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**On- and off-farm labor decisions by slash-and-burn farmers in Yucatan (Mexico)**

**by**


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# On- and off-farm labor decisions by slash-and-burn farmers in Yucatan (Mexico)

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**Abstract**

The availability of basic assets influences peasants' economic behavior, their livelihood diversification strategies and their responses to land degradation. In addition, when pressed by economic hardships households can also expected to work more than better off ones. Whether this implies more or less on- or off-farm labor supply is an empirical question. This in turn can have an asymmetric effect on poverty traps and the extent of forest clearing under slash-and-burn farming. This paper examines the determinants of labor allocation among forest based shifting cultivating households in two communities from Yucatan (Mexico). The effects of wage rates and structural socio-economic factors are tested for both farming household heads and other family members and their implications discussed. While the former seems to be bound by structural factors, the latter are very sensitive to labor market signals and show a negative elasticity to off-farm labor supply. This calls for providing specialized training and education programs to increase human and social capital for household heads in order to reduce pressure on forest land and to assist households to avoid poverty traps arising from the predicted falling wage rates due to post-NAFTA liberalization of rural labor markets.

**Keywords:** Deforestation, shifting cultivation, livelihood diversification, off-farm labor supply, Mexico

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# 1 Introduction

Peasant households make use of land and natural resources, their own labor, formal and informal financial assets and purchased inputs including hired labor, to generate flows of product and/or cash income. The availability of some of these basic assets influences peasants' economic behavior, their livelihood diversification strategies and their responses to land degradation and labor conditions outside the farm, such as wage rates. These relationships continue to be critical to peasant households in developing economies, as the incidence of rural poverty and inequality is generally not declining in Latin America, Asia and sub-Saharan Africa (de Janvry and Sadoulet, 2000). Increasing land degradation in fragile agroecosystems, unfavorable market conditions, and weak institutions in rural regions further increase the dependence of farm households on the rural non-farm economy for additional income opportunities. Given these trends, there is a resurgent interest in assessing the potential of rural non-farm employment (RNFE) as a means to sustain income levels by those peasant households without adequate farming livelihoods.[1]

There is a growing volume of empirical work assessing the scope of RNFE and farm households' livelihood diversification strategies in developing countries on poverty alleviation (Hassan and Babu, 1991; de Janvry and Sadoulet, 2000; *Special Issue in World Development v.29*, 2001; Davis, 2003) and inequality (Reardon et al., 2000). Estimates show that the share of income from RNFE is lowest in South Asia (29%) and largest in South/East Africa (45%) with Latin American farmers deriving 40% of income off-farm (Reardon, 1997; Reardon, Berdegué and Escobar, 2001; Ellis, 2000; Barrett, Reardon and Patrick, 2001). However, in terms of the percentage of rural workers employed in the RNFE sector, the trend reverses with 10% of the rural workers employed in the RNFE for Africa, 25% for Asia, and 35% for Latin America (Davis, 2003). While these regional trends attest to the livelihood diversification strategy of farmers, the evidence suggests that the poorer rural households tend to hold lower paid and more unstable non-farm jobs (Lanjouw and Lanjouw, 2001; Start, 2001; Reardon et al., 2001). Thus there appears to be a relationship between rural poverty, off-farm wages and the quality of off-farm employment.[2]

An increasing number of econometric studies have focused on the effect of RNFE opportunities on households' income levels. The analyses show that the determinants of RNFE for farmers engaging in low-input/low-yield agricultural systems in developing countries are of a different nature. For example, while demand-pull drivers reflect a 'positive adaptation' to new market opportunities by such farming households, distress-push drivers reflect immiserizing conditions on-farm (or a 'negative adaptation'). Education (Yúnez-Naude and Taylor, 2001), closeness to urban areas (Ferreira and Lanjouw, 2001), access to credits (Escobal, 2001), social capital (Zhang and Li, 2004) are all pull factors for farmers engaging in low-input agriculture. 'Push' factors instead reflect inadequate farm yields, land availability constraints and adverse natural phenomena such as draughts (Islam, 1997; Reardon et al., 2000; Lanjouw, 2001; Reardon et. al, 2001). Other analysts have instead focused upon the effect of changes in income on low-input farming households' labor supply decisions (e.g., Sahn and Alderman, 1988; Skoufias, 1994; Ruben and van den Berg, 2001).

However, existing studies of off-farm employment decisions of poor rural households have paid insufficient attention to how the state of the natural resource base for farming (e.g., soil fertility) may influence these labor allocation decisions, thus possibly biasing any wage effect on labor decisions. This is surprising for two reasons. First, the state of the soil resource and its impact on a peasant household's labor returns from farming could be a key push factor driving poor rural households to participate in the RNFE. Second, when the "push" factor of declining soil fertility and land degradation is omitted from the analysis, it may possibly bias the influence of off-farm wages on the household's decision to allocate labor to RNFE. In this paper we pay special attention to the effect of the quality of land for cultivation in the labor allocation decisions of rural households.

This analysis also has important implications for any natural resource management policies that may influence the level of soil fertility and land degradation faced by farmers. Of particular interest are complex low-input low-yield agricultural systems, such as slash-and-burn (shifting cultivation) in the tropics, where high poverty levels and increased pressure on forest resources combine to affect fallowing periods and the regeneration of soils on converted cropland. Additional policies may be needed to assist both forest conservation and poverty alleviation through providing increased RNFE opportunities. However, which policies are adopted are crucially determined by the relationship between declining soil fertility in slash-and-burn agriculture and the willingness of shifting cultivation households to supply labor to off-farm activities. Interestingly, very few existing studies that focus on the role of off-labor and income diversification strategies by these households examine the corresponding effects on resource management and land degradation. Bluffstone (1995) shows that the existence of off-farm employment opportunities, even with low wages, leads to improved management of open access forests in Nepal. In a more descriptive conceptual model, Scatena et al. (1996) contend that shifting cultivating farmers' choice of the length of forest fallows in the Brazilian Amazon depends on RNFE conditions. More recently Shively and Pagiola (2004) find that the rate of deforestation in upland areas of the Philippines has declined by increased labor substitution from forest clearing based farm activities to off-forest labor activities that have higher returns.

