition to problems of sustainability of 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. Unlike production taxes and subsidies (which affect only producer prices), trade taxes alter both producer and consumer prices (Corden 1957) 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 economic welfare the food price, 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. In the model, at a given level of 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.[3] 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.

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. 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*. 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 (in our simulation experiments we relax the dual labor market assumption). 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. 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 cost minimization by a representative producer in each sector; (3') and (6') are zero profit conditions stating that after-tax revenues are exhausted in factor payments. The factor market clearing conditions (7') show 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. Because developing countries are typically small in relation to world markets for their traded goods we regard world prices of tradables as exogenous. The pricing conditions (8') relate domestic prices of tradables to world prices and tariffs or export taxes. Lastly, we allow for food production to be taxed at different rates in each region. Equation (9') shows that the producer price of food in each region is equal to the aggregate market-clearing price less a region-specific production tax.

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 "shocks". For simplicity 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 a given developing country 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.[6] . 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. We find our results to be robust with respect to these two widely different labor market assumptions.

Let the proportional change in any variable X be denoted by a "hat", 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 cost share of the ith factor used in the jth sector is given by θ_{ij}. In (7), the share of the jth sector in employment of the ith factor is denoted by λ_{ij}. In (8), changes in domestic prices of tradable goods are set by changes in world prices and in trade taxes, denoted by $\hat{T}_j = \widehat{(1+t_j)}$, where $j \in \{X,M\}$. Finally, the changes in the producer price of food grown in each region is equal to the change in the consumer price and that in sector-specific production taxes, given by $\hat{S}_j = \widehat{(1-s_j)}$, where $j \in \{U,L\}$.

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

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

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

$$\hat{N}_j = \hat{Y}_j - \theta_{Kj}\sigma_j(\hat{V} - \hat{Q}_j) \qquad j \in \{L,M\} \tag{4}$$

$$\hat{K}^j = \hat{Y}_j + \theta_{Nj}\sigma_j(\hat{V} - \hat{Q}_j) \tag{5}$$

$$\hat{P}_j = \theta_{Nj}\hat{V} + \theta_{Kj}\hat{Q}_j \tag{6}$$

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

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

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

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

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

Equations (1) describe changes in upland land demand in terms of changes in upland food output and relative factor prices. The latter convey information about the relative profitability of producing food versus treecrops in uplands (the Stolper-Samuelson result). However, outputs and factor prices may themselves be altered by tax or tariff changes, and (1) does not by itself indicate how economic changes originating outside the upland might affect upland resource allocation. The expression indicates only the *partial equilibrium* determinants of changes in the upland land allocation. We will return to the general equilibrium impact of policies and their effects on relative food prices later in this section. First, however, we consider the effects of tariffs and taxes on resource allocation and factor pricing in the two regions. For brevity we concentrate on expressions relevant to land allocation in uplands since these bear directly on the erosion rate. In order to focus on policy changes we assume zero growth in factor endowments, setting $\hat{N}^U$, $\hat{N}^L$, $\hat{K}^U$, $\hat{K}^L$, and $\hat{K}^M$ equal to zero.

Using (1) - (7) we obtain reduced form expressions for proportional changes in sectoral outputs and relative factor prices in terms of changes in exogenous variables: taxes, tariffs, world prices of tradables and food prices. First, 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). Next, using (9) and (8) we also solve for output changes in upland sectors:

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

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

where $\varepsilon_{FF}^{U} > 0$ and $\varepsilon_{XX} > 0$ are own-price supply elasticities of upland food and treecrops.

