AN EMPIRICAL INVESTIGATION OF ACTIVITY CHOICE, LABOR ALLOCATION, AND FOREST USE IN SOUTHERN MALAWI

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Abstract

In this paper we explore forest use and activity choice among low-income households in Malawi. Using data from three villages in southern Malawi we investigate factors related to forest use by jointly estimating four labor share equations for forest use, maize production, wage-work, and self-employment. This approach allows us to examine factors influencing competing and synergistic livelihood strategies simultaneously undertaken by households living at the forest margin. Results from constrained ML estimation indicate greater incentives to degrade forests where the returns to forest use are high. Factors that reduce pressure on forests include availability of low-cost fuel substitutes, tree planting on the farm, favorable returns to wage-work and opportunities in the self-employment sector. We find that wealth is inversely related to forest pressure.

JEL classification: J22; O13; Q12;

Keywords: labor allocation, deforestation, resource extraction, Malawi

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Introduction

Throughout the developing world forests contribute importantly to the livelihood of the rural poor, providing land and a wide range of products and services (Arnold 1998). Nearly a quarter of the world's poor depend directly or indirectly on forests for livelihood (World Bank 2000). While forest use is nearly ubiquitous in the developing world, the degree of forest dependence varies considerably across households. For some rural households forests are a main source of livelihood, for others they serve primarily a supplementary role or as a safety-net in difficult times (Warner 2000). Understanding why dependence on forests differs across households is important for both forest conservation and poverty alleviation. Households that are heavily dependent on forests are an important source of forest degradation and tend to be quite vulnerable to the effects of forest decline.[1] Thus there exists a "vicious circle" in which the rural poor are both agents and victims of resource degradation (Cleaver and Schreiber 1994).

In this paper we examine the factors related to forest use with data from southern Malawi. The study is motivated by methodological and empirical concerns. From a methodological perspective, we develop and estimate a time allocation model in which households allocate labor to four sectors: the forest, the farm, wage-work and self-employment. The model draws on the broader literature exploring factors related to labor supply decisions in agricultural households (Abdulai and Delgado 1999; Jacoby 1993; Rosenzweig 1980), and extends existing research by explicitly incorporating the forest as part of a household's diversification strategy (Dasgupta 1993). From an empirical standpoint, a distinctive feature of this study is the inclusion of multiple sources of forest degradation in the analysis. Forest degradation occurs not only when forest is cleared for agricultural expansion but also when households extract forest products at a level exceeding sustainable yield. Yet the existing literature has tended to either focus on forest clearing (e.g. Coxhead et al. forthcoming; Godoy et al. 1998; Shively 2001) or on fuelwood collection (e.g. Amacher et al.1996; Heltberg et al. 2000). By including data on a diversity of forest-based activities, we provide a comprehensive assessment of factors leading to forest decline. By estimating labor share equations jointly, we also provide a theoretically consistent treatment that leads to economic and policy insights obscured by a single equation approach to studying forest use.

Study Area And Data

Data for the study come from a survey of three villages in southern Malawi. Data were collected at monthly intervals between June 1999 and August 2000. Villages were selected to represent three forest management types and a spectrum of market access. Village 1 is ten kilometers from a tarmac road and adjacent to a state forest reserve managed by the Forestry Department. Village 2 is a Village Forest Area (VFA) managed by a village headman and a committee of twelve village leaders. Located 20 kilometers from a tarmac road and the nearest town, Village 2 is rather remote, but it is close to Mozambique (5 kilometers) where agricultural commodities can be purchased at prices well below those prevailing in Malawi. Village 3 is adjacent to a tarmac road linking it to Blantyre (Malawi's largest urban center) 40 kilometers away. Forest access in

Village 3 is de-facto open access. In each village, households were randomly selected from sample lists obtained by household censuses. The sample size is 99 households, representing 12 percent of the total population in the three villages. [2] Sample households were interviewed monthly about a range of issues including forest use, tree planting, labor allocation, agricultural production, income, expenditures, asset accumulation and food consumption.

Table 1 presents data on household labor allocation. Households in the study villages generally consider themselves maize farmers (maize/cassava farmers in the case of Village 2), and farming occupied the majority of household members' time during the survey period.
Data in Table 1 also document the sample households' heavy reliance on forests. Without exception, households depended on forests for basic needs – food, fuel, shelter and health. Observed differences in forest use across the study sites are illustrated in Table 2. For example, although all households used fuelwood for household energy needs, the main household energy source in Village 2 was harvest residues. This may indicate a response to physical scarcity, but more likely reflects availability of harvest residues at a low cost since cassava (a staple crop in Village 2) produces considerable biomass. Wood purchasing was most common in Village 2, where wood was either purchased in Mozambique or within the village.

Markets for wood are well developed throughout Malawi and sales of wood are an important source of income for rural households, including many in the study site. Although wood marketing is a direct violation of the existing forest rules in villages 1 and 2, this did not prevent sample households from selling wood as is evident from data in Table 2. In both villages people are only supposed to extract forest products for domestic use, except under special circumstances (e.g. funerals). In addition, wood collected from the state forest reserve in Village 1 is subject to a fee of 5 Malawi Kwacha (MK) per headload. The Forestry Department (Village 1) and the village head (Village 2) appeared to be largely ineffective in enforcing these rules during the survey period. Discussions with women in Village 1 in monthly interviews and focus groups indicated that the fee for headloads was not paid except on the rare occasion that a forest guard was met. Likewise, while cutting live trees and hunting are prohibited in both villages, during forest walks one frequently encounters villagers engaging in these activities. Several villagers reported adaptation of their forest exploitation behavior, e.g. some evaded forest patrollers by visiting forests at night or on Sunday mornings (when guards or the village head were in church).

Villages did however exhibit differences in forest use, with respect to forest clearing and charcoal marketing. This may reflect differences in forest management institutions and market access. As elsewhere in Malawi, agricultural landholdings were small at the sites, averaging 1.2, 1.0 and 1.7 hectares in villages 1, 2 and 3 respectively. Although the forest represents an important potential source of agricultural land, forest clearing was common only in Village 3. Enforcement of rules prohibiting forest clearing in villages 1 and 2 appear to have been effective, perhaps because it is rather easy to identify those who have cleared forest land for farming.[3] Although charcoal marketing is highly profitable, it occurred only in Village 3, in all likelihood because villages 2 and 3 are quite far from charcoal markets. [4]

Table 3 highlights the importance of trees and forests to the livelihood of sample households. Forest-derived cash income accounted for 43, 23 and 35 percent of total cash income for sample households in the three villages. During the survey year sample households engaged in a wide range of forest-dependent income generating activities: traditional medicine and the sale of numerous forest-derived items such as mushrooms, fruit, wooden furniture, bricks burned with wood, bamboo baskets, clay-fired pots and food and drink prepared with wood. The relatively high forest income shares in villages 1 and 3 reflect high rates of employment as sawyers and plank carriers in Village 1 and high rates of charcoal production in Village 3.

