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Consequences of a food security strategy for economic welfare, income distribution and land degradation: the Philippine case*

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Abstract

Like many developing countries, the Philippines pursues a food security strategy in which self-sufficiency and price stabilization feature prominently. In addition to their widely debated welfare effects, food policies based on price and trade restrictions may also accelerate land degradation by promoting expansion of relatively erosive grain crops. We explore the welfare and environmental implications of food policies first with a simple heuristic model, then with an applied general equilibrium model. Comparing market restrictions with technical progress as alternative food policy strategies, we find that the former increase land degradation and reduce welfare; moreover, anti-poverty and distributional benefits often claimed for such interventions may be illusory.

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1. INTRODUCTION

Staple grains are intensely political goods in most poor countries. In food importers, a combination of import restrictions and consumer price ceilings is frequently pursued with the multiple objectives of attaining self-sufficiency in production, supporting producer incomes, and providing urban consumers with cheap food at stable prices (Anderson). Such programs inevitably involve tradeoffs between economic efficiency on one hand, and their potential redistributive and anti-poverty effects, as well as non-economic impacts such as self-sufficiency, on the other. However, there are other aspects of staple food policies that have not been explored, and which may be important in developing countries. Among these is environmental damage. Although environmental controls are now prominent in the agricultural policies of wealthy countries, they have yet to establish a firm presence in the minds of many developing country planners. In countries where reliance on the natural resource base remains a key feature of the lives of poor people, the value of agricultural development policies that could result in resource degradation must be very carefully assessed.

In this paper we identify and quantify some environmental as well as economic implications of current Philippine agricultural policies directed at achieving self-sufficiency and price stability in rice and corn. These crops occupy 50 per cent of Philippine agricultural land. About half of this area is upland or rainfed land, much of which is of generally poor quality and, when used to grow annual crops, is highly erosion-prone due to slope, soil structure, weather, or some combination of the three. For this reason we extend the conventional analysis of the welfare and distributional effects of agricultural policies to include a quantitative assessment of agricultural land degradation.

In spite of several decades of relatively rapid economic growth, agriculture in the Philippines retains considerable importance in factor incomes and trade, and basic foods constitute a large share of consumer spending. All Philippine governments in the postwar era have attempted to increase domestic production with the explicit goals of achieving national self-sufficiency and ensuring price stability for producers and consumers alike, as key components of food security and income redistribution strategies (Mangahas; Intal and Power; Pagulayan).[1]

Philippine grain yields are low by Asian standards, and with relatively low spending on agricultural infrastructure and technology, yields have not risen as rapidly as in comparable countries. Consequently, output growth has been due primarily to area expansion, promoted by trade and price policies. The chief agency of food policy has been the National Food Authority (NFA), which from 1950 until the early 1990s held a monopoly over Philippine cereal trade as well as engaging in domestic purchase, storage and release to promote production and to defend producer price floors and consumer price ceilings. Given the political significance of self-sufficiency, NFA grain imports are historically very tightly circumscribed,[2] and in spite of liberalization in recent years, nominal protection rates (NPRs) remain high by comparison with other agricultural commodities. The NPR for rice averaged 8 per cent from 1960-86. That for corn has generally been much higher, especially after the mid-1970s when self-sufficiency was made a goal: the NPR averaged 18% in 1970-74, and 42% in 1983-86 (Intal and Power); in 1990 it reached 63% (Pagulayan), and has remained at or above this level since (for comparison, all other crops except sugar have negative average NPRs, while the average manufacturing NPR exceeded 30% until recently). While the rhetoric of agricultural policy also prioritizes technological progress and infrastructure development, the net subsidy received by the NFA for its grain price and marketing programs exceeds the agricultural R&D budget by a factor of 50 (Manasan).

Expansion of the permanent agricultural area takes place mainly at the frontier, in upland agronomic zones. It occurs through replacement of perennial and long-fallow agricultural systems (including forests) by short-season crops, among which corn predominates.[3] In seasonal cropping the soil is tilled more frequently and exposed for longer periods to the erosive effects of rain and wind, so this land use change has been associated with rapid increases in upland land degradation and soil erosion. Corn in particular is associated with high rates of soil nutrient uptake and erosion in tropical soils, and among upland crops in the Philippines is the chief contributor to land degradation by virtue both of its high relative erosivity and its large share of upland cropped area (David). Agricultural policies that support corn prices thus contribute to increased land degradation.[4] Technical progress could inhibit this by raising yields on existing croplands, thus allowing food self-sufficiency targets to be achieved at lower levels of price support. Lower protection for corn producers would in turn diminish incentives to continue expanding corn production in uplands. In other words, investments in technical progress might help the Philippines achieve its food policy goals at a lower environmental cost than the equivalent amount spent in defense of producer prices.

Our results in this study suggest that endogenous changes in the rate of land degradation caused by Philippine cereal policies aimed at self-sufficiency and price stability are large in relation to national income, agricultural factor markets, and the budgets of government agencies charged with promoting soil conservation. These environmental costs should be included in assessments of the benefits and costs of agricultural policy.

METHODOLOGICAL APPROACHES

Natural resource accounting (NRA) studies have quantified losses from agricultural land degradation in several developing countries (Repetto *et al*.; Barbier and Bishop). However, NRA generates only circumstantial evidence on the causes of land degradation, and thus has limited capacity to inform policy-making. Other methods are required to identify economic causation and thus to indicate specific solutions. In developing countries, where agriculture is frequently large in relation to income, trade and domestic markets, a general equilibrium approach to the measurement of losses from agricultural development is appropriate.[5] However, most policy-environment analyses for developing countries are conducted at a high level of generality; in spite of much policy interest there are still few general equilibrium models providing rigorous empirical analyses of specific policies and particular environmental phenomena within such economies.[6] The contribution of this paper is first to provide comparative static analysis of a set of food sector policies common in some form to many developing countries, and second to conduct an empirical general equilibrium examination of the environmental, welfare and distributional implications of specific policies in the Philippines.

The empirical core is a set of experiments using an applied general equilibrium (AGE) model of the Philippine economy, in which we evaluate the effects of policy changes and technical progress affecting cereal crop sectors under alternative trade and agricultural pricing policy regimes. In order to understand the results from this large and complex model, we first provide a highly simplified sketch of its microeconomic foundations. This exercise provides valuable help in identifying environmental and welfare changes associated with policy changes or technical progress in the presence of trade and price interventions. Subsequently, we quantify these analytical insights by means of experiments with the AGE model. In a final section we discuss the value of predicted economic and environmental changes and evaluate some policy implications.

(a) Heuristic general equilibrium model

In this section we develop a simple model with which to explore interactions between agricultural price and trade policy, land degradation, and economic welfare. To focus on land degradation, we abstract from other forms of environmental damage—not only non-agricultural pollution, but also the off-site effects of chemical use and soil erosion in upland agriculture.

Suppose that upland land is used to produce two crops, and that one, *D*, is relatively land degrading (in the sense of drawing nutrients from the soil and contributing to erosion and soil structure degradation) while the other, *C*, is not. Suppose also that *D*, the land-degrading crop, is a cereal such as rice or corn. Other things equal, reallocating land from *C* to *D* production increases land degradation, and in this way land quality is endogenously related to land use. Our assessment of the net social benefits of grain sector policies that induce land use change will then depend on whether we assign a positive or zero value to the land quality change.

In the analyses that follow we compare pairs of welfare outcomes following policy or technology shocks. Each pair consists of an outcome in which land degradation costs are ignored, and another in which they are given positive values. In general, ignoring environmental costs gives results in which a particular shock yields an unambiguously positive or negative welfare change. Including environmental costs, however, introduces ambiguity to these results. This ambiguity is the focus of our interest since it draws attention to specific structural features of the economy, policy regimes and technologies as determinants of the final welfare outcome.

In the analysis that follows we first define the effective land endowment and develop a measure of welfare change inclusive of the value of changes in this endowment. We then examine the welfare and land degradation effects of agricultural policies and technical progress under alternative assumptions about cereal sector policies, particularly price and trade restrictions that correspond broadly to the Philippine case.