We use the solutions for changes in outputs and relative factor prices (10)-(12) to solve the upland factor demands (1) and (2) in terms of changes in commodity prices, taxes and export taxes. Applying this substitution to the change in demand for land in upland food production yields:

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

where $\varepsilon_{NU} = \varepsilon_{FF}^{U} + (\sigma_U \theta_{NU}/\theta) > 0$.[7] Other things equal, the area of upland devoted to food crops is increased by a rise in the price of food. At constant food price an increase in the power of the tree crop export subsidy ($\hat{T}_X > 0$) or an upland food production tax ($\hat{S}_U < 0$) will reduce food area. Expression (13) tells us how, by changing the relative profitability of food and tree crop production, production and trade taxes imposed *directly* on upland sectors can alter resource allocation - including that of land - in the upland. Recommendations for the use of price policy to address upland environmental problems typically rely on these direct instruments to alter relative crop production incentives. .

We now consider endogenous changes in the price of food. This price responds to tax and tariff changes, as we will show below, so signs of factor demand responses to policy interventions depend greatly on the sign of the change in food's price. Suppose, for example, that the treecrop export subsidy is increased by 1%, so $\hat{T}_X = 1$. Through factor market and consumer demand adjustments this causes a change in P_F. From (13), with no change in world prices or the other policy variables the change in upland land demand with respect to the subsidy change is:

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

For any exogenous price or policy change, the sign and magnitude of a change in the price of food relative to other goods helps determine whether demand for land in upland food will rise or decline when a tax or subsidy is applied in another sector.

In general equilibrium, that relative price change in turn depends on food supply changes in *both* regions as well as on changes in food demand, which itself depends on changes in consumers' real incomes. The change in food's price thus provides a conduit through which changes in taxes and tariffs levied on lowland sectors affect upland land allocation. These regional links broaden the scope for economic policies to affect upland resource allocation, and therefore the rate of soil erosion. They also raise the possibility that price policies targeted at apparently unrelated sectors might have unexpected environmental consequences in uplands.

Links between regions: the budget constraint and the food market

For political economy reasons most developing country governments insulate domestic markets for staple foods from international price movements. To reflect this fact we now suppose that food is not traded internationally by the developing country. For simplicity we assume food to be homogeneous, so consumers make no distinction by the region in which it is produced, although coexistence of two distinct food production technologies enables us to explore region-specific supply response and policy measures.[8] Under these assumptions 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 influence resource allocation, production and input prices in the other. In the following paragraphs we show how the food market links resource allocation in the two regions, and by implication affects the rate of upland soil erosion.

Income-constrained utility maximization by a representative consumer (or several consumers having identical homothetic preferences) is summarized by an expenditure function $E(\boldsymbol{P},U)$ in the vector of commodity prices $\boldsymbol{P}$ and utility U. Aggregate income in each region is summarized by a revenue function $G^r(\boldsymbol{P}^r)$, where each $\boldsymbol{P}^r$, a subset of $\boldsymbol{P}$, contains the prices of goods produced in region r (e.g. $\boldsymbol{P}^L = (P_M, P_F)$). 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:

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

where j subscripts on E and G indicate partial derivatives of these functions with respect to P_j, and superscriptsw indicate upland or lowland food sectors. By Shephard's lemma $E_j = C_j$ is consumer demand for j, and $G_j^r = Y_j$ is production of j .

Market clearing for food requires that domestic demand equals supply:

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

The welfare and food price impacts of a small change in tariffs or taxes are found by totally differentiating (14) and (15) using the price definitions in (8) and (9).[9] Effects on upland land allocation are then found by substituting solutions for changes in the price of food into the upland food land allocation relation (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

In order to focus on the policy change let the prices of tradables be fixed and choose units so that initially $P_F = P_X{}^* = P_M{}^* = 1$ and thus $P_M = 1+t_M$. We then take the total differentials of (14) and (15) and express the resulting equation system in matrix form as (16) below. In arriving at (16) we define the change in real income as $\mathrm{d}Y = E_U \mathrm{d}U$, where E_U is the inverse of the marginal utility of income. We denote excess demand for goods (i.e. net imports $(E_j - G_j)$) as Z_j, and note that $E_{FU} = C_F E_U$ and $E_{MU} = C_M E_U$. We also define initial production in each sector so that in initial equilibrium $Y = 1$. Real income and food price changes in response to a tariff increase are found from the solution to:

$$\begin{bmatrix} 1\text{-}t_M C_M & -t_M Z_{MF} \\ C_F & Z_{FF} \end{bmatrix} \begin{bmatrix} \mathrm{d}Y \\ \mathrm{d}P_F \end{bmatrix} = \begin{bmatrix} t_M Z_{MM}\mathrm{d}(1+t_M) \\ -Z_{FM}\mathrm{d}(1+t_M) \end{bmatrix} \tag{16}$$