A Model Of Labor Allocation

Conceptual Framework

To investigate factors related to forest use, we develop a household model of labor allocation. We draw upon the economic theory of farm households (Singh et al. 1986) and empirical studies of household labor allocation in developing countries (Abdulai and Delgado 1999; Jacoby 1993; Rosenzweig 1980). The model explicitly accounts for the fact that farm households in Malawi are both producers and consumers of agricultural and forest goods, and that markets for key factors and products are weak or absent. As a result, production decisions are influenced by consumption needs, and so production and consumption decisions in the model are assumed to be made jointly in response to changes in input and output prices.

We assume households allocate family labor across four major categories of activities: maize production (L_M), forest use (L_F), wage-work (L_W) and self-employment (L_S). The household seeks to maximize household utility:

$$\max_{L_M, L_F, L_W, L_S, X} U = U(M, F, O, L_L; H) \tag{1}$$

where utility is derived from consumption of a representative staple crop – maize (M), a composite forest product (F), leisure (L_L) and other goods (O).[5] We assume household and individual characteristics (H) influence preferences. Utility is maximized subject to production functions for maize and forest products, a full income constraint, a time constraint, and non-negativity constraints:

$$Q_M = Q_M[L_M, X, A_0, A_1(L_F; K; I)] \tag{2}$$

$$Q_F = A_1(L_F; K, I) + f(L_F; K) \tag{3}$$

$$Y = p_M(Q_M - M) + p_F(Q_F - F) + p_W L_W + p_S L_S + R^* - p_O O - p_X X \tag{4}$$

$$T - L_L = L_M + L_F + L_W + L_S \tag{5}$$

$$F, M, O, X, Q_F, Q_M, L_F, L_M, L_W, L_S \geq 0 \tag{6}$$

Equation (2) describes smallholder production of maize, which is assumed to be a function of labor (L_M), purchased inputs such as fertilizer and seed (X), the household's land endowment (A_0) and additional land acquired through land clearing, represented by the function $A_1(\bullet)$. Cultivated area in the model is endogenously determined. Note that maize production can occur either through intensification (via X) or extensification (via $A_1(\bullet)$), or both. Although customary land ownership implies that land markets are generally absent in much of rural Malawi, land can be "purchased" by using labor (L_F) and capital (K), e.g. an ax, to clear uncultivated, and possibly forested land (Barrett 1999). The existence of forest management institutions (*I*) also enters as an argument in A_1 reflecting the potential for institutions to restrain forest clearing.

Equation (3) describes production of forest goods. The production function $A_1(\bullet)$ illustrates that when forest is cleared for agricultural expansion, forest products arise as a joint product. The technology $f(\bullet)$ describes forest "thinning" activities in which household labor is used to extract products from the forest, but land is not cleared in the process.[6] Note that the existence of forest management institutions (*I*) appears as an argument in $A_1(\bullet)$ but not $f(\bullet)$. This is consistent with patterns of forest management in the study area, which tend to be more effective at restraining forest clearing than limiting collection of forest products.

Equation (4) defines the household's full income. Prices and net hourly returns to labor are denoted by a vector of prices *p*. Households earn income from four sources: agriculture, forest use, wage-work and self-employment. Households also receive remittances (R^*), defined here as money received from relatives. Households make expenditures on maize (*M*), forest products (*F*), other goods (*O*) and agricultural inputs (*X*). A positive (negative) sign for (Q_M-M) and (Q_F-F) indicates the household is a net-seller (net-buyer) of maize and forest products. Equation (5) describes the household's time constraint. Finally, a set of non-negativity constraints (6) completes the model.

Two important assumptions inherent in the model should be noted. One, we assume that households sell but do not hire labor. Two, we assume that households do not engage in production of cash crops—beyond sales of surplus maize. While these assumptions are strong, and not appropriate in the context of rural Malawi as a whole, they are reasonable within the context of the sample. Most sample households are net-purchasers of food, constrained in both cash and maize and thereby rarely able to hire labor (often paid either with cash or maize). Only a few sample households engaged in cash crop production during the sample period, partly because tobacco, Malawi's main cash crop, has historically been produced outside the study area.

The Lagrangian for the household's maximization problem is:

$$L = U(M,F,O,T-L_M-L_F-L_W-L_S;H) - \lambda\begin{bmatrix} Y - p_M\{Q_M[L_M,X,A_0,A_1(L_F;K,I)]-M\} \\ - p_F\{[A_1(L_F;K,I)+f(L_F;K)]-F\} \\ - p_W L_W - p_S L_S - R^* + p_O O + p_x X \end{bmatrix} \quad (7)$$

After some rearranging of terms, first-order conditions for the problem can be expressed as:

$$\frac{\partial U}{\partial L_M} = \lambda p_M \frac{\partial Q_M}{\partial L_M} \quad (8a)$$

$$\frac{\partial U}{\partial L_F} = \lambda p_M \frac{\partial Q_M}{\partial A_I}\frac{\partial A_I}{\partial L_F} + \lambda p_F \frac{\partial A_I}{\partial L_F} + \lambda p_F \frac{\partial f}{\partial L_F} \quad (8b)$$

$$\frac{\partial U}{\partial L_W} = \lambda p_W \tag{8c}$$

$$\frac{\partial U}{\partial L_S} = \lambda p_S \tag{8d}$$

$$p_M \frac{\partial Q_M}{\partial X} = p_X \tag{8e}$$

$$\frac{\partial U}{\partial M} = \lambda p_M \tag{8f}$$

$$\frac{\partial U}{\partial F} = \lambda p_F \tag{8g}$$

$$\frac{\partial U}{\partial O} = \lambda p_O \tag{8h}$$

$$Y = p_M(Q_M - M) + p_F(Q_F - F) + p_W L_W + p_S L_S + R^* - p_O O - p_X X \tag{8i}$$

Equations (8a) through (8d) indicate that, at the optimum, households allocate labor across activities so as to equate the marginal value of household leisure with that of time spent on each productive activity, i.e. value marginal product or net hourly returns to labor. Equations (8e) through (8h) equate marginal values with prices. Equation (8i) recovers the full income constraint.

Expressions for labor supply, input demand, and commodity demand can be derived as functions of all exogenous variables.

$$\left.\begin{matrix} L_M \\ L_F \\ L_W \\ L_S \end{matrix}\right\} = g(p_M, p_F, p_W, p_S, A_0, H, K, I, T). \tag{9}$$

Properties Of Labor Supply

Below we seek to identify empirically the factors that condition labor allocation and directly or indirectly impact forest use. Before proceeding to the empirical analysis we briefly examine the properties of the labor supply equations. To begin, consider the Slutsky equation relating a change in the net hourly returns to wage-work to the forest labor share. This is:

$$\frac{\partial L_F}{\partial p_W} = \left.\frac{\partial L_F}{\partial p_W}\right|_{U=\bar{U}} + \frac{\partial L_F}{\partial Y} L_W \ , \tag{10}$$

where the first term on the right hand side of equation (10) is a substitution effect and is unambiguously non-positive. The second term is an income effect. While L_W is non-negative, the sign of $\partial L_F / \partial Y$ may be positive or negative. With rising income the demand for leisure (L_L) should increase if leisure is a normal good, but for the same reason the demand for forest products (F) should also increase. More leisure should mean a lower forest labor share. However, higher consumption of forest products could imply an increase in the forest labor share. This would be the case, for example, if the household collected rather than bought additional forest goods. Such behavior might be expected for a household that is a net-seller of forest products. In sum, the net effect of a change in the returns to wage-work on the forest labor share is ambiguous. A negative relationship whereby higher wages reduce forest pressure is plausible and could arise under several different scenarios: if forest products are inferior goods, if forest products are normal goods but the income-induced demand for leisure outweighs that for forest products, if forest products are normal goods but the household buys rather than collects forest products, or if a negative substitution effect dominates a positive income effect. A positive relationship between p_W and L_F could arise if the income-induced demand for forest goods outweighs that for leisure, the household is a net-seller of forest goods and the income effect dominates the substitution effect. Analysis for returns to self-employment is analogous.