(i) The basic model

Let T stand for the effective (i.e. quality-adjusted) endowment of upland land available for agricultural production. We define this as the product of the physical endowment of land, T^*, and an augmentation parameter, A, representing the effects of technical progress. Technical progress is sector-specific, so in our two-sector representation of the upland economy $T = A_c T_c^* + A_d T_d^*$.

However, production in each sector is also associated with some rate of land degradation, which we denote by $\alpha_j \geq 0$. When this is counted, the definition of the effective land endowment adjusted for environmental effects becomes:

(1) $$T = (1 - \alpha_c) A_c T_c^* + (1 - \alpha_d) A_d T_d^*$$

As indicated above, we distinguish two cases conditional on values of α as follows. *Free disposal* attaches no value to land degradation, so in this case we assign $\alpha_j = 0$ for all crops j. In uplands of developing countries, open-access is generally a good approximation of prevailing property rights. This market failure as well as the inherent difficulty of measuring soil quality makes it reasonable to assume that the on-site effects of land degradation may not be fully capitalized into land values.[7]

The alternative case is *weak disposal*, in which at least one α_j is strictly positive. In welfare analysis, accounting for land degradation losses in this way amounts to applying NRA methods for upland land degradation. Under weak disposal, technical progress or price changes that create incentives to increase the use of uplands for relatively land-degrading crops may reduce aggregate welfare in spite of being privately profitable. In order to identify welfare effects, we now locate this agricultural land degradation story in its general equilibrium context.

In developing the model we assume competitive markets and constant returns to scale and make use of the following notation and definitions. Aggregate expenditure (by a representative consumer) is denoted by the expenditure function $e(\mathbf{p},u)=\min\{\mathbf{p}\ \ \mathbf{c}\,|\,u\}$, and aggregate income by the revenue function $g(\mathbf{p},v)=\max\{\mathbf{p}\ \ \mathbf{y}\,|\,\mathbf{v}\}$, where $\mathbf{p}$, $\mathbf{c}$, and $\mathbf{y}$ denote vectors of prices, consumption and production respectively, and u stands for utility. The vector $\mathbf{v}$ is the economy's factor endowment, of which the effective land endowment T is one element. Partial derivatives of the expenditure and revenue functions with respect to the *j*'th price give commodity demands by consumers and supplies by firms. We denote these by $e_i = \partial e(\mathbf{p},u)/\partial p_i > 0$ and $y_i = \partial g(\mathbf{p},v)/\partial p_i > 0$ respectively, and note that their difference $(e_i - y_i)$ is net trade (positive if the good is a net import; negative if it is a net export). The derivative of the revenue function with respect to each factor endowment gives the shadow price of that factor; thus for upland land with price *r*, $r = \partial g(\mathbf{p},\mathbf{v})/\partial T$. In a competitive economy the optimal factor demands of cost-minimizing producers are exactly those consistent with the vectors of optimal commodity supplies and factor prices obtained from revenue maximization (Dixit and Norman). Thus, using $\mathbf{w}$ to represent the vector of factor prices and $y_i c^j(\mathbf{w})$ for the unit cost function in sector *j*, we can write the demand for land in each sector, T_j, in terms of exogenous price and endowment changes as:

$$(2) \qquad T_j = y_j \frac{\partial c^j}{\partial r} = \frac{\partial g_j(\mathbf{p},\mathbf{v})}{\partial p_j}\frac{\partial c^j}{\partial r(\mathbf{p},\mathbf{v})} \qquad j=C,D.$$

This expression demonstrates the general equilibrium nature of the land allocation problem by showing land demand to be a function of economy-wide prices and factor endowments.

At the level of the whole economy, firm-level land degradation externalities are internalized in the form of reductions in the effective land endowment. In the absence of price policy or other interventions, aggregate expenditure in each period must be equal to aggregate income minus the current value of land degradation. This implies an economy-wide budget constraint of the form:

$$(3) \qquad e(\mathbf{p},u) = g(\mathbf{p},\mathbf{v}) - \sum_j \alpha_j y_j \frac{\partial c^j}{\partial r}.$$

We can see from (3) that under weak disposal (i.e., some $\alpha_j > 0$), an increase in the price of one agricultural good, with other prices held constant, will influence aggregate welfare through two channels: directly, via changes in production, consumption and net trade, and indirectly, through changes in the natural resource base. As an example, to see the welfare effect of an increase in the price of *D*, take the total differential of (3) with respect to p_d, holding other commodity and factor prices constant,[8] to obtain:

$$e_u \frac{\partial u}{\partial p_d} = -(e_d - y_d) - \sum_{j=C,D} \alpha_j \left\{ T_j^* \frac{\partial y_j}{\partial p_d} + y_j \frac{\partial T_j^*}{\partial r} \frac{\partial r_j}{\partial p_d} \right\} \qquad j = D,C, \tag{4}$$

Since e_u is the inverse of the marginal utility of income, the left-hand side is a money metric of welfare change with respect to p_d, holding other prices constant. Under free disposal (all α_j=0), a rise in p_d is just a terms-of-trade shock: welfare will improve if *D* is a net export, and worsen if it is a net import. Under weak disposal, however, the value of land degradation changes could modify this result. The sign of the term within braces in (4) depends on each upland sector's supply response, on land use responses to factor price changes, and on the effect of the commodity price change on land returns. The second term within the braces can be signed only once we know which upland sector is relatively land-intensive.[9] Under weak disposal with $\alpha_d > \alpha_c$, the rise in p_d will unambiguously raise welfare only if *D* is a net export *and* the sum of the terms within braces is less than $e_d - y_d$. The latter is the more likely if the *D* sector is less price-responsive, and if the technology of production of *D* is less land-intensive than *C* (since then $\partial r/\partial p_d < 0$). Conversely, welfare will unambiguously decline if *D* is a net import, is relatively land-degrading, and is more land-intensive than *C*. Between these polar cases there is clearly a range of intermediate results in which under weak disposal the net welfare impact cannot be predicted without first assigning values to the parameters of land degradation, land-intensity of production, and supply response.

The analysis of technical progress runs parallel to that of a price change. For the purpose of developing the model we restrict our attention to the case of factor-neutral technical change (the model is capable of more general forms). Technical progress in sector *j* can thus be modeled by defining the effective producer price vector $\tau\mathbf{p}$, where the productivity augmentation parameters τ_j take initial values of 1 for all *j*, and technical progress is represented by $d\tau_j > 0$. Redefining the revenue function as $g(\tau\mathbf{p},\mathbf{v})$, and evaluating the total differential of (3) with respect to τ_d gives:

$$(5) \qquad e_u \frac{\partial u}{\partial \tau_d} = \frac{\partial g}{\partial \tau_d} - \sum_{j=C,D} \alpha_j \left\{ T_j^* \frac{\partial y_j}{\partial \tau_d} + y_j \frac{\partial T_j^*}{\partial r} \frac{\partial r_j}{\partial \tau_d} \right\},$$

which can be rewritten in terms of price change parameters as:[10]

$$(6) \qquad e_u \frac{\partial u}{\partial \tau_d} = p_d y_d - p_d \sum_{j=C,D} \alpha_j \left\{ T_j^* \left(\delta_{dj} y_j + p_j \frac{\partial y_j}{\partial p_d} \right) + y_j \frac{\partial T_j^*}{\partial r} \frac{\partial r_j}{\partial p_d} \right\}.$$

where $\delta_{dj} = 1$ for j=d, and 0 otherwise. Under free disposal the marginal welfare gain from technical change is the value of an additional unit of D sector output, $p_d y_d$. With weak disposal, this gain may be increased or reduced by the valued land degradation effects of changes in sectoral outputs and factor intensities— the first and second terms respectively within braces in (6).[11] Again, the analysis draws our attention to the need to obtain more information on agricultural technology (land-intensity) and supply response if welfare predictions are to be made.

Compared with free disposal, in our examples both technical progress and a price increase have additional first-order welfare effects under weak disposal because they induce land use shifts to the more erosive crop. Whether a particular shock causes welfare to increase or decline depends on whether its environmental effects augment or offset its 'conventional' economic effects.