The determinant of the coefficient matrix is $|\mathrm{A}| = (1 - t_M C_M)Z_{FF} + t_M C_F Z_{MF} < 0$ in stable models (Dixit and Norman 1980)[10], so:

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

and

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

In an economy with existing tariff distortions the aggregate welfare impact of a tariff increase is unambiguously negative.[11] The tariff change has two effects on food prices. The first term inside brackets is a pure substitution effect of food for importables and is positive as long as F and M are net substitutes, in which case Z_{FM} (the cross-price elasticity of excess demand for food) is positive. The second term captures the negative impact on excess food demand of the real income decline caused by the tariff increase; this effect is larger for a higher initial tariff rate. Unless this income effect is so large as to outweigh the substitution effect -- an unlikely event -- increasing the tariff will raise the relative price of the nontraded good, food (Dornbusch 1974; Edwards and van Wijnbergen 1987).

Clearly higher tariffs will reduce food production in lowlands, where manufacturing and agriculture compete for lowland labor. What will happen to food production and land allocation in uplands? To find out, we substitute the general equilibrium food price change (18) into (13), the expression for the change in upland land allocated to food production. First, we convert (18) into proportional changes:

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

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

$\beta_{ij} = (\partial C_i/\partial P_j)P_j/C_i$ 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 region r's share in total food production;

$\rho_M = C_M / Y$ is the share of consumption of importables in total expenditure;

$\gamma_M = Y_M / Y$ is the GNP share of domestic production of importables; 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 welfare impact of the tariff change. Substituting (19) into (13) gives the general equilibrium change in upland food land allocation:

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

Considering (19) and (20) together it can be seen that raising tariffs tends to increase upland food land area through substitution effects in consumption (β_{FM}>0) and in lowland production (ε^L_{FM}>0) since manufacturing protection draws labor out of lowland food and reduces its supply. This effect has a greater 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 the importable, 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 (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 imposing the subsidy will thus be negligible and can reasonably be ignored in order to simplify the analysis. Real income and food price changes due to the subsidy are found from:

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

as

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

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 as long as we ignore its fiscal cost.[12] 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 price of food. To find the effect on upland land allocation we write (23) in proportional changes:

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

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 probability 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. Commodity taxes raise the price of food and reduce aggregate real income in addition to restricting food sector output in the region to which they are applied. Subsidies achieve the opposite price and production results. Their welfare effects are ambiguous, however, since their imposition alters tariff revenue through cross-price effects in production and consumption. As in the export subsidy case, 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 would in principle reduce erosion to a socially acceptable rate by aligning private and social profitability in that sector. Even were it administratively and politically feasible, however, a production tax on upland food would not unambiguously reduce upland food area. The outcome depends on the extent to which the tax causes the economy-wide food price to increase, and on the consequent lowland supply response. If we consider $d(1\text{-}s_U)$, holding world prices and other policies constant, we obtain:

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

and

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

When the upland production tax is imposed (i.e. when $d(1\text{-}s_U) < 0$) aggregate welfare is reduced by deadweight losses associated with the tax, as shown by the first term in parentheses. 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 excess demand parameterZ_{MF}>0). Tariff revenues thus increase, and to the extent that these revenues contribute to initial income this offsets the negative income effect of the tax.