This paper focuses on-farm and non-farm labor decisions by forest-based shifting cultivating households from Yucatan (Mexico). Besides the importance of soil quality and the forest resource base for slash-and-burn agriculture the surveyed farming households in the study area routinely allocate their labor to non-farm employment (RNFE) based on income and subsistence considerations. In addition, this is an area of widespread and persistent rural poverty amidst rapid liberalization of labor markets across Mexico as a result of the North American Free Trade Agreement (NAFTA). Thus the study area in the Yucatan is an ideal site for examining the main determinants of the links between resource quality, household labor allocation to off-farm employment and rural poverty.

Results show that these links have significant, heterogeneous effects on both the wages and the non-farm labor supply by household heads and other household members. Thus we cannot reject the hypothesis that the state of the natural resource base for slash-and burn farming (e.g., soil fertility and the state of the forest) may influence both the labor allocation decisions of the surveyed Yucatan households and any wage effect on their labor decisions. Moreover, we find that, while household heads' off-farm labor choices are relatively insensitive to small changes in wage rates, other family members display negative own-wage off-farm labor supply elasticities. The latter effects are sufficiently large that, for households on average, the aggregate off-farm labor supply schedule is backward bending. These findings indicate that there may be a role for specialized training and education programs to increase human and social capital for household heads in order to reduce pressure on forest land and to assist households to avoid poverty traps arising from the predicted falling wage rates due to post-NAFTA liberalization of rural labor markets.

The paper is organized as follows: The next Section develops the econometric household labor allocation model relating RNFE, poverty and land use change in slash-and-burn forest based agroecosystems. Section 3 describes and contextualizes the data used in the estimations and section 4 presents the empirical results. The last section concludes and offers some policy recommendations.

## 2 Model and estimation issues

### 2.1 The Model

Existing studies on-farm households' labor allocation decisions in developing countries tend to estimate the determinants of market and non-market labor supply decisions under absent or constrained off-farm wage employment due to fixed transaction costs or age/gender rationing (Jacoby 1993; Skoufias, 1994; Sadoulet, de Janvry and Benjamin, 1998; de Janvry and Sadoulet, 2001), agricultural seasonality (Olfert, 1993; Skoufias, 1996), stochastic events such as rainfall (Fafchamps, 1993; Rose, 2001), and imperfect substitutability between market and non-marketed goods in consumption by subsistence farmers (Khan, 1995). These models are empirically estimated by randomly surveying households that engage in subsistence farming and those who also participate in local off-farm labor markets. The standard procedure is generally to use a semi-reduced form of labor supply by first estimating the marginal revenue product of farm labor that is treated as the implicit farm demand wage. Others have estimated the determinants of RNFE participation and supply using reduced form equations (Acharya, 1998; Abdulai and Delgado, 1999; de Janvry et al., 2001; Mathse and Young, 2004).

Here we are interested in estimating both on- and off-farm labor supply decisions. Our general approach is based upon the behavioral labor allocation model by Huffman and Lange (1989). The conventional method in such labor-supply models is to consider the two-adult (usually husband and wife) nuclear household as the unit of analysis while treating the labor supply decisions of other family members as exogenous (e.g. Rosenzweig, 1980; Sahn and Alderman, 1988; Jacoby, 1993; Skoufias, 1994; Abdulai and Delgado, 1999). Here a distinction is made between time allocations of the head of the household (HoH) and the rest of the household (RoH), where the latter is restricted to members between the ages of 15 and 64, thus the other active (in working age) adults.

It is assumed that a sufficient degree of consensus exists between the household head and other household members so that the household's welfare function exists. By framing labor allocation decisions in terms of household utility, based on combined family income and leisure, rather than in terms of individual utility, we preclude any notion of conflicts in intra-household resource allocation decisions. This assumption seems to hold generally for the surveyed peasant farming households in the Yucatan.

The problem of each household is to choose the labor allocation by the HoH and a representative member of the RoH that maximize the household's utility over time:

$$W = \max_{F_j, M_j} \sum_{t=0}^{\infty} \rho^t U(c_{st}, c_{ct}, l_t; \mathcal{P}, \pi_c) \tag{1}$$

for $j = 1$ (HoH) and $j = 2$ (RoH) and where $t$ represents time and the discount factor is given by $\rho = 1/(1+r)$ for a periodic discount rate, $r$. Household consumption is represented by $c_s$ and $c_c$. They are the households' staple consumption and non-food consumption goods, respectively. The household's aggregated leisure is given by $L$. The leisure term is not just related to pure leisure, as in standard wage-earning consumer household in a developed economy, but also to the use of time for various livelihood support activities (e.g. cooking, fuelwood collection and hunting). Given the heterogeneous nature of this variable we decide to aggregate it. Utility is also affected by taste shifters: $\mathcal{P}$ stands for the level of poverty of the household and $\pi_c$ is a vector of exogenous household characteristics that affect utility via household tastes. The household allocates $F = \sum_j F_j$ time to farming and $M = \sum_j M_j$ to RNFE. It can also hire $H$ amount of labor for farming. In addition, based on the evidence from our Yucatan study area, we assume competitive markets for farm outputs, inputs and labor.[3]

The household thus faces a binding time constraint expressed as:

$$T_t = L_t + F_t + M_t \tag{2}$$

with a non-negativity constraint in terms of participation in on- and off-farm work $F_{tj} \geq 0$ and $M_{tj} \geq 0$ for $j = 1, 2$ in a given year $t$.

The technology of farm production is represented by a twice differentiable and continuous production function with labor and soil fertility as inputs:

$$z_t = f[F_{tj}, H_t, q_t; \pi_z] \tag{3}$$

where $z$ and $q$ are crop output and soil quality, respectively. The household's characteristics affecting crop decisions are reflected in vector $\pi_z$. Income comes from a variety of sources that include the net return on the farming operation, non-farm labor revenues and income transfers. The household's income constraint is in turn specified as:

$$p_{ct}c_{ct} + p_{st}(c_{st} - z_t) \;=\; w_{mjt}M_{tj} - w_{ht}H_t + e_t \tag{4}$$

where $w_H$ is the hired labor wage rate, $w_{mj}$ is the RNFE wage rate and $p_s$ and is $p_c$ are the unit price of the food and composite good, respectively; $e$ refers to non-labor income.