(ii) Trade restrictions and government purchases

Food security policies typically involve interventions in international trade and domestic markets, aiming for self-sufficiency and price stability. If a domestic supply shock occurs in cereals and restrictions on international trade are binding, then either cereals' prices must adjust to clear the domestic market, or the market may clear at a constant price through a quantity mechanism such as government purchases and releases from buffer stocks. We can accommodate either possibility by equating net government grain purchases, D^G, to the excess of domestic supply over demand:

$$(7) \qquad D^G = g_d(\tau\mathbf{p},\mathbf{v}) - e_d(\mathbf{p},u).$$

In the absence of international trade, when D^G is fixed the domestic grain price adjusts to clear the market just as for a pure non-traded good. Alternatively, the government can defend a fixed price by allowing D^G to adjust to balance changes in supply with consumer demand. Suppose that the government maintains budget balance by means of a lump-sum tax on households; when $D^G > 0$, aggregate household consumption is reduced by the amount of tax revenue required to fund the grain purchase. We capture this by restating the aggregate income-expenditure constraint (3) as:

$$e(\mathbf{p},u) = g(\tau\mathbf{p},\mathbf{v}) - p_d D^G - \sum_j \alpha_j y_j \frac{\partial c^j}{\partial r(\tau\mathbf{p},\mathbf{v})}. \tag{8}$$

Simultaneous solution of (7) and (8) yields the equilibrium value of aggregate real income and either (a) the domestic grain price p_d, with D^G fixed, or (b) the level of government purchases D^G, with p_d fixed.[12] These are polar cases of a typical food policy based on both trade restrictions and domestic purchases. Closure (a) is more appropriate when government policy targets a predetermined grain buffer stock; closure (b) more closely resembles the use of food price stabilization as a tool of agricultural growth, anti-poverty and redistributive programs. For brevity, and anticipating the Philippine case study in the next section, we will examine only case (b), setting grain prices exogenous and examining the effects of price and technology changes. (At the end of this section we discuss other closures, including the possibility that some trade occurs but that imports and domestically produced goods are imperfect substitutes).

Substituting for D^G in (8) from (7) and taking the total differential with respect to p_d yields an expression for welfare change analogous to the no-intervention case shown in (4):

$$\gamma \frac{\partial u}{\partial p_d} = p_d Z_{dd} - \sum_{j=C,D} \alpha_j \left\{ T_j^* \frac{\partial y_j}{\partial p_d} + y_j \frac{\partial T_j^*}{\partial r} \frac{\partial r_j}{\partial p_d} \right\}, \tag{9}$$

where $\gamma = e_u - p_d e_{du} > 0$ in stable models and $Z_{dd} = e_{dd} - g_{dd} < 0$ is the price response of excess demand for D. This expression shows that under free disposal (α=0) the welfare cost of raising the grain price is positive when the quantity of grain purchased by government is endogenous. Under weak disposal the value of this loss is increased by the value of environmental damages associated with the movement of land into grain production.

The effect of technical progress with a trade ban and domestic price controls can be seen by again substituting from (7) into (8) and taking the total differential, this time with respect to τ_d:

(10) $$\gamma \frac{\partial u}{\partial \tau_d} = -p_d^2 \frac{\partial y_d}{\partial p_d} - \sum_{j=C,D} \alpha_j \left\{ T_j^* \frac{\partial y_j}{\partial p_d} + y_j \frac{\partial T_j^*}{\partial r} \frac{\partial r_j}{\partial p_d} \right\},$$

This result may be surprising at first: even under free disposal, technical progress generates an unambiguous welfare loss when government purchases all additional output from sector *D*. Relative to the initial equilibrium, technical progress in the protected sector simply induces overproduction; part of the *D* sector supply increase is obtained at the expense of production in other sectors. To preserve budget balance, consumers must pay for government purchases, which they do through lump-sum taxation. At constant prices the value of the aggregate real income gain due to technical progress is outweighed by the cost of financing the grain purchase program.[13] Since technical progress also causes more land to be used for the land-degrading crop, relaxing the free disposal assumption merely worsens this prediction.

The foregoing analysis serves two purposes. First, it posits a direct linkage between food policies and the environment and permits us to explore the welfare implications of this linkage. Under free disposal, policies that increase grain production and absorb the resulting excess supply through market interventions will impose costs in terms of aggregate real income or in terms of foregone opportunities for growth due to technical progress. Under weak disposal—inclusive of environmental damages—the model shows that food policies can have uncertain welfare results. Second, the analysis then helps us understand the sources of ambiguity in welfare outcomes by identifying characteristics of the economy—agricultural technology, factor mobility, and agricultural supply responsiveness—that condition the welfare impact of a price or technology shock. If a shock causes the grain sector land use to expand, then welfare is more likely to be reduced if that sector makes a relatively large contribution to land degradation, either by virtue of its share of overall land use or the technologies it employs. These effects occur in addition to any other welfare effects associated with price-setting or trade interventions.

(b) Analytical versus numerical approaches

A heuristic model helps us to think formally and rigorously about land degradation. However, it has clear limitations when we turn to empirical questions. As we have seen, the relative magnitudes and even the signs of the changes in (9) and (10) cannot be identified without additional economic and agronomic information. Moreover, the analysis has thus far been conducted at the simplest possible level in terms of sectors, inputs and technology and with a single consumer; and we have excluded many complicating factors, including policies affecting other sectors. By comparison, a numerical or applied general equilibrium (AGE) approach is less transparent but affords more complexity and thus much greater realism. The AGE approach has the advantage that we can assign magnitudes as well as signs to predicted changes, thus complementing the predictions of the heuristic model with empirical results.

One important gain, among many, from the AGE approach is the option of relaxing "polar" assumptions about market structure and price formation. Equations (6) and (10) showed extreme cases of free trade and no trade in grains respectively. However, they shared the property of a fixed grain price— in the first instance because it is set in world markets and in the second because it is defended by government purchases. The AGE model that follows employs intermediate cases in which producer grain prices are somewhat responsive to market changes. There are several key differences. First, imported and domestically produced cereals are imperfect substitutes, so that even without quantitative trade restrictions a change in the domestic market can alter the grain price. Under this assumption an increase in domestic output, due for example to technical progress, may be reflected in part in a decline in the producer price, thus dampening the welfare and environmental effects shown in (6). Second, the AGE model captures intermediate purchases. Since farmers sell their grain not to consumers but to millers and traders, this is important when price policies effectively target consumer prices rather than prices at the farm gate—as in the Philippine case. Third, the AGE model captures intersectoral linkages operating through factor markets, so that agricultural prices and profitability are subject to many other influences, including policy interventions in non-cereal sectors. These linkages increase the possibility that upland agricultural growth could be welfare enhancing even when land degradation increases.

Finally, by increasing the number of factors of production, disaggregating households, and constructing household-specific consumer price indices based on observed expenditure patterns, an

AGE model can capture the real distributional implications of price and technology changes. This is important in an empirical assessment of food policies, since reductions in poverty and inequality are major justifications offered for their adoption.

THE APEX MODEL OF THE PHILIPPINE ECONOMY

(a) An outline of the APEX model

We now use an AGE model to examine the economic and environmental implications of technical progress and trade and price interventions in Philippine grain markets, simulating their impacts on factor and product markets, household incomes, government revenues and trade. Our vehicle is APEX, a large, empirically based AGE model of the Philippine economy designed for policy analysis. The following is a brief overview of the model.[14]

APEX was designed for the analysis of technical progress in agriculture, economic policy and income distribution in the Philippines. It is a comparative-static model in the so-called Johansen tradition, meaning that the model is linear in the proportional changes of its variables from their values in a base year. Several features of APEX set it apart from similar developing-country models. Most notably, all elasticities of production, consumption and trade are econometrically estimated from Philippine time series data using flexible functional forms, a feature which greatly increases the realism of its simulation results.