The upland food production tax also has an ambiguous effect on food prices:

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

As in the tariff change case, the upland production tax has two effects. The upland food sector contracts (the first term on the right hand side of (28)) 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 find:

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

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

Taxing upland food production will reduce upland food land area except in the unlikely 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, the 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. Suppose $d(1\text{-}s_L) > 0$, holding world prices and other policies constant. As before, totally differentiating (14) and (15) we obtain:

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

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

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

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 the net welfare gain is probably negative, but not unambiguously so. Again converting (33) into proportional changes and substituting in (13), we find:

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

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

The food price is reduced by the lowland supply response, but this 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 instruments just considered yield contrasting outcomes. Ignoring direct fiscal gains or losses other than those associated with the tariff, the probability of a reduction in upland land area is greatest when interventions apply directly to upland sectors. However, the possibility exists that the same result could be achieved by subsidizing lowland food, or by *reducing* tariffs (the opposite of the case analyzed by us).

There are good political and economic reasons to consider the effects of the lowland interventions on upland resource allocation. Food self-sufficiency goals continue to motivate governments to seek supply gains from the technologically more advanced lowland areas. Conversely, ease of collection and a relatively diffuse impact means that trade taxes continue to be the primary instruments of fiscal policy in many developing countries. Moreover, current structural adjustment programs stress tariff reduction as contributing to an overall strategy of reducing inefficiency and reallocating resources in ways amenable to growth that is sustainable in an economic sense. 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 costs of a tariff reform program.

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).

A partial equilibrium analysis considering 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 elsewhere in the economy 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 increases in trade taxes will increase rates of resource depletion.[13] Our analysis contradicts such predictions in the case of annual crops grown in uplands.

Comparative statics predictions such as those presented above 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 presented we can make few firm predictions about the signs of changes even with the assumption of a dual labor market, i.e. with only a single market linking upland and lowland regions. When changes in endogenous variables cannot be predicted *a priori,* numerical simulation provides an appropriate alternative.

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.[14] These data (Table 2) indicate that together the two lowland sectors account for nearly four-fifths of GNP while treecrops contribute 14% and upland food 9%. Upland sectors, however, account for half of total employment. Of the four sectors, manufacturing is the least and upland food the most labor-intensive with the other two sectors holding intermediate positions. 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 of the expenditures of the representative consumer, manufactured goods 40% and treecrops 4%. 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 explicit measures of changes in trade volumes and values, government revenues and expenditures. We also add one new distortion, a subsidy on lowland agricultural production. This distortion 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 government budget consists of net revenues from tariffs and the upland food production tax and expenditures on the treecrop exports and lowland food subsidies:

$$B = T_M P_M^* M - S_L P_F Y_L - T_X P_X^* X + S_U P_F Y_L$$

where M and X are import and export volumes. These net revenues accrue to the representative consumer in the model, so the economy's aggregate budget constraint is satisfied when consumption expenditures equal factor payments plus net tariff and tax revenues. When this condition is met, the current account of merchandise trade is also in balance, by Walras' law.

We assume the inital rate of tariff and lowland agricultural subsidies to be 30% and 7.1% respectively; at these rates revenues from the tariff are exactly matched by spending on the subsidy. 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:

$$dB = T_M P_M^* M\,(\hat{P}_M^* + \hat{M} + \frac{1}{T_M}dT_M) - S_L P_F Y_L\,(\hat{P}_F + \hat{Y}_L + \frac{1}{S_L}dS_L) - P_X^* X\,dT_X + P_F Y_L\,dS_U.$$

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* balances on the budget and on the current account, in our simulations we permit both to move into deficit or surplus. However, as we will show, the aggregate budget constraint continues to be satisfied. Permitting the budget and trade accounts to display temporary disequilibria is not merely appropriate for a short-run simulation; it also reveals the kinds of macroeconomic stresses exerted by a policy change to which a government is likely to pay close attention. By this means our analyses reveal not only the environmental outcome from each policy change, but also some of its 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 upland land areas devoted to food production.[15] 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 produciton. 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 two policy interventions directly affecting upland sectors -- the Pigovian tax and the treecrop export subsidy -- have the greatest impact on upland resource allocation. The upland food production tax, for example, reduces that sector's land demand by 34% in the dual labor market case and 66% if labor is regionally mobile. However, tariff reduction and the lowland subsidy also contribute to reductions in upland food land area. In the single labor market case, reductions in upland food labor demand are not matched by increased employment in the more land-intensive treecrop sector. The policy changes thus promote outward migration from the upland region.