There is an additional asset accumulation constraint that reflects the evolution of land quality for cultivation:

$$q_{t+1} - q_t = g(F_t, H_t, q_t; \pi_q) \tag{5}$$

where $\pi_q$ is a vector of exogenous biophysical elements that parameterize the evolution of land quality under forest based shifting cultivation.

One prevalent characteristic of shifting cultivation in Yucatán is that land is held as 'ejido', a well established common property land tenure institution in tropical Mexico and the Yucatan Peninsula in particular, besides the land-tenure reforms that started in 1992.[4] The land tenure reforms have not led to large-scale transfers of land ownership from ejido members to nonmembers in forested areas of Mexico (Barbier, 2002; Pascual, 2005) This implies that a competitive market for land allocation, and therefore for soil quality does not exist in shifting cultivation communities in the area of study. Therefore, the necessary condition of complete markets for attaining the recursive property of standard agricultural household models for time allocation is precluded (Singh, Squire and Strauss, 1986; Sadoulet and de Janvry, 1995).

However, the non-recursive feature of the household's complete resource allocation decision is not a major obstacle for the main purpose of our analysis, which is not dependent on the full solution of the time allocation decision of the household. Here we are more interested in estimating the joint labor supply decisions by the head of the household (HoH) and the rest of the household (RoH), and on the linkages between resource quality, RNFE labor allocation and poverty. Thus, we can simplify the household's allocation decision considerably by imposing an assumption on the intertemporal structure of the labor supply model. Adapting the approach of MaCurdy (1981) we assume that the observed level of soil quality in the household's farm is equal to that in the long run, i.e., $q_{t+1} = q_t$ so that $g(\cdot) = 0$. By adopting this assumption, the model now becomes recursive (see Appendix)

Depicting long run values with an asterisk, $q^* = q(F^*, H^*; \pi_q)$. The new long-run production function becomes: $z^* = f[F^*, H^*, q(F^*, H^*; \pi_q); \pi_z]$, or in reduced form:

$$z^* = f(F^*, H^*; \pi_z, \pi_q) \tag{6}$$

A system of long-run labor input demand equations which do not depend on the preference structure of the household is given by:

$$f_{F_j^*} - \frac{f_{F_j^*} g_q}{g_q - r} = \frac{\gamma}{\lambda p_s} = \frac{w_{mj}}{p_s} \tag{7a}$$

$$f_{H^*} - \frac{f_{H^*} g_q}{g_q - r} = \frac{w_H}{p_s} \tag{7b}$$

Equations (7a) and (7b) represent optimal on-farm family ($j = 1, 2$) and hired labor demand functions, respectively. Ideally, both equations would need to be solved jointly for optimal farm labor allocation, ($F_j^*$, $H^*$), based on-farm technical efficiency shifters, $\pi_z$, and slash-and-burn agroecological characteristic variables (e.g. soil quality, forest tree structure), $\pi^q$. The on-farm labor demand functions for household member $j$ becomes:

$$F_j^* = F_j^*(w_{mj}, p_s, \pi_z, \pi_q, H^*, F_k^*) \tag{7a'}$$

for $k \neq j$, thus the HoH's farm labor allocation depends on the RNFE wage rate, soil quality and production shifters as well as on the RoH's and hired farm labor. We estimate $F_j^*$, for the HoH and RoH jointly. As positive labor hours in slash-and-burn by the HoH are always observed, while only a fraction of RoHs may allocate some labor on-farm. The Nelson and Olsen (1978) model, later adjusted by Maddala (1983), to estimate a simultaneous equation model with a continuous ($F_{HoH}^*$) a censored ($F_{RoH}^*$) endogenous variable. [5]

In turn, allocation of hired-in labor depends on $F_j^*$:

$$H^* = H^*(w_h, w_{mj}, p_s, \pi_z, \pi_q, F_j^*) \tag{7b'}$$

Since not all households are assumed to hire labor the Heckman (1979) model to estimate equation (7b'). Once optimal shifting cultivation input levels are obtained, optimal non-farm labor supply can be estimated using the predicted labor inputs as exogenous covariates. The underlying procedure is the following: using the cash-income constraint (4), along with the crop production (6) and the input demand equations (7a', 7b'), the income function is restated as $y^*$:

$$y^* = p_s z^* + \sum_j w_{mj} M_j^* - w_H \hat{H}^* + e \tag{8a}$$

where the *'hat'* is a predicted optimal value. The predicted income level ($\hat{y}^*$) will be above or below a poverty line. The income poverty index, $\mathcal{P}^*$, used here is given by the poverty gap in relation to the extreme poverty line, thus it is a continuous variable that can take positive and negative values. Under optimal levels of farm and non-farm labor allocation, it follows that the income determination function is represented by a reduced-form equation containing all the exogenous parameters:

$$\mathcal{P}^* = \mathcal{P}(\pi_c, \pi_z, \pi_q, w_m, p_s, p_c, e_j) \tag{8b}$$

By jointly solving the first order conditions of the maximization problem (equations A4–A8 in the Appendix) and recalling equation (8b), the household's demand equations for the utility yielding commodities ($i = c_{st}, c_{ct}, l_t$) can be obtained:

$$d_i^* = d_i^*(p_s, p_c, w_m, T, \mathcal{P}) \tag{9}$$

and substituting equations (7a', 7b') and (9) into the time constraint (2), the RNFE allocation equation for member $j$ is given by:

$$M_j^* = T_j - F_j^* - l_j^* = S_{M_j}(F_j^*, w_{mj}, p_c, p_s, T, \mathcal{P}) \tag{10}$$

We are interested in ascertaining the extent and direction of the link between income poverty ($\mathcal{P}$) and RNFE ($M_j^*$). Since $M_j^*$ is naturally censored from below at zero, the simultaneous determination of both variables follows the adjusted Nelson-Olsen model. Theory does not provide firm predictions for the coefficients of variables in structural labor supply equations. Hence the effect of wages, non-labor income, farm labor and poverty levels need to be determined empirically.