The model is highly disaggregated. It has fifty sectors, of which seven produce agricultural goods. Some of the seven jointly produce several goods; notably, rainfed rice, corn and root crops are jointly produced in the sector called "rainfed crops" (irrigated rice is a separate sector). There are eleven agricultural goods in all; each is produced in three regions corresponding to the main island groupings (Luzon, Visayas, and Mindanao). Agricultural production uses land, labor, fertilizer and other intermediate goods. Primary factors and fertilizer are aggregated into a single primary input in each region with econometrically estimated parameters; this composite input is combined with intermediate inputs in fixed proportions for a given technology (agricultural parameter estimates are reported in Warr (1995)). Given input prices, a representative producer in each region is modeled as buying a production possibility set, upon which the commodity composition of aggregate output is decided by revenue maximization with respect to product prices and technology. Figure 1 summarizes the structure of the agricultural economy.

APEX also contains very detailed descriptions of production, input use, and trade in non-agricultural sectors. These sectors employ skilled labor in addition to the primary factors already named; the composite labor input is a constant elasticity of substitution (CES) aggregation of skilled and unskilled labor. Private absorption and factor ownership is modeled for five representative households, each having a unique pattern of factor ownership and consumption expenditures. These are based on Philippine data on the quintile distribution of income and expenditures. Input-output and trade data are obtained from the 1989 Philippine social accounting matrix. Savings and investment, and government revenues and expenditures are also modeled in detail from national accounts data. For importable goods, Armington elasticities of substitution between imports and domestically produced goods are estimated separately for each commodity.

For this study we extend the model just described to include measures of agricultural land degradation. We do this by accounting for changes in soil quality associated with changes in upland land use and technology. Our measure of a change in land degradation is a change in the amount of land allocated to more erosive uses, principally corn and upland rice. We assume homogeneous soil conditions and technology, and use the nutrient replacement cost method (see below) to construct estimates of on-site costs associated with upland land use changes.

(b) Closure: the policy setting

The macroeconomic closure of a general equilibrium model reflects assumptions about economic structure. Alternate closures can thus be used to conduct what might be called 'structural sensitivity analysis', i.e. to examine the robustness of simulation results with respect to the specification of macroeconomic relationships. We can use this to identify the contribution of food policy interventions to observed outcomes. In the following experiments we use two closures: one with and one without grain market interventions of the type discussed earlier. In the first closure, domestic grain prices are endogenous and international trade in rice and corn is unrestricted (although the government levies an import tariff).[15] Grain markets thus clear entirely through endogenous adjustments in trade and domestic prices, as in (3) - (6) above. We label this standard representation of market structure the *unrestricted* closure.

In the second closure we capture the effects of interventions by fixing cereal imports exogenously and making government purchases of the output of the rice and corn milling sector endogenous, as in (8) - (10) above. We label this the *NFA* closure. Without trade, in this closure the government buys the entire excess of domestic cereal supply over demand, with the intent of fixing nominal consumer cereal prices. This in turn supports producer prices of rough rice and corn, since these are strongly influenced by demand from the grain-milling sector from which government is assumed to make its purchases.

Both closures share some other characteristics. World prices of imports and exports are exogenously fixed (the small country assumption) as is the nominal exchange rate, providing a *numeraire* for domestic prices. The current account, budget deficit and real savings of households are also fixed, so the effects of shocks are fully absorbed by current-period changes in real household expenditures. Budget balance is maintained by endogenous adjustments in a lump-sum tax on households.[16] In all experiments we hold the physical agricultural land area constant.[17]

EMPIRICAL EXPERIMENTS

In order to compare alternative paths towards food security, we now present the results of three simulation experiments. In the first we adopt the NFA closure and assess the effects of a ten per cent rise in cereal support prices. In the second and third experiments we evaluate the effects of productivity growth in corn, the major crop in environmentally marginal upland and rainfed areas. Experiment 2 does this in a no-intervention setting (the unrestricted closure), while in experiment 3 we adopt the NFA closure, re-evaluating the effects of technical progress in the presence of the price-supporting interventions. In all experiments we maintain the assumption that technical progress and land management practices change exogenously, but that changes in land allocation to different crops are responsive to changes in relative commodity and factor prices. The main results are summarized in Figures 2–7.[18]

(a) Effects of price policies and technological change

(i) Cereal price increase.

An increase in the support price promotes profits and output in rice and corn sectors at the expense of other agricultural activities (Figure 2) as land and other resources are drawn into grain production. Although cereals are not traded in the NFA closure, the price support nevertheless affects trade: outputs of all major export crops (coconut, sugar, banana and fruit) decline. Domestic prices of livestock products, the producers of which are major buyers of corn for feed, rise by about 3% (Figure 3). Raising the cereal price benefits agricultural processing industries (of which rice and corn milling form a major part), but raises costs and so reduces output in natural resource, manufacturing and services sectors (Figure 4).

At the level of the aggregate economy, the price support reduces real GDP (-0.4%) and average real household consumption expenditures (-1.5%) (Figure 5). It has a progressive impact on distribution (Figure 6). However, all real household incomes decline: the policy enables poor households to gain a larger slice of a smaller overall pie. Finally, by raising returns to grains, the price support draws more land into production of these relatively erosive crops, promoting a more rapid rate of agricultural land degradation (Figure 7). The environmental impact of the price support is most strongly seen in Mindanao, the Philippines' major corn-growing region.

(ii) Technical progress in corn production.

In our second and third experiments we simulate a 10% rate of factor-neutral technical progress in corn. In the second experiment we do this as a counterfactual in the unrestricted closure; in the third experiment we re-examine the effects of technical progress in the NFA closure used for experiment 1. Domestic demand for cereals is highly inelastic, so as Figure 2 shows, technical change in corn leads to a less than proportional increase in corn output, and—unlike the price support case—the increased output is not won at the expense of production in other sectors.

Indeed, the productivity gain results less in increased sales than in a price drop (Figure 3). Moreover, because the corn sector is large in relation to agricultural factor markets, its decline drives down unit costs in other sectors, which can thus increase their output even as they pass on some of the gains in the form of lower prices.

Assuming free disposal, technical progress raises real GDP and aggregate real household consumption (Figure 5). All quintiles of households gain in terms of real consumption expenditures, although the wealthy gain most (Figure 6). Since erosion rates in corn are higher than in other crops, the price decline reduces land degradation (Figure 7). Technical progress in corn, by driving down producer prices, has caused some agricultural land to be shifted from corn production to less erosive agricultural uses. Since real expenditures increase and land degradation declines, it follows that aggregate welfare increases even in the weak disposal definition.

Experiment 2 shows that in the absence of grain price supports, technical progress in corn is beneficial both in terms of conventional measures of economic welfare and in terms of environmental quality. The former result is as predicted earlier in equation (6); the latter is influenced by the imperfect substitutability of imported for domestic corn. If the law of one price prevailed, technical progress in corn would instead have a minimal price impact, and corn area might expand rather than contracting as shown in the experimental results; this could produce an outcome in which the land degradation cost of technical progress exceeds the free disposal benefit.

(b) Shocks in the presence of interventions

In experiment 3 we re-evaluate the same technical progress shock in the policy-distorted NFA closure. When grain output rises due to the productivity increase, the government now absorbs excess supply by buying cereals from the grain-milling sector at a fixed price. Consequently, grain demand is substantially more elastic, and this dampens the price-reducing effect of the technical change. Corn output rises by twice as much as in the unrestricted case (Figure 2), and the producer price decline is 15% lower (Figure 3). As a result, less land is drawn out of corn production, and land degradation declines by a smaller amount in each region (Figure 7). The national average erosion decline is a little more than four-fifths of that observed in the price support experiment.

Relative to the unrestricted case, the additional resources attracted into rice and corn production in the NFA closure generate reduced rates of output growth in the services, natural resources and manufacturing sectors, and boost agricultural processing industries (Figure 3). However, it is on the consumer side of the economy that the NFA intervention is most strongly felt. With price supports in place, consumer prices of cereal products decline relative to the CPI when output grows. Poor households are the main beneficiaries, so the relative distribution of gains and losses among households is somewhat more equal than in the unrestricted case. However, the rise in real aggregate household expenditures is one third smaller. One reason for the diminished welfare gain is that in order to finance its cereals purchases and still maintain budget balance, the government must raise additional revenue, which it does by increasing the rate of the lump-sum tax on households. The other is that the price supports increase the relative profitability of production in corn, a sector already supported by distortionary interventions in the form of tariffs, and reduce it in less protected sectors such as export agriculture. The price supports thus increase deadweight losses to the economy by reducing the transfer of resources out of the relatively highly protected sector.