From a purely environmental viewpoint the results in Table 3 indicate that direct policies are most effective in reducing upland food land areas, and should therefore reduce erosion rates faster in the short run. However, the current account, budget and real GNP changes reported in

Table 4 reveal considerable asymmetry in the macroeconomic impacts of the four policy changes. Both trade tax changes increase real GNP, while the food sector interventions reduce it (each change in real GNP is matched by an equal and opposite change in the current account, which demonstrates that the aggregate budget constraint is satisfied). Moreover, the fiscal costs of the food sector taxes are substantially greater than those of the trade tax reforms. The food sector instruments and the export subsidy are all sources of new deadweight losses. In the former cases 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, in addition to new tariff revenues it creates, are sufficient to offset any new resource misallocation costs created by the subsidy.[16]

In table 5 we report factor price movements caused by the policy changes. The treecrop sector, which expands in each case, is land-intensive relative to upland food, so returns to upland land increase. Conversely, the contraction of labor-intensive upland food production reduces returns to upland labor, in the dual labor market case by 30%. These effects are of course moderated somewhat when labor is mobile across regions.

In sum, the *environmental* benefits from a Pigovian solution to upland erosion must be weighed against questions about its*economic* sustainability. First, policies which require developing country governments to increase their 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 long run the upland food tax could conceivably cause erosion rates to *increase*, by reducing the terms of trade of upland farmers and raising their rates of time discount.

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, 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 which helps illustrate the interactions between upland and lowland agricultural systems and to draw implications of some public policy changes in different sectors for upland soil erosion rates implied by shifts of land between more erosive food crops and less erosive tree crops.

We find that although Pigovian pollution taxes are superior instruments for reducing upland food area (and by extension, erosion), they and several other measures are inconsistent with other likely goals of policy, notably reduced budget deficits and improved welfare of poor groups. By extension, subsidies or price rises for upland food producers - recommended by some as palliatives for land degradation problems - would almost certainly have the effect of increasing upland food 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 (functions of land area devoted to food) 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 food's price 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.

For governments in developing countries concerned about the implications of environmental policies for what they regard as more pressing economic goals, the analysis we present invites explicit *ex ante* comparisons of the effects of alternative policy changes in relation to multiple objectives. Our results using this very simple model suggest a positive relationship between manufacturing tariff reduction and moves away from erosion-causing upland resource use patterns. If these results remain true in larger, more richly specified models, then some of the 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:		
$N_j = N_j(Y_j, W, R)$	$j = U,X$	(1')
$K_j = K_j(Y_j, W, R)$		(2')
$P_j Y_j = W N_j + R K_j$		(3')
Production and factor demand in lowland sectors:		
$N_j = N_j(Y_j, V, Q_j)$	$j = L,M$	(4')
$K_j = K_j(Y_j, V, Q_j)$		(5')
$P_j Y_j = V N_j + Q_j K_j$		(6')
Regional factor markets		
$N_U + N_X = N^U$		(7.1')
$N_L + N_M = N^L$		(7.2')
$K_U + K_X = K^U$		(7.3')
Domestic prices of tradables		
$P_j = P_j^*(1 + t_j)$	$j = M,X$	(8')
Regional producer prices of food		
$P_r = P_F(1 - s_j)$	$r = U,L$	(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_i	Lowland land/capital price ($j = L,M$)	N^R	Labor endowment in region R
K^U	Land endowment in upland region		
P_i	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_i	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	−13.9	−10.7	−28.6	−7.4
Lowland food	0.6	0.5	0.1	0.7
Treecrops	8.9	6.9	18.4	4.8
Manufacturing	−0.9	−0.7	−0.1	−1.2
Labor Demand				
Upland food	−11.8	−9.1	−24.4	−6.4
Lowland food	1.5	1.1	0.2	1.9
Treecrops	11.8	9.1	24.4	6.3
Manufacturing	−2.8	−2.2	−0.4	−3.5
Land Allocation				
Upland food	−16.4	−12.6	−33.8	−8.7
Treecrops	7.3	5.6	15.0	3.9
Single Labor Market				
Output				
Upland food	−24.1	−18.5	−66.0	−22.7
Lowland food	1.6	1.2	3.7	2.2
Treecrops	12.0	9.2	29.6	9.3
Manufacturing	−0.8	−0.6	0.3	−1.0
Labor Demand				
Upland food	−23.1	−17.8	−65.9	−23.3
Lowland food	3.9	3.0	9.1	5.5
Treecrops	13.3	10.2	29.8	8.5
Manufacturing	−2.5	−1.9	0.8	−3.0
Land Allocation				
Upland food	−25.2	−19.4	−66.2	−22.0
Treecrops	11.2	8.6	29.4	9.8