The Slutsky equation describing the impact of a change in the price of maize on the forest labor share is:

$$\frac{\partial L_F}{\partial p_M} = \left.\frac{\partial L_F}{\partial p_M}\right|_{U=\bar{U}} + \frac{\partial L_F}{\partial Y}(Q_M - M) \ , \qquad (11)$$

where, as above, the first and second terms represent substitution and income effects. The substitution effect may be positive or negative. In the case of a higher maize price, households should respond by allocating more labor to maize production and less to other activities, either in pursuit of profits (in the case of net-sellers of maize) or to avoid having to purchase maize at the now higher price (net-buyers of maize). This implies a negative substitution effect. However, it seems reasonable that some net-buyers might increase labor allocated to both maize production *and* the forest, in response to higher maize prices, particularly if the forest is open access, if forest land is available, and if households opt to clear forest to expand maize production. This would indicate a positive substitution effect suggesting that a priori the income effect is of ambiguous sign. Again, $\partial L_F / \partial Y$ may be positive or negative depending on the relative demand for leisure and forest products and whether the household is a net-seller of forest goods. The term (Q_M-M) is also indeterminate, being positive for net-sellers of maize and negative for net-buyers. As a result, the direction of the relationship between the price of maize and the forest labor share depends on several conditioning factors. These include availability of and access to forested land, whether households are net-buyers or net-sellers of maize, and whether households are net-sellers or net-buyers of forest products.

Finally, the response of the forest labor share to changes in the price of forest products can be found via the relevant Slutsky decomposition. This is:

$$\frac{\partial L_F}{\partial p_F} = \left.\frac{\partial L_F}{\partial p_F}\right|_{U=\bar{U}} + \frac{\partial L_F}{\partial Y}(Q_F - F) \qquad (12)$$

The substitution effect is positive as a higher price of forest goods implies increased net benefits of forest exploitation.[7] The income effect is again indeterminate. The sign on the term $\partial L_F / \partial Y$ depends on the relative demand for leisure and forest products and whether the household is a net-seller of forest goods. The term (Q_F-F) is positive for net-sellers of forest products and negative for net-buyers. The income effect is positive for net-buyers of forest products because both $\partial L_F / \partial Y$ and (Q_F-F) are negative. For net-sellers of forest products the income effect is positive if the demand for forest goods outweighs that for leisure and negative if households opt for relatively more leisure when income rises. Thus the net effect of a change in the price of forest goods on the forest labor share is ambiguous, again depending on the conditioning factors highlighted above.

The foregoing analysis reveals ambiguous relationships between returns to activities and the forest labor share. In contrast, several reported models of tropical forest decline posit a positive relationship between agricultural output prices and deforestation, and a negative relationship between off-farm wages and deforestation (for a review of studies see Kaimowitz and Angelsen 1998). Why does the current model produce indeterminate results for all price variables? First, the model presented here is non-separable, which gives rise to both income and substitution effects. These effects often have opposite signs, and either effect can dominate. Second, net-buyers of maize or forest products respond differently to changing prices compared with net-sellers of these goods. And third, because we allow households to purchase additional land with labor alone, even substitution effects can be indeterminate, leading to the possibility that the forest labor share could rise or fall in response to a change in the price of maize.

Below we focus on development and implementation of an econometric model to investigate empirically the factors associated with labor allocation to forest use. In so doing, we take labor shares as our dependent variables, asking how changes in household characteristics and key policy parameters directly and indirectly influence rates of forest use.

Empirical Model

Our empirical model is a system of four, jointly estimated labor share equations where each labor share is a function of variables indicated in the household model. These explanatory variables include returns to labor, farm size, household and individual characteristics, capital, and forest management institutions.[8] Table 4 provides definitions and descriptive statistics for explanatory variables used in the analysis. Note that the price of maize is observed only for households that marketed maize and net hourly returns are observed only for households engaging in activities. Although a household may not participate in a given activity, it still faces an opportunity price in that sector. Leaving such observations out of the share equations would bias our results. Thus, values for missing prices and net hourly returns were imputed using regression results derived for observed data.[9] The imputation procedure and results from the regressions used to derive replacement values are reported in Appendix A.
Using the subscripts i and j to represent maize, forests, wage-work and self-employment, the labor share equations take the general form:

$$L_i = \alpha_i + \sum_j \beta_{ij} LOG(p_j) + \sum_k \delta_{ik} H_k + \gamma_i R + \varepsilon_i \qquad (13)$$

where the vector H_k represents household characteristics and R represents a binary, village-level variable indicating the presence (0) or absence (1) of a forest management regime. The selection of variables for H is consistent with previous econometric studies of tropical deforestation (Amacher et al. 1996; Coxhead et al. forthcoming; Godoy et al. 1998; Heltberg et al. 2000; Pichon 1997; Shively 2001). The model is non-separable and theory provides little guidance on exclusion restrictions for explanatory variables. As a result, we use identical sets of exogenous variables in the labor share regressions.

To reiterate, the four dependent variables (L_i) are labor shares allocated to the forest, the farm, wage-work and self-employment. Our labor share model is similar to standard models of commodity or factor demand, such as the almost ideal demand system (AIDS). As in the context of the AIDS model, parameters of the labor share system are constrained across equations. By construction, the observed labor shares sum to one. In order to ensure that predicted labor shares also sum to one, we impose the following constraints:

$$\sum_j \beta_{ij} = 0 \tag{14a}$$

$$\sum_i \delta_{ij} = 0 \quad \text{and} \quad \sum_i \beta_{ij} = 0 \tag{14b}$$

$$\sum_i \varepsilon_i = 0 \tag{14c}$$

$$\alpha_M + \alpha_F + \alpha_E + \alpha_S = 1\,. \tag{14d}$$

The homogeneity restriction (14a) requires that a given labor share is invariant to proportional changes in all prices. Constraint (14b) requires that the individual effects of changes in explanatory variables on labor allocation are offsetting, and therefore that the net effect of a change in a given explanatory variable on labor allocation is zero. Constraint (14c) indicates that, for each observation, error terms across equations are linearly dependent. Constraint (14d) combined with the so-called adding-up restrictions ensures that the estimated labor shares sum to one. With constraints imposed, the econometric model reflects the fact that labor allocation decisions across activities are related. To impose the restrictions, we divide the price of maize and the returns to forest goods and wage-work by the returns to self-employment. To avoid singularity of the disturbance covariance matrix, the self-employment equation is dropped. The system of labor share equations are estimated using constrained maximum likelihood (ML) estimation. This ensures that outcomes are invariant to the choice of which equation we drop (Greene 2000). The estimating equations follow the form:

$$L_i = \alpha_i + \sum_j \beta_{ij} LOG(p_j / p_s) + \sum_k \delta_{ik} H_k + \gamma_i R + \varepsilon_i \tag{15}$$

where *i, j = maize, forest, wage employment*.
In addition to homogeneity and adding-up restrictions, we impose three restrictions for symmetry of cross-price effects.

$$\beta_{ij} = \beta_{ji} \text{ for } \forall\; i, j. \tag{16}$$

In the case of standard demand models, the symmetry restriction is grounded in economic theory. This is not so in the case of labor shares. For this reason, testing for the symmetry restriction – which we do in the next section – is imperative in this setting.

