

**The Effect of National Policies and Labor Market on Land Use Decisions in  
Developing Countries: An Application of Maximum Simulated Likelihood to System  
of Censored Acreages with Panel Data**

Bayou Demeke and Ian Coxhead<sup>1 2</sup>

University of Wisconsin-Madison

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<sup>1</sup> The authors , respectively, are PhD candidate and Professor in the Department of Agricultural and Applied Economics at the University of Wisconsin-Madison. Financial support for this research was provided by USAID through SANREM CRISP South East Asia.

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Abstract

This paper estimates land use responses of households to relative output prices and wages, using panel data from the Philippines. We present multi-output profit maximizing model to elicit the role of relative prices on land allocation between crops and fallowing. We estimate systems of random effects Tobit acreage equations using maximum simulated likelihood technique. The results show that rising return to labor and management intensive crop reduces land expansion. In addition rising wages also reduce agricultural expansion. The results reveal a potential role for market based policies in shaping environmental outcomes in developing countries.

**JEL Classification:** C33, O13, Q15, Q19, Q24

**Keywords:** Land Use, Maximum Simulated Likelihood, Panel Data, Tobit, Philippines

## 1. Introduction

How do farmers in poor, remote upper-watershed areas respond to agricultural price signals? And how do we measure the response? Until relatively recently, and in the absence of contradictory data, it was widely assumed that outside of commercial plantations, upland agriculture was primarily for subsistence. This belief, if correct, has important implications for the design of programs aimed at economic development or environmental protection in upper-watershed areas. Subsistence production decisions are only indirectly subject to market forces, and as such place producers substantively beyond the reach of economic policies. Without market instruments, upland poverty alleviation efforts, or programs addressing protection of forest, soils or watershed functions must rely on direct interventions by government agencies, development projects or NGOs. Such direct interventions – including the use of command and control policies to conserve natural resources – comprise the core of most resource conservation strategies in the countries of the humid tropics. Market-based agricultural policies, by contrast, are directed at “commercial” farmers (implicitly, those in lower-watershed or non-upland areas); only in very rare instances are incentive-based instruments applied to upper-watershed environmental targets.

In this respect, most upland development and conservation strategies now lag behind the realities of areas at which they are directed. While pockets of more or less pure subsistence production undoubtedly persist in the least accessible regions of rural Asia, the improvement of roads and the tremendously rapid expansion of market and communications infrastructure (including mobile telephone and even the internet) have inexorably brought the majority of upland farmers into close contact with markets and in

doing so, have transformed the basis of upland agricultural production decisions. Accumulating anecdotal evidence indicates that farmers in remote regions, whose land use and production decisions were tightly bound by the need to ensure household food supplies, are increasingly willing to rely on the market to supply food that they will buy with the proceeds of sales of other crops. This opens up land use decisions to more commercial considerations, and thus greatly increases the spatial and sectoral “reach” of economic policies. Relative to direct interventions and command and control, market-based policies are generally highly cost-effective, so the implications of agricultural commercialization for upland economic development and environmental conservation programs are potentially profound.

The relationship between economic development and the depletion or degradation of natural resources and the environment in the uplands and watersheds of developing countries is highly dynamic. The primary agents (mainly poor farmers) and the resources they work with (land, labor) are highly heterogeneous, even within samples drawn from small areas. Pursuing changes in the economy-environment relationship with strong firm-specific effects is thus best conducted with panel data. Such data are only now becoming available as the products of long-term research investments made since the early 1990s.

In this paper we use a decade long panel data to test the hypothesis concerning the influence of national policies and local labor markets on land use decisions in the Philippines. We hypothesize that national policies are responsible, at least in part, for the expansion of corn and some vegetables at the expense of other sustainable land uses, including perennials such as coffee and regular fallow. Such a shift in land uses has

increased deforestation and exacerbated upland land degradation (Coxhead and Demeke, 2004; Coxhead et al, 2002). If so, then policy reforms and other macroeconomic changes could have large environmental impacts at forest margins of developing countries. In this paper we explore the extent to which land use decisions made by farmers in one upland area of the Philippines are subject to the influence of markets, and thus of policies. This information is potentially valuable in its own right, as a means of quantifying the leverage that such instruments can be expected to exert over resource allocation decisions. It has broader implications too, for the design of upland development and conservation programs.

This paper contributes to the literature in three fronts: Contribution to multioutput models, econometrics contributions, and empirical contributions

### *Contributions to multioutput models*

The economic model we present relies on two-step optimization technique. In the first stage decision makers choose optimal level of input use for a given land allocation, and in the second stage land allocation that yield a maximum profit is chosen. Using this method, we present a theoretical analysis of multioutput short-run profit maximizing behavior and the detailed analysis of comparative statics. In the model we assert that households are constrained by quantity of land and by the availability of family labor. We argue that, though hiring labor is possible, family labor is a critical input in farming due to management and supervision requirements. Most household models in the development literature also incorporate family labor constraint mainly due to the prevalence of imperfect factor markets, and the existence of significant supervision cost (e.g. Eswaran and Kotwal 1986; Feder 1985). The implications of comparative statics from such

formulation drastically differs from the standard economic models- in models where family labor and/or quantity of land are not assumed fixed. For example, the comparative statics results reveal that the effect of rising wages on acreages is ambiguous. In addition, rising returns to a management intensive crop could potentially decrease total area cultivated. Additional theoretical restrictions that stem from profit maximization are also derived and presented.