In both technical change experiments, the inelastic nature of domestic cereals demand creates a treadmill effect in which the productivity gains enjoyed by corn producers are more than offset by terms of trade losses. As long as land can be reallocated to less erosive uses, this inelasticity clearly has a positive environmental effect, causing corn area to decline as yields increase. The corn area decline occurs whether or not there is intervention in grain markets. However, interventions dampen the treadmill effect and thus reduce the likelihood of significant environmental gains from technical change. Interventions also do little to improve the distribution of real household expenditures, and moreover impose substantial deadweight losses.

(c) Valuing land degradation changes

A full valuation of land degradation changes is extremely difficult. Off-site damages evolve slowly over time, and downstream damages may also be offset by soil deposition on lowland farms—although these are widely regarded as small in relation to damage costs. In this study we maintain a conservative stance by accounting for on-site losses from upland rice and corn cultivation only. Combined, these sectors account for roughly 42 percent of land area in Philippine uplands, but about 90 percent of upland agricultural soil loss (Coxhead and Shively).

We calculate the aggregate value of changes in land degradation (J) by the formula $J = PdE$, where P is the annual estimated value of erosion (per ton), and E is initial aggregate erosion, calculated from slope-specific crop erosion rates, regional rice and corn area, and the regional distribution of land of medium and high slope (Coxhead and Shively).[19] Endogenous changes in rice and corn area in APEX simulations are reflected in the change in E. For valuations we rely on computed erosion losses for three critical soil nutrients in two major Philippine watersheds by Cruz *et al.* They obtain kilogram-per-hectare estimates for nitrogen loss and urea equivalents; phosphorus loss and solophos equivalents; and potassium loss and potash equivalents, and calculate the replacement costs of these nutrients using market fertilizer prices. Their valuation of nutrient loss at $US0.60 per ton of eroded soil is also highly conservative, since it accounts for losses from sheet erosion only, and neglects changes associated with soil structure decay. Substituting this value for P above yields the figures reported in 1.

The 10% support price rise produces an increase in land degradation as land moves into rice and corn production, and is associated with a cost in terms of on-site losses alone of $4 million (Table 1). In contrast, technical progress in the relatively erosive crop drives down its price and causes the transfer of land to more profitable uses. This results in reduced on-site losses of $12 million in the unrestricted closure, and $10 million in the NFA closure. These amounts, while small in relation to total GDP, represent substantial fractions of the agricultural budget and of the component of that budget devoted to environmental preservation. The changes in land degradation losses are also large relative to the GDP growth gains predicted to occur as a result of the technical progress. These results are robust with respect to variations in assumptions regarding the unit value and rate of soil quality losses (Table 2).

(d) Land degradation and income distribution

Any exogenous change that affects upland agricultural profitability will also alter the distribution of factor incomes. Specifically, trade restrictions and the failure to assign full value to land degradation losses both generate rents that accrue to the owners of factors used intensively in a protected or land-degrading sector. As noted earlier, an important role for the NFA has been to promote a more equal distribution of income in the Philippines by supporting producer prices and containing consumer prices of staple foods. In practice, however, the agency has had relatively little success in sustaining producer prices during periods of rapid agricultural growth. Its impact on the distribution of the gains from economic growth has thus been slight, as can be seen by comparing distributional changes across closures in Figure 6. Price support policies have a positive distributional effect but reduce all incomes, including those of the poor. The technical change experiments show that in spite of government purchases the distributional impact of technical change in corn production remains regressive; however, the rise in inequality is accompanied by a general increase in real income. Comparing experiments 2 and 3 shows that the modest narrowing of the distribution of real expenditure changes that NFA intervention does achieve relative to the unrestricted case is won at the cost of a lower gain in overall economic welfare.

(e) Price stabilization

While our approach captures important general equilibrium linkages, it does so at the expense of some other potentially relevant economic phenomena. In the context of food policy, the most important is price stabilization. Since APEX considers only the first moments of price variables, we have implicitly assumed that agents are risk-neutral. If they are risk-averse then price stabilization may have positive economic value, and this has been argued to be important in assessing other developing country grain trade and pricing policies (Dawe). Food price stabilization may have other non-market benefits not captured in the model. As part of a more general argument on agricultural growth and economic development, Peter Timmer has argued that volatile prices, together with long-term declines in the share of agriculture and in real world commodity prices, create a "dignal extraction" problem that "serves to confuse policy makers who try to design an appropriate strategy for the agricultural sector (p.456)". Under free disposal, there may be a strong case for stabilization. On the other hand, stabilizing the producer price of a relatively risky crop creates added incentives for risk-averse farmers to plant it. At the policy level, moreover, if Timmer is right then policy makers might devote additional research and extension resources to a crop that yields a "clearer" signal through price stabilization—thus further increasing incentives to plant the crop. If the crop is relatively land degrading, then the benefits of price stabilization must be weighed against increased environmental costs associated with expansion of its planted area.[20]

Whether NFA interventions have helped stabilize Philippine grain prices is an unresolved empirical question. Recent econometric evidence suggests that the NFA had only minor effects on producer prices (Martinez *et al.*). Moreover, NFA activities probably crowded out some private sector arbitrage (Lantican and Unnevehr), so the effect of interventions on price volatility could have been positive or negative. In addition, legal and bureaucratic impediments to timely grain importation have clearly *de*stabilized Philippine grain prices during crises and demand shocks in which domestic stocks were inadequate—most recently during the rice crisis of August 1996, when delayed import approvals result in panic-buying and the trebling of retail rice prices.

Finally, the extent to which grain price stabilization reduces risk depends, in part, on interactions with environmental outcomes and other agricultural policies. Empirical research on land use responsiveness to price variability indicates a strong negative relationship between price variance and planted area for corn as well as other crops grown by upland farmers in the Philippines (Shively 1998; Coxhead *et al,* 1999). However, producers opting for expanded cereal cultivation may replace price risk with yield risk if the land use shift causes land degradation rates to increase. This phenomenon may be replicated at a national level if self-sufficiency policies require that a significant share of domestic production come from agricultural lands at risk of degradation. And the welfare role of price stabilization is of course much greater in economies where prices of other agricultural outputs are suppressed, as has very notably been the case with export crops in the Philippines (Intal and Power, Pagulayan). While more research is called for, it seems clear that a complete accounting for the welfare effects of such price stabilization as has occurred in the Philippines will reveal that Timmer's non-market benefits are to some extent offset by additional environmental costs.

CONCLUSION

Food security in staple grains is an important policy target in many developing countries. If pursued purely or primarily through trade and price interventions, however, it is likely to be achieved at some cost in terms of economic welfare. In economies where agriculture is large in relation to total income, employment, or household expenditures, the effects of agricultural support programs may be pervasive, causing reduced profitability even in non-agricultural sectors. In addition, price support for food crops causes scarce agricultural land to be transferred from generally less erosive to more erosive uses, and the consequent decline in effective land area means that future generations also bear part of the cost of policies directed at the current generation. Conversely, investments in technical progress and improved land productivity may have social benefits in excess of private profits if incentives to use land in environmentally damaging ways diminish as a result.

The empirical core of our study indicates the importance of a general equilibrium appraisal of welfare and environmental impacts of food policy. Interventions—whether they serve self-sufficiency, price stabilization or distributional goals—may create environmental 'surprises' through the reallocation of depletable natural resources or through externalities. Moreover, if the Philippine results are a guide, the distributional gains often cited in defense of market-based food policies may well take the perverse form of a "leveling-down" of all incomes.