Results And Discussion

Regression results for the system of four share equations are presented in Table 5. The calculated *F*-statistic of 254.6 is significant at the 95% confidence level, providing support for a hypothesis of joint significance of the explanatory variables. Mean observed and predicted labor shares are reported at the bottom of Table 5 for comparison purposes.[10] Parameter estimates for the forest, maize and wage-work equations were obtained with constrained ML estimation. Parameters of the self-employment equation were calculated from the adding-up restrictions. We use a likelihood ratio test (LRT) to test symmetry restrictions. The 95% chi-square test statistic for three restrictions is 7.8 which exceeds the calculated LRT statistic of 6.0. Since the LRT is less than the critical chi-square we fail to reject the null hypothesis of symmetry. To test the homogeneity and adding-up restrictions we use a Wald test. The calculated Wald statistic is 79.3. The 95% chi-square test statistic for a model with 12 restrictions is 21.0. Thus the null hypothesis of homogeneity and adding-up is rejected. Although this suggests our data may be inconsistent with the restrictions, it is also possible that the rejection reflects the tendency of the Wald test to over-reject true null hypotheses in small finite samples (Laitinen 1978).

Table 5 includes results for each labor share equation. However, we focus our discussion on results of importance to the forest labor share equation. Six of the point estimates for variables in the forest labor share equation are individually different from zero at a 90% confidence level. The positive sign on returns to forestry in the forest labor share equation clearly indicates that households that obtain higher returns to forest use allocate a greater share of household labor to the forest. This finding is consistent with other studies in the tropical deforestation literature (e.g. Amacher et al. 1996) and provides insight into the Slutsky decomposition for $\partial \mathrm{L_F} / \partial \mathrm{p_F}$. Importantly, the positive sign could indicate that the positive substitution effect dominates a negative income effect, or that both effects are positive. Under what circumstances would the income effect be positive? One reasonable assumption is that the majority of sample households are either self-sufficient or net-sellers of forest products.[11] In such a case, households with extra cash on hand would most likely use this cash to buy food rather than forest goods. Under this net-seller assumption, a positive income effect means the demand for forest products outweighs demand for leisure. This seems plausible for extremely poor households. Given that food insecurity is widespread throughout southern Malawi (and the sample), with a hungry season that by some accounts is said to average six months of the year (Stolz 2000), it seems probable that households experiencing a small rise in income would opt for more food (and then collect fuelwood to cook the food) rather than consume leisure.

Wages are negatively correlated with the forest labor share, consistent with patterns reported in Nepal (Bluffstone 1995) and the Philippines (Shively 2001). Recall that a negative sign for $\partial L_F / \partial p_W$ implies one of four possibilities: (i) that forest products are inferior goods, (ii) that forest products are normal goods but the income-induced demand for leisure outweighs that for forest products, (iii) that forest products are normal goods but the household buys rather than collects forest products, or (iv) that a negative substitution effect dominates a positive income effect. Of these possibilities, most plausible is that the substitution effect dominates the income effect, yielding a negative $\partial L_F / \partial p_W$. It is unlikely that forest products are inferior goods in rural Malawi, where fuelwood is the dominant fuel for households of various levels of income (GOM 1998). Likewise it is unlikely that an income-induced demand for leisure outweighs that for forest products or that households experiencing increased income opt to buy rather than collect forest products, for reasons outlined in the discussion of $\partial L_F / \partial p_F$ above.

The allocation of household labor may change over the life cycle of the household head (Godoy et al. 1998). To assess the extent to which forest labor allocation changes over time, we included two variables: age of the household head (AGE) and the head's age squared (AGESQ). We find no direct statistical support for life cycle effects in any of the share equations.

Other things equal, households that primarily use harvest residues for cooking (HRCKG) spend a smaller proportion of their time in forests. All of the sampled households in villages 1 and 3 use fuelwood as the dominant cooking fuel, while 72 percent of households in Village 2 reported harvest residues as the main cooking fuel. The magnitude of the HRCKG variable indicates that households that primarily use harvest residues for cooking spent 119 fewer hours in the forest in 1999/2000 compared with those that cook mainly with wood. Using data on quantity of wood collected per hour from another survey in rural Malawi (Brouwer et al. 1997, Table 5), 119 hours translates into between 550 and 961 kilograms of wood. It is clear that substitutes for wood for cooking can reduce forest pressure.

Studies in a number of tropical countries indicate a positive correlation between poverty and dependence on forest resources for livelihoods (for a review see Neumann and Hirsch 2000). To examine this potential link in the context of Malawi, we included as regressors two indicators of economic well-being: holdings of productive capital (land) and non-productive capital (iron roof). In rural Malawi land holding size per capita (PCFSIZE) provides a good indication of the level of food security enjoyed by a household (Whiteside and Carr 1997; Peters 1996). And an iron sheet roof (IRON) is a key non-productive wealth holding in southern Malawi. Why might the poor be more heavily dependent on forests for their livelihoods? Forest exploitation typically has low returns to effort and many forest activities have associated risk and displeasure. Yet the poor, with few alternative sources of income, have little option but to exploit natural resources such as forests in their struggle to secure livelihoods. In addition, forest exploitation has low capital investment requirements making it a feasible activity even for the very poor (Neumann and Hirsch 2000). While forest use rarely provides a springboard to improved economic well-being, it does enable the poor to make up for income shortfalls – providing an important safety-net (Arnold 1998; Warner 2000). In Malawi, rural households have been observed to increase their participation in woodfuels' marketing in years of particularly poor harvests. Likewise, forest clearing for farm land is a strategy pursued by Malawian farm households in the face of low and declining crop yields (GOM 1998).

If land holding per capita and iron sheet roof serve well as wealth proxies, then the positive signs on the coefficient estimates may be suggestive of the poverty-environment links widely discussed in the literature (e.g. Duraiappah 1998; Perrings 1989; Takasaki et al. 2000; Zwane 2002). The PCFSIZE and IRON variables are both positively correlated with the forest labor share at a statistically significant level. Taken together with the statistically significant results in the other share equations, our findings indicate that wealthy households in the sample allocate a lower proportion of household labor to the forest and the farm and a higher share to wage-work and self-employment. [12] That said, the picture of overall demand for forest products remains unclear. A detailed survey of environmental resource use in Zimbabwe found that poor households depended on resources more than rich households, but that aggregate demand for environmental resources was greater among rich households (Cavendish 2000).