### Econometric contributions

Acreage allocation decisions commonly involve corner solutions, requiring an estimation method that handles censoring. When a significant proportion of observations in which acreage allocation to one or more crops is zero, the econometric model should allow for zero acreage to occur with positive probability. Moreover, acreage allocation equations are not independent: increase in one crop area imply a decrease in another crop area, so the error terms across equations are correlated. Hence single equation estimation does not yield efficient estimates. Standard estimation methods for these models do not take into account zero expenditure and consequently yield inconsistent estimates of parameters. Despite these facts, most acreage allocation studies have ignored either systems of equations approach or data censoring mainly due to the challenges of the estimation method. To our knowledge, this is the first study that estimate systems of censored acreage demands using household level panel data from developing countries. For instance, Moore and Negri (1992), admit the presence of corner solutions in their data and estimate single equation Tobit acreage demands. Though these estimates will be consistent, single equation estimation will not achieve efficiency. Arnberg (2002), on the other hand, estimates land allocation decisions by dropping those farms with zero land

acreage allocations. However, if observations containing zero acreage allocations are excluded for the purpose of estimation, this will not only reduce significantly the sample size but the estimators would also be biased and inconsistent (Chakir and Thomas, 2003). Apart from estimation issues, for lack of farm level data, many of acreage allocation studies use time series aggregate regional or county level data (e.g. Coyle, 1993; Moore and Negri, 1992; Wu and Segerson, 1992; Holt, 1999 ).

In this paper we use household level panel data from environmentally fragile upland watershed in the Philippines. Panel data is useful to control for unobserved individual heterogeneity by measuring effects that are not measurable in pure cross-section or in pure time-series data. To our knowledge, literature on efficient estimates of a structural system of corner solutions with random effects are lacking. One exception to this is a study by Chakir and Thomas (2003). In that study they used virtual price approach in deriving systems of firm energy demand from a cost function, and estimated random effects model.

We use restricted profit function to derive systems of acreage allocation equations, and estimate the systems using a random effects Tobit model. We also impose the theoretical restrictions that follow from profit maximization. The major estimation challenge in estimation of systems of random effects Tobit model is that the likelihood function involve multiple integrals. To avoid the evaluation of multiple integrals, we adopt Maximum Simulate Likelihood Methods. The estimation approach we have adopted is also useful for related empirical research that warrant corner solution problems, systems approach, and panel data. Thus, this paper not only contributes to the

econometrics of land use decisions, but also to the applications of limited dependent variables with panel data.

### *Empirical contributions*

The empirical exploration of links between national markets and policies and upland land uses has only a few antecedents in the Philippines ( e.g. Coxhead and Demeke, 2004; Coxhead, Shively and Shuai, 2002; Shively and Pagiola , 2004; Rodríguez-Meza et al., 2004). Findings based on farm-level studies have awaited the accumulation of time series data and are therefore very recent. This study builds on findings of several earlier studies in the Philippines. In a precursor paper, Coxhead, Shively and Shuai (2002) (hereafter CSS) examined farm-level land use decisions and related them to expected levels and variances of prices and yields, input prices, and the quantities of fixed factors such as family labor. Their findings confirmed the price-responsive ness of land use decisions; however, prices were found to have relatively small land use effects. CSS, however, used a short series of observations on highly heterogeneous farms. For lack of data, CSS precluded any labor market analysis. Using panel data methods, Coxhead and Demeke (2004), extended CSS, by accounting for data censoring and also including labor market in the analysis. The results in that paper have shown strong land use responses to prices and wages. Coxhead, Rola and Kim (2001), using market price information collected from local traders and provincial and regional wholesale markets, established that agricultural markets in the study areas are integrated, and further, that local producer prices are determined exclusively by those in external markets. That analysis established a robust, one-directional link between prices in national markets and farm gate prices in a typical upland area.

This paper, using innovative econometric method, contributes to the understanding of the importance of national policies and labor markets on land use in the Philippines. The results from the empirical analysis reveal that producers in the upland agriculture do respond to relative prices by reallocating resources. For example a rise in corn revenue significantly increases the share of corn area while reducing shares of both vegetables and fallow. Rising wages shrink the share of land allocated to vegetables and corn. An interesting result that emerges from the analysis is that a rise in vegetables revenue increases area allocated to vegetables while at the same time increasing fallow area. The environmental implication in this case is ambiguous. Fallowing and reduction in corn area constitute environmental quality improvement, while expansion in cultivation intensive vegetables could lead to environmental deterioration. However, if the difference between the environmental impact of corn and vegetables is small, a rise in vegetable revenue can have an environmental benefit while at the same time increasing income of the poor farmers in the uplands. When households are constrained with the availability of family labor and/or capital, a rise in revenue of management and labor intensive crops will likely reduce agricultural expansion in the uplands of developing countries.

The paper is organized as follows. Section 2 presents the economic model with detailed comparative statics, in section 3 we present the econometric strategy, in section 4 the estimation results and discussion are presented, section 5 presents conclusion and future research direction..

## 2. Economic model

Acreage response models are useful in understanding the environmental consequences of economic policies. We present a multioutput short run profit maximization subject to land constraint and family labor constraint. The model permits land to be fallowed depending on which of the two constraints bind. The model also permits the minimum family labor required for management to vary across crops. For example, we believe that vegetables production is more management intensive than corn production.

We use the following notation through out the paper:  $A_m$  ( $m=1, \dots, M$ ) is land allocated to production of crop  $m$ .  $\mathbf{y} \in \mathbf{R}_+^M$  is a vector of outputs;  $\mathbf{l} \in \mathbf{R}_+^v$  is the vector of variable inputs.  $\mathbf{l}_m$  ( $m=1, \dots, M$ ) is a vector of variable inputs used in producing crop  $m$ ;  $\mathbf{w} \in \mathbf{R}_{++}^v$  is vector of strictly positive prices for variable inputs.  $\mathbf{p} \in \mathbf{R}_{++}^M$  is the vector of strictly positive output prices.