### 2.2 Further estimation issues

When the market wage, $w_{mj}$, of household member $j$ is greater than its reservation value in terms of farm time, $w_{rj}$, a positive number of hours in RNFE will be observed for that member (Killingsworth, 1983). Observed RNFE wages are assumed to depend on human capital ($\pi_{mj}$). In order to estimate $w_{rj}$ when $M = 0$, equation (10) is employed in order to solve for $w_{mj} = w_{rj}$. It follows that $w_{rj}$ is determined by production shifters, i.e., household characteristics affecting labor productivity ($\pi_z$), such as farming experience and farm characteristics. In traditional slash-and-burn farming with negligible use of physical capital, labor productivity is proxied by the level of technical efficiency, which in turn is determined by both socio-demographic characteristics and the agro-ecological conditions of the farm plot (Pascual, 2005). Technical efficiency in farming is given by $\theta_j = \theta(\pi_{zj}, \pi_q)$. In addition, utility taste shifters, $\pi_c$, are assumed to influence the effect of on-farm labor productivity on $w_{rj}$ (Huffman and Lange, 1989). It follows that the reservation and RNFE wage rate equations are given, respectively, by:

$$w_{rj} = w(w_h, w_m, p_c, p_s, e_j, \theta_j, \pi_{cj}, T) + u_{rj} = \gamma_r \eta_{rj} + u_{rj} \tag{11a}$$

and

$$w_{mj} = w(\pi_{mj}) + u_{mj} = \gamma_m \eta_{mj} + u_{mj} \tag{11b}$$

where $\eta_{rj}$ and $\eta_{mj}$ are the vectors of exogenous variables that determine the productivity of farm labor and the potential market wage through human capital, $\pi_{mj}$, respectively. The random disturbance terms for the sample population are given by $u_{rj}$ and $u_{mj}$; $\gamma_m$ and $\gamma_r$ are the parameter vectors to be estimated.

Equations (11a–11b) lead to the specification for the RNFE participation decision by defining a dichotomous variable, e.g., $x_j$:

$$x_j^* = \begin{cases} 1 & \text{if } M_j > 0 \\ 0 & \text{if } M_j = 0 \end{cases} \tag{12a}$$

It follows that

$$Pr(x_j^* = 1) = Pr(w_{mj} - w_{rj} > 0) = Pr(u_{rj} - u_{mj} < \gamma_r \eta_{rj} - \gamma_m \eta_{mj}) = \Phi(\gamma \eta_{rj}) = \Phi(p_c, p_s, e_j, \theta_j, \pi_{mj}, \pi_{cj}, T) \tag{12b}$$

where, $Pr(\cdot)$ is the probability of RNFE participation occurring, i.e., $\gamma\eta_j = \gamma_r\eta_{rj} - \gamma_m\eta_{mj}$, and $\Phi$ is the cumulative distribution function for the random variable $v_j = u_{rj} - u_{mj}$. Equation (12b) says that the probability of a household member participating in RNFE depends on all the exogenous variables in equations (11a–11b). The variables that improve the reservation wage, reduce the likelihood of RNFE participation. Conversely, variables that raise off-farm wage, increases this likelihood. *A priori* variables that increase both the reservation and the market wage have uncertain effects on the probability of engaging in the labor market. The decision to participate in RNFE is estimated using (12b), in order to then estimate the shifting cultivating household's on- and off-farm labor decisions.

We assume that once the participation decision is reached, households are not restricted on the hours supplied off-farm. However, information on $w_{mj}$ is only observed for those who participate in RNFE ($x_j^* = 1$). In order not to suffer from non-random sampling selection bias (by disregarding the subsample for which $x_j^* = 0$) non-working household members' hedonic wage rates are predicted by instrumented human capital potential. The hedonic $\hat{w}_{mj}$ is estimated following the Heckman model and is then used as a covariate in all labor allocation equations. While the HoH's RNFE wage rate information was given by the respondents directly, the average RoH's hourly $w_m$ is calculated by dividing total RNFE earnings to total hours worked in that activity. As any error in hours worked now becomes inversely related to the estimated wage rate of the RoH, the off-farm labor elasticity is biased towards minus one. To correct for this possible simultaneity bias, the RoH's predicted wage rate is used as suggested by Sahn and Alderman (1988). Thus, the hedonic RNFE wage for member $j$ takes the form:

$$w_{mj} = \alpha\eta_{mj} + \sigma\lambda_j + \epsilon_j \tag{13}$$

where $\lambda$ is the standard Inverse Mills Ratio (IMR). We use the predicted $\hat{w}_{mj}$ for household members not participating in RNFE in all labor equations. Further, the wage equation (13) includes variables excluded from the hours equation so that the predicted wage is not perfectly collinear with the regressors in the hours equation (10). Hence we include dummy variables that distinguish between job types. Since there is no theoretical reason justifying the inclusion of job dummies, they are excluded from the hours equation.

# 3 Case study and data and description

The data used in the empirical analysis were obtained through household and agronomic surveys from the municipality of Hocaba, in the henequen (sisal) zone of Yucatan, Mexico, between 1998-99. In 1998 there were 1035 households living in the municipality, 60% of which were actively engaged in shifting cultivation, the primary farming method in the region after the decline since the beginning of the 20th century and final collapse of the henequen industry in Yucatan in the early 1990s (Lutz, Prieto and Sanderson, 2000). The data corresponds to 74 households (12% of all shifting cultivating households) randomly selected from a complete sampling frame of the two villages or communities of the municipality: Sahcaba and Hocaba. Structured interviews were conducted with household heads, generally the eldest fit male in the family, and his spouse. This provided information on household demographics, detailed land use activities, on- and off-farm labor allocation and non-land asset holdings in relation to 1998.

The climate of the region has determined a rainfed agroecological system based on the utilization of tropical dry deciduous forest in a slash-and-burn system locally known as *roza-tumba-quema* or *milpa*, to grow maize in very much the same way as described by the first Spanish chroniclers of the 16th century (Lutz et al., 2000). Maize harvests are around 300kg/ha, with households clearing about a hectare of newly cleared forest land every year. The meagre yields are due to the structural characteristics of the soil which is mostly shallow and rocky but also due to the demographic pressure (about six households/km$^2$) on the forest biomass, the critical asset in the traditional milpa, which is relatively high and reflected by the short fallow periods averaging 15 years (Pascual, 2005).