In Malawi the incorporation of trees in the agricultural landscape is widely practiced (Dewees 1995; Warner 1995). Households with a greater number of trees on their fields or homesteads should require less time to collect wood and other forest products, reducing the forest labor share and freeing up labor for other activities. We find that tree planting on private land (TREE) is negatively correlated with the forest labor share. Admittedly, the coefficient estimate on the variable in the forest labor share equation is rather small, indicating a 0.0015 decrease in the forest labor share with the planting of an additional tree. Yet if we consider a household that planted 12 trees (the sample mean) in the past five years, this household would have spent about 29 fewer hours in the forest in 1999/2000. Using figures from Brouwer et al. (1997) the 29 hours represent about 134 – 234 kg of forest biomass per household.

The potential impact of recent policy changes in Malawi is captured in the regressions by an indicator of receipt of a Starter Pack (PACK). The Starter Pack Scheme is a free inputs program that began in 1998 and continued through 2000. Each starter pack contained seed and fertilizer sufficient to plant about 0.1 hectare and produce an additional 100 kg of maize – enough to feed a family for during one month of the hungry season (Blackie et al. 1998). Although all of the estimated 2.86 million smallholder Malawian households were entitled to receive a starter pack, for a number of reasons many did not. In our case, 69 percent of sampled households received a starter pack. Although the point estimate for PACK is statistically weak in our regressions, it does have the expected sign. In the non-forest labor share equations we find that households that received a starter pack did spend a greater share of their time on farm but most of the reduced labor came from self-employment activities, rather than forest activities. The lack of significance of PACK in the forest equation may indicate that it will take several years before farmer experimentation with improved seed and fertilizer (with the Starter Pack) encourages intensive, rather than extensive agricultural cultivation.

Finally, to assess the extent to which forest management regimes reduce forest exploitation at the study sites, the regressions include a binary variable indicating Village 1 residence (VILL1). The harvest residues variable (HRCKG) approximates Village 2 residence, since only households in Village 2 use harvest residues as a main source of fuel. Note that the correlation between HRCKG and Village 2 residence is 0.86. Villages 1 and 2 have forest management institutions, albeit rather weak, whereas the forest commons in Village 3 is de-facto open access. It is the case that forest clearing for agricultural expansion and charcoal marketing only occur in Village 3, the management systems in the other villages at least partly being responsible for the absence of such of activities. Though statistically weak, VILL1 has an unexpected positive sign. The negative sign and statistical significance of HRCKG indicates that households in Village 2 use the forest less intensively than those in Village 3. This may be a function of the existing community-based management system, a finding that accords with some studies in the literature (e.g. Heltberg et al. 2000). However, it must be noted that HRCKG and VILL1 are indicators of differences across space that could arise due to any number of factors.

Conclusions And Policy Recommendations

In this paper we examined the factors related to forest use by jointly estimating a system of four labor share equations corresponding to forest use, maize production, wage-work, and self-employment. From a methodological standpoint, the novelty of this study is our use of a systems approach. Alternatively, we could have estimated a single equation Tobit model of forest labor allocation. However, a systems approach more closely corresponds to theory, as forest use is one of several livelihood strategies simultaneously undertaken by households living at forest margins. Use of a systems approach reveals relationships among these often competing livelihood activities. For example, study findings suggest that forest use and wage-work are substitute activities for sample households. A higher price for forest commercialization increases the forest labor share and simultaneously reduces the wage-work share. Likewise, as returns to wage-work rise, households devote a greater share of their labor to employment and a lower share to forests. Participation in self-employment also appears to substitute for forest use as evidenced by opposite signs on several coefficients. Relatively "wealthy" households (with iron sheet roofs and larger land holdings) devote a lower share of labor to the forest and a higher share to self-employment. Households that plant more trees on farm and cook mainly with harvest residues spend less time in the forest and more time on self-employment.

Though not surprising, the positive relationship between the returns to forest use and the forest labor share provides a cautionary message for policy makers and others concerned with the fate of Malawi's forests. In the near term it seems probable that the returns to forest use will increase as the aggregate demand for forest products rises and supply declines. In particular, the marketing of wood as fuel seems assured due to the recent elimination of subsidies and rising tariffs on kerosene and electricity (GOM 1998). Recent estimates suggest that wood-based fuels account for 94 percent of urban household energy demand in Malawi (Arpaillanje 1996).

On a more optimistic note, the positive own-price effects in each labor share equation suggest that sample households respond well to production and work incentives, an essential element in economic development. Likewise, negative cross-price terms in most equations indicate that labor can be drawn away from one sector through price incentives in another. For example, the findings here and elsewhere suggest that public sector investment in the wage-work sector is a potential strategy to reduce forest pressure (Shively 2001; Barrett 1999; Bluffstone 1995). However, it should be stressed that considerable job creation and improvements in human capital will likely be necessary for the success of such a strategy. High wage jobs in the wage-work sector are few and available to the minority of educated workers. Agricultural contract work, the main form of wage employment in rural areas, is low paying and provides limited competition with the forest as an income generating activity. Also at issue from the standpoint of agricultural development is that agricultural contract work naturally occurs during the agricultural period. Participation in such work, therefore, reduces the time available for tending one's own garden. In the near future, food-for-work interventions during the dry season may offer more promise for absorbing low-skill labor, and subsequently, reducing forest use.

Our finding that self-employment and forest use are substitute activities is a new one. Importantly, it suggests that the self-employment sector, similar to the wage-work sector, can absorb labor that might otherwise be engaged in forest exploitation. The range of self-enterprise activities in rural Malawi is vast, but a common denominator is that financial capital is required for participation. Key to the success of any program aimed at encouraging self-employment is improved access to cash. Better-off farmers have savings to use for start-up costs. At issue is how to get cash into the hands of poorer households. One possibility is food-for-work interventions as discussed above. In addition, some credit schemes such as the Tikolore clubs that are said to be self-selecting for poorer individuals hold promise (Whiteside and Carr 1997).

The study's findings support the thesis that household labor can also be drawn away from forests if households switch to substitute sources of forest products. Households that used harvest residues for cooking spent significantly less time on forest activities than did those who cooked mainly with wood. Where low-cost alternatives to wood are available (as in the case of cassava residues in Village 2), households may at least partially move away from cooking with wood. Interventions that increase agricultural productivity, e.g. the Starter Pack Program, provide a method to increase availability of harvest residues for cooking and for food.

Another possibility to reduce household demand for wood is through the use of improved wood stoves. All of our sample households used the traditional three-stones method of cooking. Evidence suggests that improved stoves perform rather well, increasing from three days to five days the amount of time a head load of wood lasts. Cost, availability, and information on use all preclude widespread adoption of stoves at the moment (Knacck Consultants 1999).

Our data indicate that households have incentives to cultivate trees and that doing so reduces forest pressure. More than half of the sample households planted trees on farm in the past five years, and in most instances seedlings were purchased or collected locally. Incentives to plant trees that can improve soils are largely absent, however, as indicated by the absence of agroforestry systems on sample farms. This is unfortunate as observers in Malawi contend that low and declining maize yields are mainly a function of declining soil fertility (Blackie et al. 1998; Smale and Heisey 1997). At present households choose to plant trees that provide construction materials and fruit. Thus while policy interventions to encourage tree planting *per se* are not required to encourage Malawian smallholders to plant trees on their farms, there may be a role for policies to promote adoption of agroforestry species (Dewees 1995).