To begin, we suppose that households are endowed with a quantity of land and family labor . Consider the following short run profit maximization problem:

$$\begin{aligned} & \underset{A_1, \dots, A_m, A_f}{Max} \sum_{m=1}^M \mathbf{p}_m (p_m, \mathbf{w}, A_m) \\ & s.t. \sum_{m=1}^M A_m + \leq \bar{A} \\ & \sum_{m=1}^M \mathbf{a}_m A_m \leq F \end{aligned}$$

where  $A_m$  represent land allocation to crop  $m$ ,  $m = 1, \dots, M$ ;  $\mathbf{p}_m(p_m, \mathbf{w}, A_m, \mathbf{z})$  is the indirect profit function for crop  $m$  given land allocation  $A_m$ ;  $\mathbf{a}_m$  is family labor requirement to operate a unit of land;  $\bar{A}$  represent the total quantity land available for

cultivation;  $F$  is available family labor;  $\mathbf{p}$  and  $\mathbf{w}$  are vectors output prices and variable inputs, respectively.

It is widely accepted in the development literature that family labor and hired labor are not perfect substitutes, because of the need to supervise hired workers (e.g., Eswaran and Kotwal 1986; Feder 1985) and since family labor embodies farm-specific land and crop management skills (CSS). Thus, it is reasonable to assume that, in the short run, family labor is fixed in supply (see also CSS). The reliability of family labor to perform critical operations that require timely operation also makes family labor a necessary input. We assume that each unit of land cultivated requires  $\mathbf{a}_m$  units of family labor for management and supervision. In this model, supervisory costs are implicitly included via requiring minimum number of family labor. However, once the minimum required family labor is available, we assume that hiring labor does not necessitate additional supervisory cost.

The Lagrangean function of the constrained maximization problem is given as:

$$L = \sum_{m=1}^M \mathbf{p}_m(\mathbf{p}, \mathbf{w}, \mathbf{r}, A_m, \mathbf{z}) + I(\bar{A} - \sum_{m=1}^M A_m - A_f) + \mathbf{m}(\bar{F} - \sum_{m=1}^M \mathbf{a}_m(A_m) \cdot A_m) \quad (1)$$

The formulation in equation (1) is closely related to several acreage allocation models (e.g. Coyle, 1993; Moore and Negri 1992).

where  $I$  is the shadow price of the land constraint.

The solution to the Lagrangean problem ( $A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^* \geq 0$ ), such that the following Kuhn Tucker FONC conditions hold.

$$\frac{\partial L}{\partial A_m}(A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^*) \equiv \frac{\partial \mathbf{p}_m}{\partial A_m}(A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^*) - I^* - \mathbf{m}^* \mathbf{a}_m \leq 0 \quad (2)$$

$$\left[ \frac{\partial L}{\partial A_m} (A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^*) \right] A_m^* = 0 \quad (3)$$

$$\frac{\partial L}{\partial I} (A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^*) \equiv \bar{A} - \sum_{m=1}^M A_m^* \geq 0 \quad (4)$$

$$\left[ \frac{\partial L}{\partial I} (A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^*) \right] I^* = 0 \quad (5)$$

$$\frac{\partial L}{\partial \mathbf{m}} (A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^*) = \bar{F} - \sum_{m=1}^M \mathbf{a}_m A_m^* \geq 0 \quad (6)$$

$$\left[ \frac{\partial L}{\partial \mathbf{m}} (A_1^*, A_2^*, \dots, A_m^*, I^*, \mathbf{m}^*) \right] \mathbf{m}^* = 0 \quad (7)$$

Assuming interior solution and assuming a binding family labor constraint, condition (2) can be restated as:

$$\frac{\partial \mathbf{p}_i / \partial A_i}{\mathbf{a}_i} = \frac{\partial \mathbf{p}_j / \partial A_j}{\mathbf{a}_j} \quad (8)$$

Equation (8) equates the marginal profit from extra unit of land per incremental labor requirement. When family labor is not a limiting factor, (i.e.  $\mathbf{m}=0$ ), land will become a limiting factor and condition (2) requires that marginal profit from each crops be equalized; i.e.  $\frac{\partial \mathbf{p}_i}{\partial A_i} = \frac{\partial \mathbf{p}_j}{\partial A_j}$ .

Allocation of land and labor can be solved from the systems of first order conditions.

### Comparative statics

#### *i) The effect of prices and wages*

The Primal-Dual results states that, when the land constraint binds, the matrix denoted by  $\mathbf{D}$  in equation (9) is symmetric positive semi-definite. When family labor is the binding constraint,  $\mathbf{I}$  will be replaced by  $\mathbf{m}$  in equation (9).

$$\begin{aligned}
 \mathbf{D} &= \begin{bmatrix} \mathbf{L}_{pA} & \mathbf{L}_{pI} \\ \mathbf{L}_{wA} & \mathbf{L}_{wI} \\ \mathbf{L}_{rA} & \mathbf{L}_{rI} \end{bmatrix} \begin{bmatrix} \mathbf{A}_p^* & \mathbf{A}_w^* & \mathbf{A}_r^* \\ ?_p^* & \mathbf{I}_w^* & \mathbf{I}_r^* \end{bmatrix} \\
 &= \begin{bmatrix} \mathbf{y}_A^* & 0 \\ \mathbf{l}_A^* & 0 \\ \mathbf{q}_A^* & 0 \end{bmatrix} \begin{bmatrix} \mathbf{A}_p^* & \mathbf{A}_w^* & \mathbf{A}_r^* \\ ?_p^* & \mathbf{I}_w^* & \mathbf{I}_r^* \end{bmatrix} \\
 &= \begin{bmatrix} \mathbf{y}_A^* \mathbf{A}_p^* & \mathbf{y}_A^* \mathbf{A}_w^* & \mathbf{y}_A^* \mathbf{A}_r^* \\ \mathbf{l}_A^* \mathbf{A}_p^* & \mathbf{l}_A^* \mathbf{A}_w^* & \mathbf{l}_A^* \mathbf{A}_r^* \\ \mathbf{q}_A^* \mathbf{A}_p^* & \mathbf{q}_A^* \mathbf{A}_w^* & \mathbf{q}_A^* \mathbf{A}_r^* \end{bmatrix}
 \end{aligned} \tag{9}$$

where  $l_m^*(A_m)$  and  $q_m^*(A_m)$  are optimal labor and variable input allocation for a given  $A_m$ , respectively. Note the matrix notation in (9), for example for two crops:

$$\mathbf{A}_p = \begin{bmatrix} \frac{\partial A_1}{\partial p_1} & \frac{\partial A_1}{\partial p_2} \\ \frac{\partial A_2}{\partial p_1} & \frac{\partial A_2}{\partial p_2} \end{bmatrix}.$$