Rural Mexico, and Yucatan in particular, is undergoing significant changes given recent market liberalizations in the post-NAFTA era. On-going liberalization of the food, labor, and land markets is particularly significant in the Yucatan, which in turn is expected to affect small-scale farmers' labor and land use decisions (Deininger and Minten, 1999; Barbier, 2002; Yúnez-Naude, 2002). While NAFTA market reforms may be a contributing factor for the reduction in rural wage rates between 1994-2001 across Mexico (Lederman, Maloney and Serven, 2003), small diversified farmers are experiencing a long-term trend of decreasing real permanent income (Salas, 2001). In addition Yucatan is one of the poorest states in Mexico, and deforestation rates are among the highest in the country (Deininger and Minten, 1999).

Households in the municipality of Hocaba, including the communities of Hocaba and Sahcaba, consist of around five members. 21% of the surveyed households had income below the poverty line of $2,376 *per capita per annum* (pcpa), or US$258 pcpa at 1998 prices and corrected for Rothbarth's () adult equivalency index. [6] While the imputed income share from the maize harvest is just 10% of total household income, this is key to households' food security. Also, most households obtained the lump-sum PROCAMPO subsidy for farming (Mex$650/ha) to buffer the social cost arising from the liberalization of the food market following the NAFTA agreement. The rest of household income derives mostly from off-farm activities (66.2%). This is higher in the smaller community of Sahcaba, 80.2%, than in Hocaba, 60.3% (Table 1).[7] This share is higher than the 55% share reported by de Janvry and Sadoulet 2001 for ejido households across all of Mexico,. It is also significantly higher than the 40% estimate for Latin America as a whole (Reardon et al., 2001).

About 78% of surveyed households obtained more than half of their income from off-farm activities, similarly to the figure reported for all Mexican households by de Janvry and Sadoulet (2001). However, in contrast to the finding by de Janvry and Sadoulet (2001), but consistent with the evidence found in other Latin American countries (Reardon et al., 2000), the off-farm income share increases with total income. Additionally, 59% of the heads of households (HoHs) and 65% of the remaining adult household members (RoHs) supplied some positive hours in RNFE. The average hourly earnings for working HoHs and RoHs are $6.67/hour and $5.26/hour respectively, with 70% of HoHs and 20% of RoH obtaining wage rates below the official minimum wage rate of $3.4/hour.

While all heads of households were engaged in shifting cultivation, only a third of remaining adult household members reported contributing on-farm labor. 40% of households hired additional farm labor, often to help overcome labor shortages during the forest-clearing season. Table 1 presents definitions and sample statistics of the variables used in the labor supply empirical analyses. Factors that are specific to the head of a household (HoH) and a representative adult member of a household (RoH) include education and age. More general household attributes include household size, the number of children, the dependency ratio and non-labor income. The level of education may indicate productivity potential on- and off-farm. The household's village (Sahcaba or Hocaba) may also be a determining factor in off-farm work decisions and wage determination since it can reflect local labor market conditions (Abdulai and Delgado, 1999). The exogenous biophysical factors include the household's amount of forest area cleared for cultivation, the forest vegetation fallow period and the structure of this vegetation.

[TABLE 1 around here]

# 4 Empirical results

## 4.1 Participation in RNFE:

Table 2 shows the results of the estimated determinants of RNFE participation (equation 12b). The hypothesis that this participation decision is jointly made by the HoH and the RoH is strongly rejected by the data and hence we apply independent dichotomous choice models for the HoH and the RoH.[8]

[TABLE 2 around here]

The results suggest that the likelihood of participating in the RNFE sector by the HoH is higher in Hocaba, which is expected given that this village is the bigger than Sahcaba and has better road links to Mérida (the capital and main labor market). Although the participation in RNFE by RoH is lower for residents of Hocaba, this result may be due to incidental truncation in the sample of RoHs remaining in Hocaba, as the survey reveals that those better suited for off-farm labor permanently migrate and are not then considered household members. The data also suggest that younger household heads are more likely to participate in RNFE, whereas illiteracy (for HoH) and low levels of formal education (for RoH) decrease the likelihood of being employed off-farm. This finding is consistent with most of the literature on off-farm employment and education (Yang, 1997) as well as with studies for rural Mexico (Pagán and Sánchez, 2000; de Janvry and Sadoulet, 2001; Yúnez and Taylor, 2001). An additional year of schooling by the RoH increases the likelihood of employment by 5.5%[9] In addition, whereas the number of infants in the household does not affect having off-farm employment, the number of children aged 6 to 16 affects positively the likelihood of off-farm labor participation by household heads. Lastly, private ownership of land appears to discourage participation by the HoH but not by the RoH. As private land in the study area is used mainly to raise cattle, this time-consuming activity may influence the RNFE participation decision of household heads considerably.

## 4.2 Hedonic wage functions:

Table 3 presents the results of the estimated equation (13) using the Heckman model with the standard errors being corrected using White's formula. The dependent variable is the log of the wage rate in the RNFE. The low significance level of the Inverse Mills Ratio in both regressions suggests that sample-selection bias is of relatively minor concern. The data indicates that older members obtain lower wages and that households that own land (DUMPRV) enjoy higher wages. Nevertheless, this effect is reduced by the amount of owned land (PRVLAND) as the few landowners possessing more land reap short-term low returns from being self-employed in cattle raising. Technical efficiency in farming is positively (though weakly) related to wage rates, possibly suggesting that farming efficiency is correlated with latent human capital that increases off-farm returns. Household heads that work as builders (DUMHoHBU), are self-employed (DUMHoHSE) or are employees in other sectors (DUMHoHEM) command higher wages than those employed in non milpa agricultural activities (e.g., henequén cashcrop production and cattle raising). Similarly, other adult members of households working in a non-agricultural salaried job (DUMARRoH) can expect to earn 63% more than if self-employed.[10] Interestingly, the expected negative effect of illiteracy on RNFE wage rates appears to be statistically insignificant.

[TABLE 3 around here]

### 4.3 labor supply in slash-and-burn farming:

Table 4 presents the results of the Nelson-Olsen model of the determinants of slash-and-burn labor use by heads and non-heads following equation (7a'). Table 5 shows the corresponding results of the hired labor demand equation (7b') which uses the predicted family members' optimum shifting cultivation labor allocation as covariates.[11] Also note that predicted hedonic wage rates are employed as regressors.