Finally, the study findings suggest that with improved economic well-being households become less reliant on forests for their livelihoods. If reduced forest reliance is positively correlated with reduced demand for forest products, this finding may suggest a complementarity between strategies aimed at poverty alleviation and those geared towards forest conservation.

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Appendix A. Imputation of Prices and Net Hourly Returns

To impute values of maize prices and returns to labor, we used sub-sample ordinary least squares (OLS).[13] For each sector (forest, maize, wage-work, self-employment) an equation for price/returns was estimated for the sub-sample of households engaged in that sector. The OLS coefficients were then used alongside observed values for explanatory variables to predict prices/returns where the data were missing. Below we provide details of the imputation procedure for each equation.

The Maize Price Equation

Of the 99 sample households, 27 reported marketing maize in 1999/2000 at an average price of MK 3.84 per kilogram (standard deviation equals MK 1.18 per kilogram). Observed maize price variability may be associated with several factors, the key ones being season and location of sale.[14] As in other settings where markets are thin, crop prices tend to follow a seasonal pattern, reaching an annual low soon after the harvest when granaries are full and increasing to an annual high just before the next harvest (Sahn 1989). It is economically advantageous for a farmer to delay maize sales until well after the harvest, but whether she/he can do so depends on the household's food security situation and access to storage facilities. Price differences may also arise across space as markets in rural Malawi are not well integrated (Kherallah et al. 2000).

To impute a price of maize for households that did not sell maize, we used data for the sub-sample of maize selling households (N=27) and regressed the maize price on three explanatory variables: MEALS, IRON and VILL3. The average number of meals taken by household residents per day provides an indication of the food security situation of the household and should be positively associated with the maize price. Households that possess buildings with iron sheet roofs have relatively effective storage. Thus IRON should be positively related to the price of maize. Households that reside in Village 3 may be able to obtain a higher maize price, all else being equal, because marketing conditions are relatively good in the village due to proximity to an urban center. The first column of Table A.1 presents the OLS results for this equation. The model fits the data quite well and coefficients have the expected signs, although only IRON is statistically significant. These coefficient estimates were used in conjunction with the observed values for the explanatory variables to impute values for the missing maize prices. For comparative purposes the mean and standard deviation of observed and imputed maize prices are included in the bottom of Table A.1.

The Equations for Net Hourly Returns

Data for net hourly returns were not collected directly.[15] For each sector (forest, wage-work and self-employment), returns were calculated by dividing annual earnings or profits by hours worked. Annual hours worked in each sector were calculated by summing over household members the product of labor share and total hours worked in all activities.[16] In the sample, 75 households reported earnings from forest use with hourly returns of 1.83 MK/hour (standard deviation = 2.22); 59 households engaged in wage-work earning 3.01 MK/hour on average (standard deviation = 3.93); 41 households were self-employed with net hourly returns of 2.46 MK/hour (standard deviation = 2.78). Observed variability in net hourly returns is not surprising given the diversity of activities in each category. In the forest sector, for example, activities include the more remunerative activities such as charcoal marketing and sawing of planks and less lucrative activities such as sales of cooked food and pottery (fired with wood). Likewise, other wage-work includes contract agricultural jobs that command a far lower wage than permanent jobs such as school teacher or forestry officer.

Three equations were estimated using data for the sub-samples of households engaged in the given activity. For each equation, the log of returns was assumed to be a function of individual or household characteristics and local marketing conditions.[17] Seven explanatory variables were initially included in each of the three equations. And two additional variables were included in the forest returns equation only. All explanatory variables are listed and defined in Table 4.

Certain personal characteristics should influence returns to effort. Following other studies we included human capital variables in the regressions (e.g. Alderman et al. 1996; Abdulai and Delgado 1999). The age of the household head (AGE), a proxy for general experience, and her/his education level (SCHOOL) may indicate potential productivity in an activity and should be positively associated with returns.

While some individuals may be *pulled* into the forest, wage-work and self-employment sectors because their experience or education level creates opportunities for relatively high returns, other individuals may be *pushed* into the more plentiful low return activities in these sectors. I.e. one would expect that individuals who engage in the low return activities in each sector do so out of need. To capture this, a variable measuring the food security situation of the household (MEALS) was included in each equation.

In noncompetitive labor markets, employment may be rationed on the basis of the status of the worker, with employers giving preference to those of a certain gender, ethnicity, religion or farmsize (Abdulai and Delgado 1999; Rosenzweig 1980). One could also extend this argument to noncompetitive credit markets, such as those in Malawi where credit is often rationed (Diagne 1999). Access to credit should in turn be associated with participation in and returns to self-employment activities, since financial capital is required to engage in a business, particularly one with relatively high returns. Men may be more likely to engage in some of the more lucrative activities in the wage-work sector (e.g. forestry officer), forest sector (e.g. plank sawyer) or self-employment sector (e.g. grocery sales) either due to hiring decisions or access to credit. To capture this, we included a dummy variable for female-headed households (FHH), which constitute 41 percent of the sampled households. Individuals belonging to one of the local dominant ethnic groups (ETHNIC) may also be more likely to be hired for well-paying work or obtain credit to start up a business. Finally, the size of the household's landholding (FARMSIZE) may factor into decisions to hire or extend credit to an individual.

Two additional variables (FTOOL and FHHAGE) were included in the forest returns equation only. Households possessing a greater number of axes, handsaws and pitsaws (FTOOL) may be more likely to engage in some of the high return forest activities, e.g. sawing of planks and charcoal production. FHHAGE is included to examine whether age has a differential association with forest returns for male- compared with female-headed households. One of the more lucrative forest income-generating activities that women engage in is traditional beer brewing (*masese*) for which it takes years to acquire a reputation as a good brewer.

Local labor market conditions should also influence hourly returns (Rosenzweig 1980). Since data are not available on local unemployment rates, population density, etc. a village dummy variable (VILL2) is used to capture differential labor market conditions across space. Village 2 should have lower forest returns compared with the other villages since neither charcoal marketing nor sawing of planks (high return activities) are undertaken in this village. Returns to self-employment should also be lower in Village 2 relative to other villages largely because the main form of self-employment in this village is the less profitable resale of agricultural commodities. Finally, the relative distance of Village 2 from a town may mean fewer opportunities for well-paying wage-work.

Results for the three regressions are presented in Table A.1. For each sector the final estimating equation includes only those explanatory variables that are statistically significant at the 90 percent level or better. The R^2 values indicate that the models explain 37-50 percent of the observed variation in the dependent variables. Results for the AGE variable may indicate that age signals a worker's productivity for skilled wage-work (e.g. teacher), but for the high paying, but physically demanding forest-sector jobs (e.g. sawing planks) it may indicate to employers a lower marginal product of labor. Results also indicate that older individuals are less likely to engage in the more profitable self-employment activities. Education of the household head is positively related to net hourly returns in the wage-work sector, but is uncorrelated with returns in other sectors.