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	5.5	−3.5	−9.3	−2.4
Lowland food	5.5	−3.5	0.7	6.9
Treecrops	10.0	0.0	0.0	0.0
Manufacturing	0.0	−7.7	0.0	0.0
Consumer Price of Food	5.5	−3.5	0.7	−2.4
Exports (volume)	15.0	11.5	27.3	7.8
Imports	17.9	13.7	−15.0	−8.3
Current Account (% of GNP)	−0.3	−0.2	1.7	5.3
Gov. Revenue (% of GNP)	0.5	−0.6	−1.4	−0.3
Gov. Expenditure (% of GNP)	1.18	−0.1	0.0	4.2
Budget (% of GNP)	−0.7	−0.5	−1.4	−4.4
Real GNP	0.3	0.2	−1.7	−5.3
Single Labor Market				
Producer Prices:				
Upland food	7.9	−1.6	−0.3	1.3
Lowland food	7.9	−1.6	9.7	10.6
Treecrops	10.0	0.0	0.0	0.0
Manufacturing	0.0	−7.7	0.0	0.0
Consumer Price of Food	7.9	−1.6	9.7	1.3
Exports (volume)	18.6	14.3	40.5	13.3
Imports	24.0	18.5	7.6	0.9
Current Account (% of GNP)	−0.5	−0.4	3.3	1.2
Gov. Revenue (% of GNP)	0.7	−0.4	−0.7	−0.0
Gov. Expenditure (% of GNP)	1.3	−0.0	0.4	4.3
Budget (% of GNP)	−0.6	−0.4	−1.1	−4.3
Real GNP	0.5	0.4	−3.3	−1.2

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	18.2	6.3	16.8	4.3
Upland labor	−4.6	−11.3	−30.2	−7.8
Lowland labor	3.7	−4.8	0.5	4.7
Lowland land	6.7	−2.6	0.8	8.4
Manuf. capital	−1.9	−9.1	−0.2	−2.4
Single Labor Market				
Factor Prices				
Upland land	13.7	2.9	0.6	−2.3
Labor	3.3	−5.2	−1.1	4.1
Lowland land	11.1	0.8	17.0	15.0
Manuf. capital	−1.6	−9.0	0.6	−2.0

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] 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).

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

[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] This result makes use of the initial food market clearing condition.

[10] 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 $|A| \cdot (E_{FF} - G_{UF} - G_{LF}) > 0$ in our model.

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

[12] 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 (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).

[13] 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).

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

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

[16] The welfare gain from the export subsidy is a demonstration of the well-known principle that in an economy with existing distortions welfare may be increased by adding a new distortion. See footnote 12.