[TABLE 4 around here]
[TABLE 5 around here]

Household heads' labor allocation in slash-and-burn farming is not determined by their RNFE wage rates, possibly due to the already very low market wage rates offered to them in the RNFE sector (i.e., 70% of household heads receive a lower wage than the official minimum wage). Also, under our assumption of a competitive labor market in the municipality, the hedonic wage rate associated with RNFE occupation will reflect automatically farm labor productivity.[12] The household head's farming labor supply is determined by household demographic characteristics, land tenure, and whether the household benefits from the PROCAMPO subsidy.[13] However, HoH farm labor supply is not determined by agroecological factors (VFALLOW, VMONTE).

Household heads in nuclear families allocate more on-farm labor than HoHs from extended households, possibly reflecting lower family labor availability in the former. Additionally, having more infants in the family exerts a positive effect on farming labor hours, which may indicate that slash-and-burn farming is important as regards to overall household food security. Household heads not farming on common property land supply less time for shifting cultivation reflecting the competing time demands in owned land due to cattle raising.

As regards the supply of shifting cultivating labor by other adult household members, this supply is sensitive to their own off-farm wage rate and that of the household head (Table 4). It is interesting to note that RoHs have a positive, inelastic on-farm labor supply with respect to the own RNFE wage rate (0.77). Furthermore, the RoH has a negative cross-wage labor supply (-0.60) and a negative elasticity (-0.80) with respect to the head's on-farm labor supply (SCLHoH). These results suggest that the RoH's farming labor is a substitute for the household head's on-farm labor, and that other adult household members will reallocate their on- and off-farm labor depending on market conditions faced by heads of households in the RNFE sector. In addition, RoHs will allocate more labor to shifting cultivation when the plots being cleared have remained fallow for some time (VFALLOW). The reason is possibly the need for more labor to clear longer fallow and thus more mature forests. Also, when the area of the converted forest plot increases, the household head increases farm labor relatively less than other family members. This is possibly due to the already higher commitment by heads to farming. Finally, on-farm labor allocation by the RoH increases with the number of adult active members (SIZERoH) and with the proportion of active adult males (PMENRoH).

As regards the decision to hire farm labor, the hypothesis of no sample selection cannot be rejected by virtue of the insignificant inverse Mills ratio coefficient. Hired labor seems to be a substitute (complement) for the HoH's (RoH's) on-farm labor supply, the elasticities being -0.72 (0.27). These results suggest that hired labor is used when the HoH's on-farm labor time constraint is binding. The data also indicates that the decision to hire labor is positively determined by the RoH's off-farm wage rate and indicates that cash availability is key to be able to hire laborers. Besides family labor availability, the main determinant of hiring labor in slash and burn is the availability of laborers in the community. Households who delay (DUMDELAY) the first farming operation in the year (forest clearing), due to their participation in off-farm employment, hire less labor. This confirms the perception from the survey that households may have faced a shortage of hired labor available locally.[14]

### 4.4 labor supply in the RNFE sector:

Table 6 presents the elasticity parameter estimates of the off-farm labor supply equation (10), based on the information from the on-farm labor allocation decisions. Rather than estimating a reduced form equation (e.g., Acharya, 1998; Abdulai and Delgado, 1999; Mathse and Young, 2004) we estimate the structural equation which allows the estimated parameter elasticities to be directly interpreted. Moreover, the determinants of the continuous RNFE decision and the level of income and thus poverty are simultaneously estimated. Given the censored nature of off-farm labor supply, and the continuous income-poverty gap index, the Nelson-Olsen procedure is applied.

[TABLE 6 around here]

The results indicate that the effect on the hours supplied of own wage rates is different between the HoH and RoH. While the former is largely insensitive to their own wage rate (WHoH), indicating that they are bound by structural rather than marked factors in their labor supply decisions, RoHs face a negative and highly elastic RNF labor supply (-4.81). This result supports various studies that have tried to explain the mounting evidence of backward-bending off-farm labor supply (long hours of work at low wage levels) by the rural poor in developing countries. Following the seminal work by Berg (1961) the most common interpretation is that labor choices by the poor are dominated either by specific household constraints on their labor allocation or by the unwillingness of households to supply additional labor once the minimum level of subsistence and needs are satisfied (Miracle and Fetter, 1970; Barzel and McDonald, 1973; Sharif, 1991; Hernández-Licona, 1996; Creedy, 1997; Dessing, 2002).The large negative elasticity estimate in the sample of RoHs may reflect households' vulnerability to hardship and their lack of options but to increase their supply of off-farm labor. This could be interpreted as a strong utility premium to avoid falling below a subsistence threshold given low wages.[15]

Coupled with the positive and inelastic on-farm labor supply elasticity of the RoH (Table 4), it suggests that the RoH reallocates time from the farm to the RNFE when wage rates fall. Furthermore, there is an asymmetric intra-household wage effect as regards RNFE, i.e., $\frac{\partial M^*_{HoH}}{\partial \hat{w}_{RoH}} > 0, \frac{\partial M^*_{RoH}}{\partial \hat{w}_{HoH}} < 0$. Moreover, if the HoH's wage fall by 1%, the RoH is expected to increase on- and off-farm labor use by 0.6%, and 0.5%, respectively.

A trade-off between on- and off-farm labor by the HoH and RoH appears to exist by virtue of the negative non-farm labor elasticity parameters with respect to on-farm labor. Thus, $\frac{\partial M^*_{HoH}}{\partial F^*_{HoH}} < 0$ and $\frac{\partial M^*_{RoH}}{\partial F^*_{RoH}} < 0$. The HoHs' RNF labor supply is elastic ($-2.09$), while the NRF labor by the RoH is inelastic ($-0.45$) with respect to their effort in slash-and-burn. Furthermore, $\frac{\partial M^*_{HoH}}{\partial F^*_{RoH}} > 0, \frac{\partial M^*_{RoH}}{\partial F^*_{HoH}} > 0$, the former effect being inelastic and the latter close to being unitary elastic. Together these estimates suggest a marked intra-household division of labor. Lastly, as expected non-earnings income (NONLAB) negatively affects farming hours for both the HoH and RoH.