Results show that female-headed households in the sample have lower wages in all sectors compared with male-headed households. The hypothesis that age has a differential association with forest returns for male- compared with female-headed households is supported by the data, age being positively related to forest returns for female heads. The ETHNIC variable has an unexpected negative sign in the wage-work and the self-employment equations. A possible explanation for the case of wage-work is that those filling the high wage, permanent jobs are transferred to the new location or move to fill the position. The FARMSIZE variable is not significantly different from zero at standard test levels in the wage-work and forest sectors. In the self-employment equation land holding size has a negative correlation with returns. It may be that FARMSIZE does not measure access to credit as posited earlier. It may be that the negative coefficient on FARMSIZE indicates that households with smaller land holdings have greater incentive to earn high returns in self-employment.

The food security variable (MEALS) is statistically significant in the forest equation only and has the expected negative sign. The forest tools variable has an expected positive sign in the forest use equation. The sign of the VILL2 variable conforms with prior expectations in all three equations, although it is statistically weak in the returns to wage-work equation.

Estimated coefficients from the three regressions for net returns were used in conjunction with observed values for explanatory variables to impute shadow wages where observed returns to labor were missing. The mean and standard deviation of observed and imputed returns to labor are included at the bottom of Table A.1.

Table 1: Labor Shares by Activity and Village, Sample Households 1999/2000

Activity	Village 1	Village 2	Village 3	All Villages
Forest use [a] (L_F)	0.32 (0.16)	0.23 (0.07)	0.28 (0.13)	0.27 (0.13)
Agriculture [b] (L_M)	0.55 (0.17)	0.59 (0.15)	0.55 (0.15)	0.56 (0.16)
Wage-work [c] (L_E)	0.08 (0.09)	0.06 (0.07)	0.13 (0.16)	0.08 (0.11)
Self-employment [d] (L_S)	0.05 (0.15)	0.13 (0.14)	0.04 (0.09)	0.08 (0.14)
Number of observations (N)	39	38	22	99

a. Forest-dependent income generating activities include: (1) employment as sawyers or plank carriers, (2) raw wood and charcoal marketing, (3) sales of food/drink prepared with large amounts of wood, e.g. traditional beer, (4) carpentry/construction, (5) sales of fired bricks, (6) sales of certain crafts, e.g. wood-fired clay pots (7) traditional medicine.

b. Agricultural activities include crop cultivation, livestock production, agricultural marketing.

c. Wage-work includes non-forest off-farm employment: contract agricultural labor (clearing fields, building ridges, etc.), forestry officer, teacher, mechanic and village head.

d. Self-employment includes non forest-based businesses: resale of agricultural commodities, tailor, money lending, sales of fish, grocery sales, public transport operation, repair, tinsmith and stone breaking.

Table 2: Forest Use, Sample Households 1999/2000

Activity	Village 1	Village 2	Village 3	All Villages
Main cooking fuel is wood (%)	100	18	100	69
Quantity wood collected (kg)	2128	1141	3354	2267
Cleared forest (%)	3	0	50	12
Area cleared (ha)	0.30	----	0.26	0.26
Purchased wood (%)	18	63	36	39
Sold wood (%)	18	29	45	28
Sold charcoal (%)	0	0	36	8
Planted trees in past 5 yrs (%)	31	71	64	54
Number of trees planted	10	9	19	12

Table 3: Cash Income (1999 $US per year) by Activity and Village, Sample Households 1999/2000 [a]

Activity	Village 1	Village 2	Village 3	All Villages
Forest use	77	30	83	60
Agriculture	16	34	46	30
Wage-work	24	15	74	32
Self-employment	21	35	13	24
Other income [b]	40	14	24	27
Total cash income	178	128	240	173

a. Conversion based on an exchange rate of 50 Malawi Kwacha (MK) = US$1.

b. Other income includes sales of assets, remittances, gifts and loans.

Table 4: Data Definitions and Descriptive Statistics, 1999/2000

	Variable Definition	Mean or Frequency (Stand. Dev.)
p_M	The producer price of maize (MK/kg); values imputed for 72 observations	3.64 (0.79)
p_F	Net hourly returns to forest activities (MK/hour); values imputed for 25 observations	1.70 (2.10)
p_W	The wage-work wage (MK/hour); values imputed for 41 observations	2.52 (3.21)
p_S	Net hourly returns for self-employment activities (MK/hour); values imputed for 58 observations	2.49 (2.69)
AGE [a]	Age of the household head by category (1=15 to 24 years; 2=25 to 34; 3=35 to 44; 4= 45 plus)	----
ETHNIC [b]	Household head belongs to one of the main ethnic groups in the village of residence (0=No, 1 =Yes)	0.77
FARMSIZE	Area of the household's agricultural land holding (hectares)	1.21 (0.93)
FHH	Female-headed household (0=No, 1=Yes)	0.41
FTOOL	Number of axes, handsaws and pitsaws owned by household residents at start of survey year	0.96 (0.92)
HRCKG	The main household cooking fuel is harvest residues (0=No, 1=Yes)	0.31
IRON	Number of household dwelling units with an iron sheet roof	0.15 (0.46)
PACK	Household received a Starter Pack (0=No, 1=Yes)	0.69
PCFSIZE	Area of the household's agricultural land holding divided by household population (ha/person)	0.32 (0.31)
SCHOOL	Education of household head (0 = no schooling, …, 9 = completed secondary school)	----
TREE	Number trees planted on household's land holding in the past five years	12.49 (23.90)
VILL1	Village 1 residence (0=No, 1=Yes)	0.39
VILL2	Village 2 residence (0=No, 1=Yes)	0.38
VILL3	Village 3 residence (0=No, 1=Yes)	0.22

a. Age is categorical because respondents generally were not aware of their age. Our approach was to refer to a list of historical events and then estimate the age of the head based on her/his responses concerning whether she/he was alive and what she/he was doing the year of the important event.

b. The Lomwe tribe is the dominant tribe in Village 1 (62 percent of household heads) and Village 2 (89 percent of heads). In Village 3 there are three dominant tribes: the Ngoni, Lomwe and Manganja tribes (82 percent of heads).