Also note that the resource constraint imposes the following adding up restrictions.

$$\begin{cases} \sum_{m=1}^M \frac{\partial A_m^*}{\partial w} = \sum_{m=1}^M \frac{\partial A_m^*}{\partial p_j} = 0 & \text{if land constraint binds;} \\ \sum_{m=1}^M \mathbf{a}_m \frac{\partial A_m^*}{\partial w} = \sum_{m=1}^M \mathbf{a}_m \frac{\partial A_m^*}{\partial p_j} = 0 & \text{if family labor constraint binds} \end{cases} \tag{10}$$

The following implications follow from the Primal-Dual result.

i. The diagonal elements of matrix  $\mathbf{D}$  are non-negative

$$\frac{\partial y_i^*(A_i)}{\partial A_i} \frac{\partial A_i^*}{\partial p_i} \geq 0 \quad ; \quad - \sum_{m=1}^M \frac{\partial l_m^*(A_m)}{\partial A_m} \frac{\partial A_m^*}{\partial r} \geq 0; \quad - \sum_{m=1}^M \frac{\partial q_m^*(A_m)}{\partial A_m} \frac{\partial A_m^*}{\partial r} \geq 0 \tag{11}$$

Equation (11) implies that own price responses are non-negative as long as  $\frac{\partial y_i^*(A_i)}{\partial A_i} > 0$ . This condition will be fulfilled if land and labor are complementary inputs.

For the case of two crops, adding up also implies that the cross price responses have to be negative. However, for more than two crops, the cross price effects need not be negative; though, at least one cross effect has to be negative in order to satisfy the adding up restrictions.

The effect of wages on acreage allocation is not clear, even though the weighted sum of the wage effects has to be negative (the weight being  $\frac{\partial l_m^*(A_m)}{\partial A_m}$ ). Because of the adding up restriction, the effect of the wage on at least one activity has to be positive. To illustrate, assume two crops and let the family labor be a limiting factor. Combining (12) and (11), the wage effect will be as given as follows.

$$\left( -\frac{\partial l_1^*(A_1)}{\partial A_1} + \frac{\mathbf{a}_1}{\mathbf{a}_2} \frac{\partial l_2^*(A_2)}{\partial A_2} \right) \frac{\partial A_1^*}{\partial w} \geq 0 \quad (12)$$

$$\text{If } \left( -\frac{\partial l_1^*(A_1)}{\partial A_1} + \frac{\mathbf{a}_2}{\mathbf{a}_1} \frac{\partial l_2^*(A_2)}{\partial A_2} \right) \leq 0 \text{ then } \frac{\partial A_1^*}{\partial w} \leq 0$$

if labor intensity of crop 1 is much greater than that of crop 2, then acreage to crop 1 would decrease. Intuitively, when wages rise, producers seek to reduce the sum of labor allocation to all crops, while satisfying the resource constraint. Reducing  $A_1$  by one unit, for example, releases  $\mathbf{a}_1$  units of family labor, while the same released labor increases  $A_2$  by  $\frac{\mathbf{a}_1}{\mathbf{a}_2}$ . The condition in equation (12), therefore, implies that, if labor needed in the expansion of crop 2 is less than labor that is saved through contraction of crop 1, a rise in

wages will reduce acreage to crop 1. This result says that, other things equal, a rise in wages could potentially reduce fallow area through contraction of management and labor intensive crop<sup>3</sup>.

In a similar fashion, when land is a limiting factor,  $\frac{\partial A_1^*}{\partial w} \leq 0$  iff

$$\left( -\frac{\partial l_1^*}{\partial A_1} + \frac{\partial l_2^*}{\partial A_2} \right) \leq 0 .$$

ii. Assuming predetermined yield, the matrix **D** implies the standard reciprocity

restrictions of profit maximization, i.e.  $\frac{\partial y_2^*}{\partial p_1} = \frac{\partial y_1^*}{\partial p_2}$ . It follows that:

$$\frac{\partial A_2^*}{\partial R_1} = \frac{\partial A_1^*}{\partial R_2} \quad (13)$$

where  $R_1 = \bar{y}_1 p_1$  and  $R_2 = \bar{y}_2 p_2$  represents revenue per hectare for crop 1 and 2, respectively.

**Proof:** Reciprocity requires that

$$\frac{\partial y_2^*}{\partial p_1} = \frac{\partial \bar{y}_2 A_2^*}{\partial p_1} = \frac{\bar{y}_2 \partial A_2^*}{\partial R_1} \frac{\partial R_1}{\partial p_1} = \bar{y}_2 \frac{\partial A_2^*}{\partial R_1} \bar{y}_1 = \frac{\partial y_2^*}{\partial A_2} \frac{\partial A_2^*}{\partial p_1} \quad (14)$$

$$\frac{\partial y_1^*}{\partial p_2} = \frac{\partial \bar{y}_1 A_1^*}{\partial p_2} = \frac{\bar{y}_1 \partial A_1^*}{\partial R_2} \frac{\partial R_2}{\partial p_2} = \bar{y}_1 \frac{\partial A_1^*}{\partial R_2} \bar{y}_2 = \frac{\partial y_1^*}{\partial A_1} \frac{\partial A_1^*}{\partial p_2} \quad (15)$$

Matrix **D** in equation (9) is symmetric, i.e.

$$\frac{\partial y_2^*(A_2)}{\partial A_2} \frac{\partial A_2^*}{\partial p_1} = \frac{\partial y_1^*(A_1)}{\partial A_1} \frac{\partial A_1^*}{\partial p_2} \quad \text{which implies} \quad \frac{\partial A_2^*}{\partial R_1} = \frac{\partial A_1^*}{\partial R_2} \quad ;$$

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<sup>3</sup> This analysis assumes that rising wages do not change the family labor constraint. The decision to work off-farm is a non-marginal decision, since many households are constrained by the availability of non-farm wages. This is not an unreasonable assumption since non-farm wages are in most of the cases much higher than on farm wages.