Table 7 presents the summary of all wage elasticities, including 'leisure'. It can be observed that there is not a statistically significant effect of own-wages on time allocation by household heads. This suggests that, given the low wage variability and the heads' prevalent role in slash-and-burn, they are structurally bound to their labor allocation decisions. However, their time allocation is affected, among other things, by the wage enjoyed by other adult household members. If this increases, household heads increase labor in off-farm activities by substituting away from leisure while keeping farm labor unchanged. On the contrary, RoHs are on average sensitive to their own off-farm wage levels and to those paid to the household head. When the average wage of RoHs falls, they increase their labor supply to the non-farm sector by substituting away from both farm labor and leisure. Further, if the head of the household's wage falls, RoHs supply more labor both off- and on-farm, and substitute away from leisure time.

[TABLE 7 around here]

Finally, Table 6 indicates that the latter measure of household poverty (PL1GAP) has no statistical effect on the RNFE decision by household heads but does affect negatively the non-farm labor decision by other household adult members. On average and after controlling for the wage effects, poorer households appear overall to supply less RNFE labor. Although it would be interesting to estimate directly the joint effect between non-farm labor allocation and the income-poverty gap index of households, our attempts at such an estimation proved to be problematic. For instance, the estimation of this jointly determined relationship indicate that the effects of the off-farm labor supply on poverty in the HoH and RoH regressions are negative but not statistically significant due to the severe multicollinearity in the regressors (few of the covariates show meaningful statistical significance, while when taken together they are significant at the 2.5% level).

## 5 Conclusion and policy implications

This paper explores the factors that affect the labor allocation decisions of shifting cultivation households. The sample of households were drawn from two representative communities in Yucatan, Mexico. The empirical results of the study have important implications for the design of policies aimed at reversing land degradation through excessive forest clearing while increasing households' income levels. The empirical findings can be used to recommend labor-market policy development in an era of widespread economic liberalization of key rural markets in Mexico.

Some of our key policy-relevant findings are that: (a) Human capital in the form of formal education helps family members to find employment off-farm. This corroborates other case studies from rural Mexico (Yúnez and Taylor, 2001). (b) Wage rates are influenced not only by human capital but also by other factors such as the type of job, technical efficiency in farming, and whether households engage in other production activities such as cattle raising. (c) There is a marked difference in the factors influencing the labor allocation decisions of household heads compared to other adult household members. The decisions of household heads seem to be affected more by households and production characteristics, while the labor allocation decisions of other adult household members are more sensitive to labor market signals.

The labor allocated to slash-and-burn production by household heads is positively influenced by the PROCAMPO subsidy and by having access to common property land but appears to be insensitive to wage rates. By contrast, other adult household members allocate less labor on-farm when their off-farm wage rate falls and when the wage rate of the household head. Increases. Thus, the on-farm labor allocation to shifting cultivation of household head and other adult members appear to be substitutes. We also find that households tend to hire additional farm labor when the household head's on-farm labor time constraint is binding.

An important finding of our analysis is that the off-farm labor supply schedule is backward bending for the household on average. This result supports some mounting evidence (Dessing, 2002) that contrary to the predictions of classical labor supply theory concerning the positive elasticity of labor supply at low wages, peasant households in developing countries appear to work fewer hours in the RNFE as their wage rates increase, i.e., they have negative elasticity of labor supply. This may be a particular feature of RNFE labor markets in Yucatan that clear at sufficiently low wage rates and when peasant households participating in these markets cannot achieve their minimum subjective income requirements for subsistence without outside employment.

While household heads' off-farm labor choices are relatively insensitive to small changes in wage rates, other family members display very large, negative own-wage off-farm labor supply elasticities.

This finding is consistent with. many other studies of labor allocation studies in developing countries that emphasize how poor rural households' labor choices are highly constrained by minimum subsistence and income targets, and thus these households have little option other than to increase their supply of off-farm labor when wages fall. This is particularly relevant in rural Yucatán where wage rates are considered to be among the lowest in Mexico (World Bank, 2001). By separately examining the labor allocation decision of household holds from the decision of other adult household members, our study is able to show that it is the latter members of the household who appear to be responsible for the observed 'backward-bending' labor supply response when low non-farm wages fall. In contrast, heads of households are responsible mainly for directing and implementing the main household production activity, slash-and-burn agricultural operations. As far as we know, this is the first study to show explicitly this intra-household division of labor for poor shifting cultivation households.

Finally, our study indicates that both poverty levels and the quality of the resource base also influence key aspects of the labor allocation decisions of these households. Again, these effects appear to influence mainly the labor allocation of adult household members other than the household heads. Although the degree of household poverty has no statistical effect on the RNFE decision by household heads, it does affect negatively the non-farm labor decision by other household adult members. On average and after controlling for the wage effects, poorer households appear overall to supply less non-farm labor. In addition, other adult household members will allocate more labor to shifting cultivation when the plots being cleared have remained fallow for some time, possibly due to the higher labor requirement for clearing heavily fallowed forest land. Also, when the area of the converted forest plot increases, the household head increases farm labor relatively less than other family members.

Thus, the allocation of household labor between shifting cultivation and off-farm employment may be structurally linked to both household poverty levels and to income considerations, such as the need to attain a minimum subsistence level, and these decisions may in turn be influenced to the quality of the natural resource base that supports slash-and-burn farming. Thus we cannot reject the hypothesis that the state of the natural resource base for slash-and burn farming (e.g., soil fertility and the state of the forest) may influence the both the labor allocation decisions of the surveyed Yucatan households and any wage effect on their labor decisions. Therefore, policies aimed at helping to conserve forest land in slash-and-burn systems in Yucatan ought to be examined for their possible incentive impacts on household decisions to participate in the off-farm market, and vice versa. However, since milpa is mostly carried out by household heads, who seem insensitive to market signals, finding suitable labor market-based policies to reduce pressure on the forest is clearly a challenge. If policies can be devised to increase off-farm participation opportunities by household heads, this may prove useful in redirecting labor out of the milpa. The reason is that, as our study results indicate, once participation in RNFE is undertaken by household heads, on-farm and off-farm labor time is highly substitutable. In particular, our findings indicate that there may be a role for specialized training and education programs to increase human and social capital for household heads in order to reduce pressure on forest land. Such investments may also assist shifting cultivation households to avoid poverty traps arising from the predicted falling wage rates due to post-NAFTA liberalization of rural labor markets and general long-term trends in the non-farm employment sectors of rural Mexico.