Table 5: Constrained MLE Results for the System of Labor Share Equations

	Forest Labor Share	Maize Labor Share	Wage-work Labor Share	Self-employment Labor Share
Constant	*** 0.4514	0.2587	0.1877	0.1022
	(0.1496)	(0.1870)	(0.1281)	(0.1608)
Log(p_F)	*** 0.0291	-0.0124	* -0.0119	-0.0048
	(0.0096)	(0.0105)	(0.0073)	(0.0082)
Log(p_M)	-0.0124	0.0194	-0.0080	0.0010
	(0.0105)	(0.0194)	(0.0106)	(0.0137)
Log(p_W)	* -0.0119	-0.0080	*** 0.0317	-0.0117
	(0.0073)	(0.0106)	(0.0110)	(0.0093)
Log(p_S)	-0.0048	0.0010	-0.0117	0.0155
	(0.0082)	(0.0137)	(0.0093)	(0.0142)
AGE	-0.0921	0.0530	0.0182	0.0209
	(0.1070)	(0.1336)	(0.0910)	(0.1151)
AGESQ	0.0181	0.0014	-0.0086	-0.0110
	(0.0187)	(0.0235)	(0.0159)	(0.0202)
HRCKG	** -0.0740	0.0596	*** -0.0807	*** 0.0952
	(0.0315)	(0.0399)	(0.0273)	(0.0351)
IRON	** -0.0563	* -0.0605	* 0.0436	*** 0.0731
	(0.0268)	(0.0333)	(0.0231)	(0.0293)
PACK	0.0043	** 0.0855	-0.0255	* -0.0643
	(0.0356)	(0.0442)	(0.0304)	(0.0385)
PCFSIZE	* -0.0657	0.0109	-0.0206	* 0.0754
	(0.0394)	(0.0496)	(0.0341)	(0.0441)
TREE	*** -0.0015	0.0005	* -0.0007	*** 0.0017
	(0.0005)	(0.0006)	(0.0004)	(0.0005)
VILL1	0.0162	0.0231	-0.0271	-0.0122
	(0.0362)	(0.0451)	(0.0309)	(0.0393)
N	99	99	99	99
Predicted	0.27	0.56	0.08	0.08
Observed	0.27	0.56	0.08	0.08
F-statistic	254.6			

Note: *, ** and *** imply significance at the 0.10, 0.05 and 0.01 probability levels respectively.

Table A.1: Results for the Maize Price and Net Hourly Returns Equations

	Maize Price	Natural Log of Returns to Forest Use	Natural Log of Returns to Wage-work	Natural Log of Returns to Self-employment
Constant	*** 2.57	0.24	0.41	*** 3.94
	(0.85)	(1.00)	(0.51)	(0.93)
AGE		*** -0.65	* 0.22	** -0.36
		(0.21)	(0.12)	(0.17)
ETHNIC		----	* -0.55	** -0.99
			(0.28)	(0.45)
FHH		*** -3.49	*** -1.39	*** -1.16
		(0.99)	(0.26)	(0.34)
FHH*AGE		*** 0.87	----	----
		(0.29)		
FARMSIZE		----	----	** -0.71
				(0.28)
FTOOL		* 0.31	----	----
		(0.16)		
IRON	*** 1.25			
	(0.31)			
MEALS	0.39	*** 0.94	----	----
	(0.40)	(0.37)		
SCHOOL		----	** 0.21	----
			(0.09)	
VILL2		* -0.63	----	** -0.91
		(0.34)		(0.36)
VILL3	0.39			
	(0.44)			
N	27	75	59	41
Imputed	3.64	1.70	2.52	2.49
	(0.79)	(2.10)	(3.21)	(2.69)
Observed	3.84	1.83	3.01	2.46
	(1.18)	(2.22)	(3.93)	(2.78)
R^2	0.58	0.35	0.50	0.37

Note: *, ** and *** imply significance at the 0.10, 0.05 and 0.01 probability levels respectively.

[1] Analysts often use the terms forest decline, deforestation and forest degradation interchangeably. There do not appear to be universally accepted definitions, but we here make the following distinctions. Forest decline is deforestation and/or forest degradation. Forest degrading activities are (1) forest clearing and (2) forest product extraction, and imply a temporary or permanent forest cover loss in the long-run. Deforestation differs from forest degradation by degree, a more permanent loss of forest cover over a larger area.

[2] Initial sample size was 110 households, reduced over the year primarily as a result of respondents' deaths.

[3] Encroachment, which has been reported in the state forest reserve, is somewhat more pronounced in villages further away from Forestry Department headquarters (de Gabrielle 1999).

[4] Rural dwellers rarely use charcoal, but there is considerable demand for it in urban areas. Urban dwellers find charcoal more convenient to use than firewood. In addition, transport costs for charcoal are 50-60 percent lower than for raw wood (Knacck Consultants 1999).

[5] Maize, the staple crop in Malawi, accounts for 85 percent of total cropland. It is often grown in rotation or association with legumes, groundnuts and other crops (Blackie et al. 1998).

[6] Over time forest "thinning" may increase the probability of forest clearing, as thinning in the presence of population growth reduces the value of standing forest.

[7] If households had secure rights over forest resources, which they do not, higher p_F would mean higher current and future values of land and the effect on L_F today would be indeterminate.

[8] The system includes total labor endowment (T), but since dependent variables are expressed as labor shares, T is simply one for all households and therefore excluded from the regressions.

[9] There are some shortcomings associated with the use of predicted prices when prices are not directly observed. From a technical standpoint, this introduces errors in measuring these explanatory variables. A theoretical shortcoming is that the predicted price is not necessarily the reservation price that makes the household indifferent between engaging in an activity or not. There is a growing literature on how to handle this "missing data" problem (e.g. Heltberg et al. 2000; Chen and Lee 1998), but generally the solutions are computationally complex and beyond the scope of the present paper.

[10] The constraints (14a) through (14d) ensure that the predicted labor shares sum to one, but do not ensure that predicted values for individual labor shares fall within the (0, 1) range. Predicted labor shares for forest and maize fall within bounds for all observations. Predicted labor shares fall below zero for two observations (wage-work) and nine observations (self-employment).

[11] Although the number of sample households reporting purchases of forest products is greater than that reporting sales (see Table 2) the number of households selling wood is likely underestimated in the sample since sales of wood taken from the commons or state forest reserve are prohibited in villages 1 and 2.

[12] While our discussion suggests that wealth endowments condition activity choice, it could also be argued that activity choice is a determinant of wealth accumulation. Although we recognize that wealth is usually endogenous to wages, we note that endogeneity may be less of an issue for the sample data since we observe iron sheet roof ownership prior to the labor allocation decision.

[13] We also used a Heckman-Lee two-stage approach (Heckman 1976; Lee 1982). For the final imputations we made the decision to use sub-sample OLS rather than the Heckman-Lee approach for three reasons. One, the inverse Mills ratio was not statistically significant in any of the equations which may suggest that sample selection bias is not an important issue here. Two, evidence from Monte Carlo experiments that sub-sample OLS performs well to the Heckman-Lee approach (MSE criterion) when the sample size is small (Zuehlke and Zeman 1991). Finally, use of the Heckman-Lee approach would imply the need to include four additional explanatory variables (the estimated inverse Mills ratios) in the labor supply equations.

[14] Quality differences may also be a factor as Malawians generally prefer flint to dent maize varieties.

[15] Rural Malawians often do not know their hourly wage. Many forms of wage-work are on a contractual basis, the employee being paid (in cash or kind) for completion of a task, e.g. agricultural contract work. Likewise, the self-employed are paid for completion of a task or for providing a product or service; these business people generally do not know their "wage".

[16] As data are not available for total hours worked in all activities during the year, assumptions were made. We assume girls, boys and men worked 8 hours per day, 312 days per year. Women are assumed to work 10 hours per day, 312 days per year. An hour of girl or boy labor is valued at half an adult labor hour.

[17] Theory doesn't provide clear guidance on functional form. The log-linear specification is widely used (e.g. Abdulai and Delgado 1999; Alderman et al. 1996; Lucas 1977).