Our analytical and simulation results suggest that some forms of agricultural growth might be consistent both with increased aggregate real income and reduced agricultural land degradation. In the Philippines, technical progress in corn— a relatively erosive crop characterized by income-inelastic domestic demand—results in reductions in corn area and thus less land degradation, so long as the gains from the productivity growth result in lower producer prices. Technical progress in corn has a regressive distributional impact, but only in the sense that the real expenditures of the poor rise less rapidly than those of the rich. Investments in productivity growth for the corn sector would thus appear to have relatively high social rates of return when the benefits of reduced land degradation are included. By contrast, market interventions appear to have only modest success in supporting producer prices and to have little ameliorative impact on income distribution. They may also promote accelerated degradation of the agricultural resource base.

ENDNOTES

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[1] Food security is regarded as synonymous with self-sufficiency by the broad majority of Filipinos, and self-sufficiency in staples has long been a major political target (e.g., Salas). The commitment to self-sufficiency has always been made explicit in Philippine government agricultural development planning, for example:

> "It is vital ... that rice and corn supplies be ensured at levels sufficient for the country's requirements. Rice and corn production over the past few years have, however, been short of demand. [...] Measures must then be implemented to reverse such trends over the medium and long terms" (Philippine Department of Agriculture:1-3).

The 1994-98 agricultural development plan from which this statement is drawn advanced a range of policies aimed at self-sufficiency, including higher tariffs on rice and corn and on substitutes such as wheat, and a range of production subsidies and R&D expenditures aimed at increasing both yield and area of grains in "Key Production Areas" (KPAs). For corn, the program set five-year targets of approximately 40% growth in <u>both</u> area and yield. Nor have policies changed since 1994: the winning candidate in presidential elections held in May 1998 ran on a platform whose central plank was food security.

[2] In December 1995 negotiations, the Philippines initiated a proposal to exempt rice from the trade liberalization program planned by member countries of the ASEAN Free Trade Area (AFTA).

[3] According to Intal and Power, the short-run direct effect of corn market interventions during 1960-86 was to raise corn output by almost 5% per year; the cumulative direct effect increased output by an average of about 12%.

[4] In the Philippines, on-site losses alone from agricultural land degradation were estimated in the 1980s to cost the economy approximately $100 million per year, or about one-fourth of one per cent of GDP (World Bank). These losses are not included in conventional calculations of the benefits and costs of agricultural policies.

[5] For surveys see Dean and Dasgupta and Maler. Several papers analyze general relationships between economic policies and the environment (Lopez, Copeland), some specifically address agricultural land degradation (Coxhead and Jayasuriya).

[6] Some recent exceptions include Pearson and Munasinghe, and Bandara and Coxhead.

[7] Given long amortization periods for terraces and even hedgerows, the lack of assurance that improvements will add to the value of land discourages many farmers from making such investments (for a Philippine case see Shively 1997).

[8] It is reasonable to suppose that non-land factors such as labor are intersectorally mobile and that upland agriculture is a price-taker in those markets. Accordingly, price change terms for these factors are set equal to zero in this and all subsequent expressions. This greatly simplifies the computations without detracting from the core analytical point.

[9] In this two-sector model the land price will rise if the commodity price change raises the relative price of the more land-intensive good—an application of the Stolper-Samuelson theorem.

[10] For product-augmenting technical progress the following relations hold:

$$\tau_i \frac{\partial g}{\partial \tau_i} = p_i \frac{\partial g}{\partial \tau_i}, \text{ and}$$

$$\tau_i \frac{\partial^2 g}{\partial \tau_i \partial p_j} = \delta_{ij} \frac{\partial g}{\partial p_i} + p_i \frac{\partial^2 g}{\partial p_i \partial p_j}$$

where $\delta_{ij} = 1$ for $i = j$, and 0 otherwise (Dixit and Norman 1980:138).

[11] This result and that in (3) echo that of Brander and Taylor, who present a model in which a similar missing market (for property rights in natural resources) causes welfare to be reduced by the opening of a small autarkic economy to trade.

[12] Full employment of factors is implied by revenue maximization, so for both (7) and (8) to hold is a sufficient condition for the general equilibrium of the economy when trade in grain is restricted and its price fixed. If aggregate income is equal to expenditure as in (8), and if the market for *D* clears as in (7), then the economy's trade deficit is identically zero, by Walras' law.

[13] Our main focus is on resource allocation in the current period, so we rule out intertemporal

arbitrage to maintain tractability. Footnote 16 addresses welfare issues raised by this assumption.

[14] Full details of the structure and database are provided in Clarete and Warr; for a summary see Warr and Coxhead. The annotated equations of the entire model can be obtained from http://aae.wisc.edu/coxhead/APEX.htm

[15] Estimated Armington elasticity values for rice and corn are 0.614 and 0.776 respectively.

[16] The government's financing of its grain stockpile through taxation can thus be thought of as a forced savings plan. Taking this into account in a multi-period model could modify our assessment of the welfare implications of the creation of the NFA interventions. However, it does not automatically follow that the present value of aggregate household consumption would be increased by the government's actions. First, the public action would replace private savings decisions, with associated efficiency losses (Williams and Wright). Second, in a multiperiod setting future agricultural output declines due to greater erosion in the present (caused by the corn price supports) would have to be taken into account.

[17] Relaxing the fixed land area restriction alters the outcomes of price support and technical change experiments in minor and predictable ways: see Coxhead and Shively for an analysis.

[18] For tables containing more detailed results, see http://aae.wisc.edu/coxhead/APEX.htm.

[19] Coxhead and Shively estimate the base quantity of soil loss from land of slope 18% and higher at $478*10^6$ tons per year.

[20] Nor is it clear how price stabilization could improve policy makers' capacity for development strategy, as argued by Timmer. The price policy is *part of* the development strategy, and the two cannot be evaluated independently unless policy makers are highly myopic. Myopic decisions (specifically, those concerning price policy and the allocation of R&D resources to specific crops) do not necessarily result in welfare gains, as Coxhead (1997) has shown in a Philippine case study.

REFERENCES

Anderson, K. (1994) Food price policy in East Asia. *Asian-Pacific Economic Literature* 8(2), 15-30.

Barbier, E. B., and Bishop, J. T. (1995) Economic values and incentives affecting soil and water conservation in developing countries. *Journal of Soil and Water Conservation*, March-April, 133-137.

Bandara, J.S. and Ian Coxhead (1998) Can trade liberalization have environmental benefits in developing countries? A Sri Lankan case study. *Journal of Policy Modeling*, in press.

BAS (Bureau of Agricultural Statistics) (1995) *Philippine Rice Statistics, 1970-92*. Philippine Bureau of Agricultural Statistics, Quezon City.

Brander, J. A., and Taylor, M. S. (1994) International trade and open access renewable resources: the small open economy case. Manuscript: University of British Columbia.

Clarete, R. L., and Warr, P.G. (1996) The theoretical structure of the APEX Model of the Philippine economy. Philippine Department of Agriculture and Philippine Economic Society, Workshop on the APEX CGE Model of the Philippine Economy. Makati, July 1992 (revised).

Coxhead, Ian (1997). "Induced innovation and land degradation in developing countries", *Australian Journal of Agricultural and Resource Economics* 41(3), September, pp.305-32.

Coxhead, I., and Jayasuriya, S. K. (1995) Trade and tax policy reform and the environment: the economics of soil erosion in developing countries. *American Journal of Agricultural Economics* 77(4), 631-644.

Coxhead, I., and Shively, G. E. (1998) Measuring the environmental impacts of economic change: the case of land degradation in Philippine agriculture. *Journal of Agricultural Economics and Development*, in press.

Coxhead, I.; Shively, G.E., and Shuai, X. (1999) Agricultural development policies and land expansion in a southern Philippine watershed. Paper presented at a conference on "Technological change in agriculture and deforestation", CATIE, Turrialba, Costa Rica, March 11-13.

Copeland, B. R. (1994) International trade and the environment: policy reform in a polluted open economy. *Journal of Environmental Economics and Management*. 26 (1), 44-63.

Cruz, W. D., Francisco, H. A. and Conway, Z. T. (1988) The on-site and downstream costs of soil erosion in the Magat and Pantabangan watersheds. *Journal of Philippine Development* XV(1), 85-111.