### 3. Econometric Strategy

#### **Data**

Our data come from a group of villages located in Lantapan municipality, central Bukidnon province, in northern Mindanao Island. The province is typical of those that just two generations ago comprised the Philippines' internal frontier. Lantapan is located in the upper Manupali River valley, 15 km south of the provincial capital, and 130 km from the closest port. The landscape climbs from river flats (500-600 masl) through a rolling middle section (600-1100 masl) to high altitude, steeply sloping mountainsides (1100m-2200 masl). Sparsely settled at Independence in 1946, the population of the province increased dramatically over the past half-century. Lantapan's population increased at an average annual rate of 4.16% in 1970-80 and 4.0% in 1980-90; only in the 1990s did this growth converge on the national rate of 2.35% (NCSO).

The total area farmed in the municipality increased faster than population, and this expansion has taken place at the expense of primary forest and other perennial crop and agroforestry systems (Coxhead and Buenavista, Ch. 1). The main crop grown by area is corn; other crops vary in importance by location, with sugarcane dominant in the lower watershed, and in the upper, vegetables. Commercial banana plantations, established in 1999, have also begun to dominate local land use patterns

We conducted a series of farmer surveys in the dry seasons of every even-numbered year from 1994 through 2002 – a total of five observations per household. Survey methods and instruments, and summaries of findings from individual survey rounds is detailed in Coxhead (1995) and Rola et.al (1995). The sample farms are drawn from nine villages in the middle and upper regions of the watershed.

The surveys elicit information on the household composition, farm production and input use, land allocation, land use history, sales, non-farm income, and farmers' perceptions of erosion and soil degradation as well as their expectations on types of crop to be grown and crop prices in the next cropping season. The original sample size was 190, later reduced to 120. Several other observations have been lost for reasons beyond our control.

Several crops are grown in the study site but the major crops are corn, vegetables, coffee and sugar. In the lower watershed sugar cane production is expanding, but for lack of sufficient observations we have ignored the sugar enterprise. So our analysis concentrates on allocation of land between corn, vegetables and conservation use which we classify as *fallowing*. The conservation use includes fallow, trees, and coffee plants. Trees are mostly grown around farmers' house and on borders of farm plots. Most of the coffee plants are old and are not the major source of income to the households. Over the years, due to low coffee prices, most farmers have either abandoned their coffee trees or have uprooted them. For the most part, coffee is considered fallow in the study area, even though there are a few exceptions.

Table 1 provides a summary of the main variables used in the analysis. In estimating acreage allocation equations, the data present us with a number of challenges.

1. The data are censored, i.e. many observations have zero land allocation to particular crops. For corn about 25% of observations are zero; for vegetables, the figure is almost 70%. Hence, estimators based on linear methods are inconsistent.

2. Since the data form a panel, controlling for unobserved household specific effects and dynamics is a challenge in non-linear models such as Tobit.
3. The error terms across acreage equations are not independent, implying single equation estimation is inefficient
4. Price data are drawn from local market surveys and thus exhibit no cross-sectional variation. For a model containing several prices and few time periods, degrees of freedom become very limited.
5. There is attrition in the data set, some of which is likely to be endogenous. The survey started with 190 farm households, but in 1996 the sample size was reduced to 120. In subsequent years another 20 households have dropped out of the survey.

In this paper we deal with the first four estimation challenges except for estimation of dynamic model described in number 2. The methods we use to deal with these challenges are elaborated as follows. First, land allocations by farmers involve corner solutions; this censoring of the data requires a Tobit estimator. There are additional complications, however. Empirical work using panel data must deal with problems of unobserved heterogeneity, such as in soil quality, managerial ability etc., and dynamic feedback effects. It has proved very difficult to address both these features together (Hu, 2002). We adopt random effects model to control for the household specific effects<sup>4</sup>. Complications also arise from the difficulty in estimating systems of Tobit

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<sup>4</sup> Even though random effects model assume zero correlation between independent variables and the unobserved household specific effects, it posses several attractive properties over fixed effects in systems of Tobit models. First, unlike the fixed effects, variables that do not vary over time could not be included. With random effects model, it is possible to test the importance of parcel-level heterogeneity. Second, unlike in fixed effects, it is possible to estimate elasticities that are useful in interpreting the impact of policies on land use. Third, fixed effects estimation is also much more complicated in systems of Tobit models, mainly due to problems with convergence.

equations with panel data, since the estimation involves evaluation of multiple integrals. In this paper we overcome the difficulty of multiple integrals using Maximum Simulated Likelihood technique. Thus, we combine the Amemiya-Tobin approach with panel data model<sup>5</sup>. This approach permits us to capture individual-specific effects while accounting for correlations across equations.

Second, we deal with the lack of cross-sectional price variation by substituting expected revenues for prices in the land demand functions. There are several studies that make use of expected revenue or expected return instead of output prices, as explanatory variable (e.g. Arnbergn2002; Holt 1999; McGuirk and Mundlak 1992; Coyle 1993; Moore and Negri 1992). Using production data, we estimate revenue per hectare as a function of farm area, slope, education, distance, soil conservation, household labor, age, tenure, and location and year dummies. We then predict expected revenues for all farms based on these estimates. This permits us to construct expected revenues for those farms with zero land allocation to a particular crop.