Dasgupta, P., and Maler, K-G. (1995) Poverty, institutions and the environmental resource base. In *Handbook of Development Economics* vol. 3a, ed. J. Behrman and T. N. Srinivasan, pp. 2371-2463. North-Holland, Amsterdam.

David, W. P. (1988) Soil and water conservation planning: policy issues and recommendations. *Journal of Philippine Development* 15 (1), 47-84.

Dean, J. M. (1991) Trade and the environment: a survey of the literature. In *International Trade and the Environment*, ed. P. Low, pp. 15-28. World Bank Discussion Paper No. 159, Washington, DC.

Department of Agriculture (1994) *Grain Production Enhancement Program*. Philippine Department of Agriculture, Quezon City.

Dixit, A., and Norman, V. (1980) *Theory of International Trade*. Cambridge University Press, Cambridge.

Intal, P. S. and Power, J. H. (1990) The Philippines. In *The Political Economy of Agricultural Pricing Policy, Vol. 2: Asia*, ed. A. O. Kreuger, M. Schiff and A. Valdes, pp. 149-194. Johns Hopkins University Press for the World Bank, Baltimore, Md.

Lantican, F.A. and Unnevehr, L. J. (1987) Rice pricing and marketing policy. In *Policy Issues in the Philippine Rice Economy and Agricultural Trade,* ed. , pp. 31-72. University of the Philippines at Los Banos, Center for Policy and Development Studies, College, Laguna.

Lopez, R. (1994) The environment as a factor of production: the effects of economic growth and trade liberalization. *Journal of Environmental Economics and Management* **27** (2), 163-184.

Manasan, R. (1994) *Breaking Away From the Fiscal Bind: Reforming the Fiscal System*. Philippine Institute for Development Studies, Manila.

Mangahas, M. (1975) The political economy of rice in the New Society. *Food Research Institute Studies* XIV (3), 295-310.

Martinez, E., Shively, G., and Masters, W. (1998) Testing the link between public intervention and food price variability: evidence from rice markets in the Philippines. Paper presented at the annual meetings of the American Agricultural Economics Association., Salt Lake City, UT, August.

Munasinghe, M., and Cruz, W. (1995) *Economywide Policies And The Environment: Lessons From Experience*. World Bank Environment Paper No. 10, Washington, D.C.

Pagulayan, A.C. Jr. (1998) Philippines, in *Agricultural Price Policy in Asia and the Pacific,* ed. Asian Productivity Organization, pp. 265-278. Asian Productivity Organization, Tokyo.

Pearson, A., and Munasinghe, M. (1995) Natural resource management and economywide policies in Costa Rica: a computable general equilibrium (CGE) modeling approach. *World Bank Economic Review* 9(2), 259-286.

Repetto, R., *et al.* (1989) *Wasting Assets: Natural Resources in the National Income Accounts.* World Resources Institute, Washington, DC.

Salas, R. 1987. *The World of Rafael Salas: Service and Management in the Global Village*. Solar Publishing Corp., Manila.

Shively, G. E. (1997) Consumption risk, farm characteristics, and soil conservation adoption among low-income farmers in the Philippines. *Agricultural Economics* 17, 165-77.

Shively, G.E. (1998) Economic policies and the environment: the case of tree planting on low-income farms in the Philippines. *Environment and Development Economics* 3(1), 83-104.

Timmer, C. . (1995) Getting agriculture moving: do markets provide the right signals?, *Food Policy* 20(5), October, pp.455-472.

Warr, P. G. (1995) Factor demand and technical change in Philippine agriculture. *Asia-Pacific*

Economic Review 1(3), 23-36.

Warr, P. G., and Coxhead, I. (1993) The distributional impact of technical change in Philippine agriculture: a general equilibrium analysis. *Food Research Institute Studies* XXXII (3), 253-274.

Williams, J. C., and Wright, B. D. (1991) *Storage and Commodity Markets*. Cambridge University Press, Cambridge.

World Bank (1989) *Philippines Natural Resource Management Study*. The World Bank, Washington, DC.

Table 1 Changes in Aggregate On-Site Costs of Erosion

	Exogenous Shock:		
	Grain Price	Technical change in corn	
Closure:	*NFA*	*Unrestricted*	*NFA*
Percentage Change in Erosion	1.44	-4.29	-3.59
Total Change in Erosion (Million tons)	6.8	-20.5	-17.2
Total Savings (Cost) (million $US)	(4.13)	-12.3	-10.3
Savings (Cost) as % of 1991 GDP	(0.014)	0.04	0.04
Savings (Cost) as % of predicted GDP change	(1.07)	3.18	2.66
Savings (Cost) as % of agricultural value added	(0.06)	0.20	0.17
Savings (Cost) as % of govt expenditures on agric.	(0.53)	1.58	1.33
Savings (Cost) as % of the environmental component of govt exp. on agric.[a]	(7.1)	21.12	17.68

For details of calculations see Coxhead and Shively.

Table 2 Sensitivity Analysis of Erosion Cost Estimates ($US m)

		Erosion Estimate		
		Low (-25%)	Medium	High (+25%)
E-1: Cereals Price Support Increase, NFA Closure				
	Low (-50%)	1.55	2.07	2.58
Replacement Cost Estimate	Medium	3.10	4.13	5.16
	High (+50%)	4.65	6.20	7.74
E-2: Technical Progress in Corn, Unrestricted Closure				
	Low (-50%)	-4.61	-6.15	-7.69
Replacement Cost Estimate	Medium	-9.23	-12.30	-15.38
	High (+50%)	-13.84	-18.46	-23.07
E-3: Technical Progress in Corn, NFA Closure				
	Low (-50%)	-3.86	-5.15	-6.44
Replacement Cost Estimate	Medium	-7.72	-10.30	-12.87
	High (+50%)	-11.58	-15.44	-19.31

Notes: Central estimate of base level erosion is 473,340,000 tons per year. Central estimate of nutrient replacement cost is $US0.60 per ton. For additional details see Coxhead and Shively.

Figure 1: APEX: Structure of agricultural production (Source: Warr and Coxhead).

Notes:

1. Technology. Composite regional agricultural outputs are produced with Leontief (fixed-proportions) combinations of intermediate inputs and an aggregate input composed of primary factors and fertilizer. The aggregate input is constructed by using flexible functional forms to estimate primary factor and fertilizer demands. Fertilizer and other intermediate inputs from domestic and imported sources are aggregated to create composites. The price of the aggregate input is thus an aggregation of primary factor prices and the prices of fertilizer from domestic and imported sources.

2. Output. Each regional agricultural industry is composed of 7 sectors. Two sectors (rainfed and smallholder aggregates) produce multiple outputs. The commodity mix of agricultural output can thus be varied within as well as between sectors and regions. This mix is determined by profit-maximizing responses to output and variable input prices, technology, and the quantities of factors specific to agriculture, i.e. land in each region.

3. Factor markets. Primary factors other than agricultural land by region are mobile within and among agricultural sectors and regions, and also between agriculture and other sectors of the economy.