### **Model Specification and Estimation Approach**

Empirical studies on acreage allocation studies have adopted two distinct approaches to estimation. The first is to specify a flexible functional form for the restricted profit function and derive the implied acreage demand functions (e.g. Holt 1999; Coyle 1993, Moore and Negri 1992). The second approach is to use Multinomial Logit model(e.g. Bergeron and Pender 1999; Wu and Segerson 1992; Lichtenberg 1989; Bewely et al. 1987). We adopt the first approach, since Multinomial Logit land share

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<sup>5</sup> We have left estimation of a dynamic model for future work. Dynamic Tobit with individual specific effects is very difficult to estimate; literature on this method is very limited (Hu; Honoré 1993; Wooldridge 2000).

equations are not derived from theoretically consistent profit functions. We also estimate the share of land allocation equations in a systems framework. This approach enables us to impose theoretical restrictions that follow from profit maximizing behavior. Assuming a normalized quadratic profit function, we derive systems of linear acreage share equations. Because not all farmers produce all crops in any single year, estimation requires the Amemiya-Tobin multivariate approach.

Consider the following system of equations for land allocation decision for  $M$  crops. We use the following notations:

$i = 1, \dots, N$  households;  $m = 1, \dots, M$  acreage equations;  $t = 1, \dots, T$  time periods;

$A_{mit}^*$  and  $A_{mit}$  = Latent and observed acreage allocation, respectively;  $\mathbf{x}_{mit}$  = vector of explanatory variables in the  $m^{th}$  equation;  $\mathbf{b}_m$  = vector of parameters in the  $m^{th}$  equation;  $c_{mi}$  = unobserved household specific term;  $u_{mit}$  = error term that is iid over time and over households in the  $m^{th}$  equation;  $\Sigma$  and  $\Omega$  = across equation  $M \times M$  variance covariance matrices.

Consider the following specification for systems of acreage allocation equations

$$\begin{aligned}
 A_{mit}^* &= \mathbf{x}_{mit} \mathbf{b}_m + \mathbf{e}_{mit} \\
 \mathbf{e}_{mit} &= c_{mi} + u_{mit} \\
 A_{mit} &= \max(0, A_{mit}^*) \\
 u_{mit} \mid \mathbf{x}_{mi} &\sim Normal(0, \mathbf{s}_{um}^2) \\
 u_{it} &\sim Normal(0, \Sigma) \\
 c_{mi} \mid \mathbf{x}_{mi} &\sim Normal(0, \mathbf{s}_{cm}^2) \\
 c_i &\sim Normal(0, \Omega)
 \end{aligned} \tag{16}$$

where  $u_{it} = (u_{1i}, \dots, u_{Mi})$  and  $c_i = (c_{1i}, \dots, c_{Mi})$ .

Note that in equation (16) the error term  $e_{mit}$  is composed of two error terms; the household specific error terms  $c_{mi}$  and  $u_{mit}$  error assumed to be *iid* across individuals and over time.

In the economic model, we have demonstrated that land share equations imply an adding up constraint on the system. We, therefore, impose the adding up restriction by dropping one of the equations as suggested in Pudney (1989) and adopted in several studies ( e.g. Yen et. al 2004; Yen et. al. 2003). We estimate the system using maximum likelihood methods. To ease the exposition of the likelihood function of the system, we categorize the function into probability regimes. For two crops, dropping the third crop due to the adding up restriction, we will then have four probability regimes.

Denoting land allocation to corn and vegetable crops by  $A_{cit}$  and  $A_{vit}$ , respectively, the likelihood functions of the four regimes are represented as follows:

**Regime 1** (when acreage of corn and vegetables are positive):  $A_{cit} > 0, A_{vit} > 0$

$$L_1 = \Pr(A_{cit} > 0, A_{vit} > 0) = f(A_{cit} - \mathbf{x}_{it}\mathbf{B}_c - c_{ic}, A_{vit} - \mathbf{x}_{it}\mathbf{B}_v - c_{iv}) \quad (17)$$

**Regime 2**(Only acreage allocation to corn is positive):  $A_{cit} > 0, A_{vit} = 0$

$$L_2 = \Pr(A_{cit} > 0, A_{vit} = 0) = \int_{-\infty}^{-\mathbf{x}_{it}\mathbf{B}_v - c_{iv}} f(A_{cit} - \mathbf{x}_{it}\mathbf{B}_c - c_{ic}, u_{vit}) du_{vit} \quad (18)$$

**Regime 3** (Only acreage allocation to vegetables is positive):  $A_{cit} = 0, A_{vit} > 0$

$$L_3 = \Pr(A_{cit} = 0, A_{vit} > 0) = \int_{-\infty}^{-\mathbf{x}_{it}\mathbf{B}_c - c_{ic}} f(u_{cit}, A_{vit} - \mathbf{x}_{it}\mathbf{B}_v - c_{iv}) du_{cit} \quad (19)$$

**Regime 4** (Acreages of corn and vegetables are zero):  $A_{cit} = 0, A_{vit} = 0$

$$L_4 = \Pr(A_{cit} = 0, A_{vit} = 0) = \int_{-\infty}^{-\mathbf{x}_{it}\mathbf{B}_c - c_{ic}} \int_{-\infty}^{-\mathbf{x}_{it}\mathbf{B}_v - c_{iv}} f(u_{cit}, u_{vit}) du_{vit} du_{cit} \quad (20)$$

where  $f(\cdot)$  denotes the multivariate normal density function.

The likelihood function of the system for household  $i$  is given in equation (21).

$$L(A_{cit}, A_{vit}) = \iint \left[ \prod_1 L_1 \cdot \prod_2 L_2 \cdot \prod_3 L_3 \cdot \prod_4 L_4 \right] f(c_{ic}, c_{iv}) dc_{ic} dc_{iv} \quad (21)$$

To estimate the parameters in (21), the household specific heterogeneity ( $c_m$ ) must be integrated out. It is apparent that evaluation of this likelihood function involves multiple integrals- four in this case. Hence, it is unsuitable to use numerical integration. To overcome the difficulty with multiple integrals, we adopt a Maximum Simulated Likelihood technique as detailed in the following section.