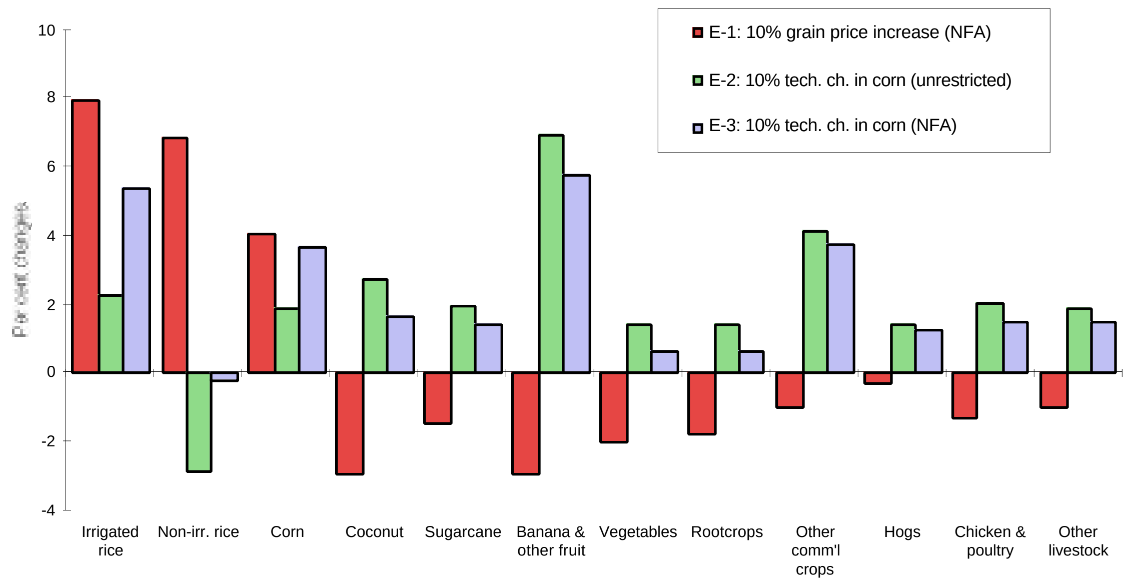

Figure 2: Changes in Agricultural Output

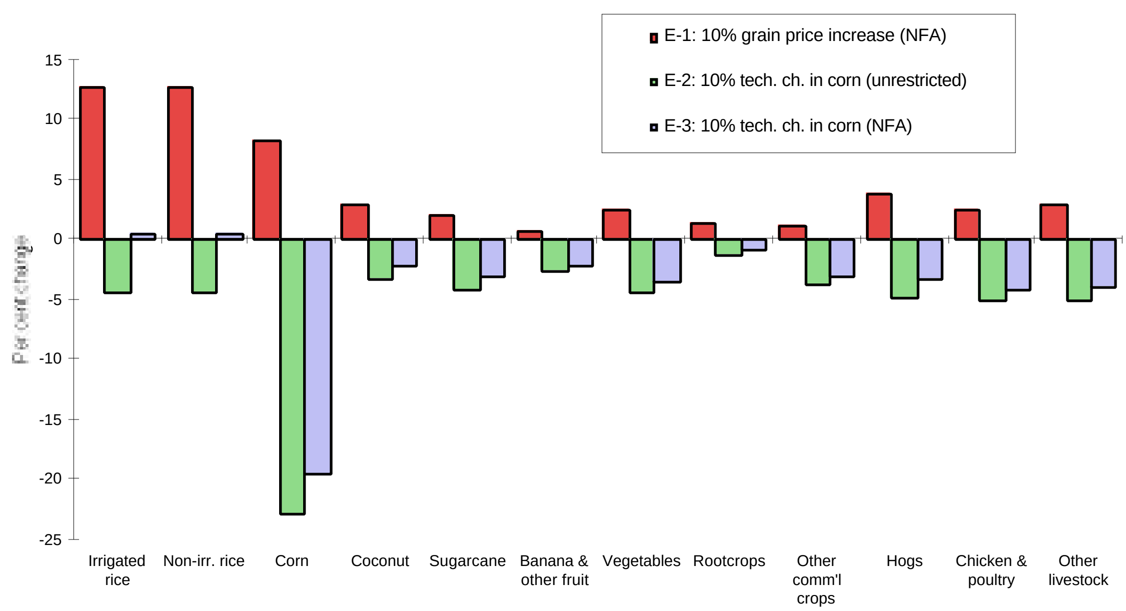

Figure 3: Changes in Agricultural Producer Prices

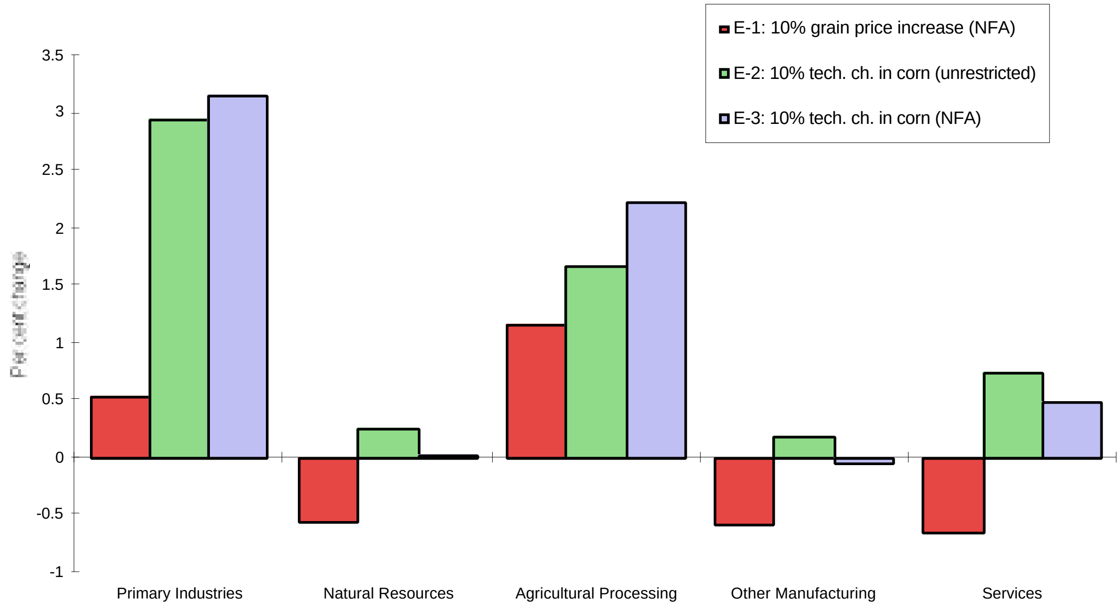

Figure 4: Changes in Aggregate Sectoral Output

Figure 5: Changes in Real GDP, Real Household Consumption and Price Indexes

Figure 6: Changes in Real Household Expenditures, by Quintile

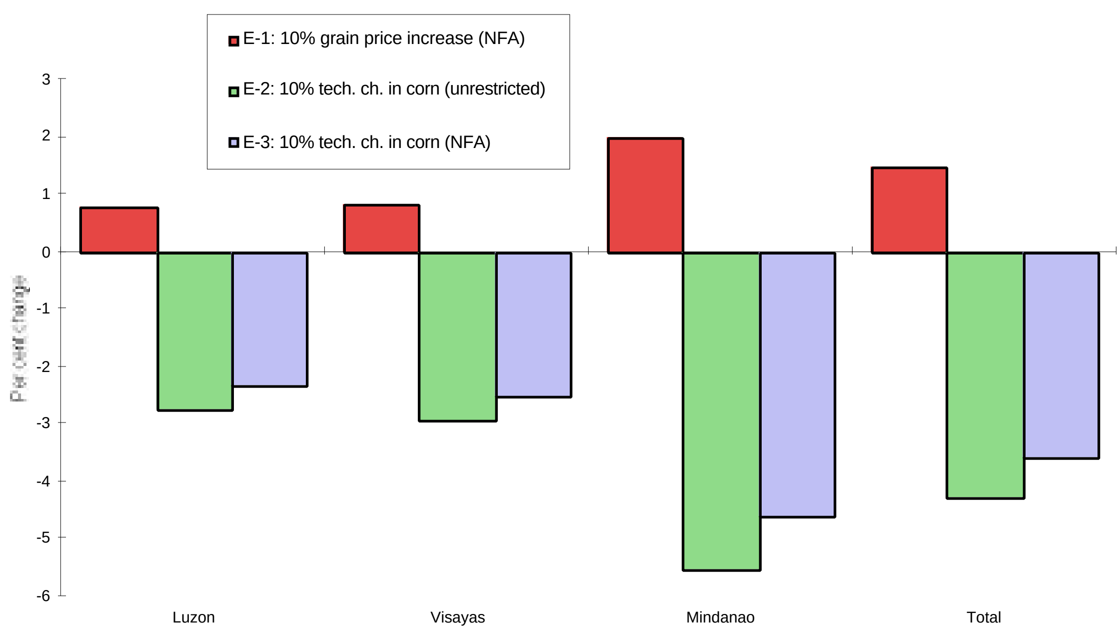

Figure 7: Changes in Soil Erosion, By Region