### The Maximum Simulated Likelihood

Since numerical integration of the likelihood function is not feasible, we follow the method of Maximum Simulated Likelihood (MSL) following (Gourieroux and Monfort 1993), and Carter and Yao (2002). Conditional on the unobserved random variables, the likelihood function is a well defined function. Hence, if we simulate over the individual specific random errors, we could estimate the model using standard techniques.

In order to simulate the bivariate error variables  $(c_{ic}, c_{iv})$ , we transform the random variables to standard normal by using Cholesky transformation.  $c_{ic} = r_{ic} \mathbf{q}_c$  and  $c_{iv} = r_{ic} \mathbf{q}_v + r_{iv} \mathbf{q}_{cv}$ , where  $r_{ic}$  and  $r_{iv}$  are realization from independent random draws of standard normal distribution.

The Cholesky Matrix is given by  $Q = \begin{pmatrix} \mathbf{q}_c & 0 \\ \mathbf{q}_{cv} & \mathbf{q}_v \end{pmatrix}$  where  $QQ' = \Omega$ .

It follows that

$$\Omega = \begin{pmatrix} \mathbf{s}_c^2 & \mathbf{s}_c \mathbf{s}_v \\ \mathbf{s}_c \mathbf{s}_v & \mathbf{s}_v^2 \end{pmatrix} = \begin{pmatrix} \mathbf{q}_c^2 & \mathbf{q}_c \mathbf{q}_{cv} \\ \mathbf{q}_c \mathbf{q}_{cv} & \mathbf{q}_{cv}^2 + \mathbf{q}_v^2 \end{pmatrix} \quad (22)$$

Similarly, for the  $u_i$  vector, the Cholesky matrix is given by  $G = \begin{bmatrix} \mathbf{h}_c & 0 \\ \mathbf{h}_{cv} & \mathbf{h}_v \end{bmatrix}$ . The

variance covariance matrix is then given as follows.

$$\Sigma = \begin{pmatrix} \mathbf{s}_{uc}^2 & \mathbf{s}_{uc} \mathbf{s}_{uv} \\ \mathbf{s}_{uc} \mathbf{s}_{uv} & \mathbf{s}_{uv}^2 \end{pmatrix} = \begin{pmatrix} \mathbf{h}_c^2 & \mathbf{h}_c \mathbf{h}_{cv} \\ \mathbf{h}_c \mathbf{h}_{cv} & \mathbf{h}_{cv}^2 + \mathbf{h}_v^2 \end{pmatrix} \quad (23)$$

We draw, for each household,  $H$  replicates from pairs of independent standard normal random variables,  $(r_{ic}, r_{iv})$ . Noting that  $c_{ic} = r_{ic} \mathbf{q}_c$  and  $c_{iv} = r_{ic} \mathbf{q}_v + r_{iv} \mathbf{q}_{cv}$ , the likelihood function for household  $i$ , for replication  $h$  is given as follows.

$$L^h(A_{cit}, A_{vit} | r_{ich}, r_{ivh}) = \prod_1 L_1^h \prod_2 L_2^h \prod_3 L_3^h \prod_4 L_4^h \quad (24)$$

where  $L_j^h$  denote the probability regime  $j$  for replication  $h$ .

The likelihood for household  $i$  is then approximated by:

$$L(A_{cit}, A_{vit}) \cong \frac{\sum_{h=1}^H L^h(A_{cit}, A_{vit} | r_{ich}, r_{ivh})}{H} \quad (25)$$

### Elasticity Estimation

Due to censoring and the presence of systems of equations, probabilities need to be predicted for all regimes. Rather than predicting regime probabilities, we adopt the approach taken in Dong et. al (2004) to evaluate expected values by simulation technique. Assume we have  $k$  replicates for the vectors the error terms  $u_i$ . Let the  $k^{th}$  simulated share evaluated at the mean values of the explanatory variables be given by:

$$(A_m^s)_k = \mathbf{b} \bar{\mathbf{x}} + u_k$$

where  $u_k$  is the  $k^{th}$  replicate of the error terms.

$$(A_m)_k = \begin{cases} (A_m^s)_k & \text{if } (A_m^s)_k > 0 \\ 0 & \text{if } (A_m^s)_k \leq 0 \end{cases}$$

$$E(A_m) = \frac{\sum_{k=1}^K (A_m)_k}{K}$$

Suppose we have a small change in  $x_j$ , Then the elasticity is calculated using mid-point elasticity formula.

{Table 2 here}

#### 4. Estimation Results and Discussion

The parameter estimates are presented in table 3, and the elasticity estimates in table 4. Crop area responses to expected revenues are positive for own-price and negative for cross price terms. If we examine the magnitude of the own and cross effect, rising vegetable revenue reduces share of corn area by more than it increases share of vegetable area. In addition own price response of corn is larger in magnitude than the cross price effect on vegetables area. These results imply that, *ceteris paribus*, rising corn revenue leads to expansion in total area planted, while an increase in vegetables revenue reduces total area planted. While a rise in vegetables revenue increases fallow area, an increase in corn revenue will reduce fallow area.

Wage rises have negative effects on area planted, most especially so in the labor-intensive vegetable enterprise. Larger family labor endowments are significantly associated with greater area planted for vegetables, where management is important, but not for corn. Second, higher wages have a strongly negative effect on land demand for vegetables. This result, together with that of family labor on vegetable area expansion, indicates that labor market events influence the expansion of upland farming in our study

site. In the later years of the sample, strong local off-farm job growth in agribusiness, and non-farm employment expansion outside the watershed have been associated with rising farm wages. These trends are now seen clearly to have slowed— and perhaps helped to reverse— the expansion of upland farming.

{Table 3 and Table 4 here}

## 5. Conclusion and Directions for Future Research

The econometrics findings of this paper substantively augment those of several earlier findings. They also have potentially important implications for our understanding of the environmental effects of trade and agricultural policies, real wage growth and internal migration, and macroeconomic policies affecting the prices of tradable farm outputs and inputs including fertilizer. These variables have direct and significant effects on the total area of upland agriculture, and also on the allocation of upland land by crop. These results may in turn have significance for the design of policies and projects directed at the development of upland agriculture and the conservation of forest, land and water resources in the headwaters of Southeast Asia's river basins.

Philippine corn and vegetable protection policy trends fluctuated in the 1990s. At the beginning of the decade, a virtual ban was in force on imports of vegetables (such as cabbage) that in the Philippines are produced at high altitudes in upper-watershed areas, thereby conferring significant rents on producers. Protection for corn producers had risen steadily, from an implicit tariff of about zero in the mid-1970s to figures that approached (and even exceeded) 100% in the early 1990s (David 2003). The early years of the decade also marked the high-water mark of agricultural expansion in upland watersheds.

WTO compliance requires that the Philippines scale back agricultural tariffs over

time; the book value of the corn tariff is supposed to fall to 50% by 2005 from its current value of nearly 100%. Coxhead, Rola and Kim (2001) have shown that these policy changes will be passed through to farm gate prices with fairly short lags. The effect of the compliance will be a significant contraction in total area planted. This effect will be even greater if the WTO and/or autonomous trends in world markets or Philippine trade policy result in continuing growth of non-farm demand for unskilled and semi-skilled labor. The agribusiness boom that brought bananas to Lantapan is one manifestation; others are seen in the country's increasing prominence as a supplier to world markets of such labor-intensive goods and services as garments, electrical machinery and components, and tradable services such as call centers. These industries are all labor-intensive, and their expansion applies upward pressure on farm wages and encourages out-migration by members of farm families. Both effects reduce agricultural expansion and in turn reduce land degradation. We would like to attract attention to one interesting result of the empirical analysis. The results of our estimates show that a rise in return to labor and management intensive crop, vegetables, reduces agricultural area expansion. We hypothesize that such a phenomenon is a result of family labor constraint and/or capital constraint. It could all well be that opportunity cost of land quality rises with rising vegetables revenue, thus inducing more land conservation. The later explanation will require estimation and specification of a dynamic model, which is left for future research. Regardless of what caused the phenomenon, if true, it has an important implication for environmental protection and poverty reduction in developing countries. In other words, rising vegetable revenue not only reduces agricultural expansion but also increases farm income. Of course, this result must be interpreted with caution, as rising

returns to a given crop could induce in-migration under a well functioning markets for land, capital, and labor, or if land is available as an open access. In-migration could occur if growth in relative revenues from agriculture is higher than relative growth of non-farm wages. Thus, future research is needed to quantify the role of off-farm employment growth and the role of rising returns in land use choices, thereby affecting land degradation.

Clearly, the model could improve if dynamics is included, especially when land quality dynamics is a concern for the households. This would require setting up dynamic programming model. Estimation of dynamic systems of Tobit models are also lacking in the literature, and thus future research should consider dynamic estimation. The model specification and estimation can also be extended to include off-farm and on-farm labor allocation decisions, since on-farm family labor constraint depends on off-farm job employment opportunities. We have left these issues for future research.

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**Table 1: Philippines: Nominal protection rates for corn and sugar (%)**

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Crop	1970-79	1980-84	1985-89	1990-94	1995-2000
Corn	24	26	67	76	87
Sugar	5	42	154	81	106

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Source: David 2003, Table 6.7.

**Table 2: Summary Statistics of Variables**

Variable	Mean	Std. Dev.
Total area planted (ha) <sup>6</sup>	1.16	1.45
Area of corn (ha)	1.02	1.46
Area vegetable (ha)	0.14	0.33
Total farm area (ha)	2.68	2.95
Relative expected corn revenue (Pesos/ha)	20.00	7.38
Relative expected vegetable revenue (Pesos/ha)	44.80	30.08
Relative wage (Pesos/day)	0.17	0.02
Slope of the land (percent)	16.38	10.70
Average distance from national road (km)	2.86	3.64
Years of education of the household head	6.28	3.43
Number of adults in the household	3.31	1.93
Age of the household head	44.39	11.79
Total number of observations	592	

<sup>6</sup> Total area planted is the sum of corn and vegetable area.

**Table 3: Parameter estimates of the systems of land share equations**

Variables	Share Corn area			Share Vegetable area		
	Estimates	Std. err.	Prob.	Estimates	Std. err.	Prob.
Parameters						
Intercept	0.339	0.032	0.000	-0.154	0.028	0.000
Wages	-0.384	0.607	0.527	-0.875	0.481	0.069
Corn revenue	1.774	0.552	0.001	-0.404	0.139	0.004
Vegetable revenue	-0.404	0.139	0.004	0.194	0.086	0.025
Education	0.074	0.085	0.385	0.155	0.052	0.003
Adult	-0.120	0.153	0.433	0.185	0.100	0.063
Age	-0.230	0.183	0.208	0.194	0.153	0.204
Distance	-0.410	0.073	0.000	-0.028	0.036	0.441
Slop	-0.259	0.292	0.374	-0.839	0.205	0.000
$q_c$	0.381	0.040	0.000	-	-	-
$q_v$	-	-	-	0.192	0.029	0.000
$q_{cv}$	-	-	-	0.009	0.035	0.805
$h_c$	0.442	0.019	0.000			
$h_{cv}$	-0.236	0.022	0.000			
$h_v$	0.288	0.019	0.000			
Log Likelihood	-.456598					
LR test for reciprocity ( $\chi^2(1)$ )	0.08568		.77			

Note that the revenue, age and slop variables are scaled down by 100; education, adult and distance are scaled down by 10.

**Table 4: Elasticity Estimates**

	Share Corn Area	Share Vegetable area
Wages	-0.167	-0.682
Corn revenue	0.708	-0.289
Vegetable revenue	-0.408	0.352
Education	0.113	0.425
Adult	-0.099	0.272
Age	-0.256	0.387
Distance	-0.255	-0.031
Slop	-0.112	-0.646