## Appendix

**The maximization problem:**

As the behavior of the RoH and HoH is assumed to be analogous, the problem of member $j$ is represented by the current value Hamiltonian ($\tilde{H}$) after suppressing for the subscript $j$ and the time index except for the multipliers and $q$, for clarity of exposition:

$$\begin{aligned}\tilde{H} = U(c_s, c_c, l; \mathcal{P}, \pi_c) + \lambda_t\{p_s[f(F, H; \pi_z, \pi_q) - c_s] - pc_c + w_m M - \ w_H H + e\} + \\ + \ \gamma_t(T - F - M - L) + \rho\mu_{t+1} g(F, H, q; \pi_q)\end{aligned} \tag{A1}$$

where, $\lambda$, $\gamma$ and $\mu$ are the multipliers for marginal utility of income, time and soil quality, respectively. Allowing for a corner solution for optimum RNFE, the optimality conditions are as follows:

$$\lambda p_s f_F = \gamma - \rho\mu_{t+1} g_F \tag{A2}$$

$$\lambda(p_s f_H - w_H) = -\rho\mu_{t+1} g_H \tag{A3}$$

$$\tilde{H}_M \leq 0, \ M \geq 0, \ M\tilde{H}_M = 0 \tag{A4}$$

$$\lambda p_s f_q + \rho\mu_{t+1} g_q = \mu_t - \rho\mu_{t+1} \tag{A5}$$

$$\lambda w_m - \gamma \leq 0, M \geq 0, M(\lambda w_m - \gamma) = 0 \tag{A6}$$

$$U_l = \gamma \tag{A7}$$

$$U_{c_s} = \lambda p_s \tag{A8}$$

$$U_{c_c} = \lambda p_c \tag{A9}$$

and constraints:

$$T - F - M - L = 0 \tag{A10}$$

$$p_c c_c + p_{st}(c_s - z) \ = \ w_m M - w_h h + e_t \tag{A11}$$

$$g(F, H, q; \pi_q) \tag{A12}$$

Equations (A2–A4) spell out the conditions for optimal on-farm, leisure and RNFE time. Assuming the household member supplies on-farm labor and has positive leisure hours, the Kuhn-Tucker condition (A4), provides the rule for RNFE participation: If $w_m - \gamma/\lambda < 0$, $M = 0$,i.e., when the subjective valuation of leisure or farm-work exceeds the competitive wage rate obtained in RNFE, then it is optimal not to supply labor time off-farm. If, instead, $w_m = \gamma/\lambda$, then $M > 0$.

**Separability of the consumption and production decisions:**

Equation (A5) can be used to obtain the discounted shadow value of soil quality in period $(t+1)$, i.e., $\rho\mu_{t+1} = \frac{\mu_t - \lambda P_s f_{q_t}}{1+g_{q_t}}$. By substituting this value into (A2) or (A3), optimum farm labor by household member $j$ and purchased hired labor hours is given by the following conditions, respectively:

$$\frac{g_{F_{jt}}}{1+g_{q_t}} = \frac{\gamma - \lambda p_s f_{F_{jt}}}{\mu_t - \lambda p_s f_{q_t}} \tag{A13}$$

and

$$\frac{g_{H_t}}{1+g_{q_t}} = -\frac{p_s f_{H_t} - w_H}{(\mu_t/\lambda) - p_s f_{q_t}} \tag{A14}$$

It can be noted that optimal levels of $F_{jt}$ and $H_t$ depend on $\mu_t$, which in turn depends on the preference orderings of the household (i.e., $\mu_t = \partial\tilde{H}/\partial q_t$). Thus, the model does not become recursive whereby production, consumption and off-farm labor decisions can be modelled independently.

Since in the long-run $\mu_{t+1} = \mu_t$, invoking (A5):

$$\mu^* = \frac{\lambda p_s f_q}{r - g_q} \tag{A15}$$

Substituting for $\mu^*$ back into (A2) and (A3), and combining with (6), then the implicit optimal input demand equations are obtained, c.f. (7a) and (7b).

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# Notes

[1]The literature on RNFE and livelihood diversification shows ambiguous definitions. See Barrett (2001) for a comprehensive discussion on this issue. Here RNFE by farm households is defined following Davis (2003) as comprising any non-agricultural activity that generates income through waged work or in self-employment, thus excluding remittances and transfers.

[2]While the majority of studies report the shares of estimated household income arising from on- and off-farm sources, the share of labour time devoted to them is rarely reported, possibly as disaggregated information is harder to obtain.

[3]The area under study is characterised by a high degree of labor market integration. See next section for details.

[4]The land reform is based on the amendment to Article 27 of the constitution that had served, since the end of the Mexican Revolution in 1917, as the embodiment of the government's commitment to the rural poor by redistributing land. Article 27 was amended in 1992 to abolish constraints to private investment in rural activities by establishing a legal framework guaranteeing property ownership. Nevertheless, despite government efforts for land liberalization through the voluntary program for land certification known as PROCEDE (*Programa de Certificacion de Derechos Ejidales y Titulacion de Solares Urbanos*), the ejido in Yucatan remains the preferred land institution by farmers.

[5]The model is based on a two-stage estimation procedure whereby endogenous variables are replaced by predicted values obtained in a first stage by regression upon an instrument set. While the Nelson-Olsen estimator is consistent, it misrepresents the true variance of the parameter estimates. We follow Maddala (1983) to correct for the variance covariance matrix of the estimates. Alternative methods are bootstraping (Mishra and Goodwin, 1997) and estimation of simultaneous tobits by full information Maximum Likelihood (Glick, 1999).

[6]$ refers to Mexican pesos at 1998 prices, unless otherwise stated. The extreme poverty level is used here following SEMARNAP (1998). It is based on a basic-needs basket that satisfy a daily caloric minimum (2,082 Kcal) for an average adult. Further, according to Rothbarth's (1943) adult equivalency index, children up to five years, 5-10 and 11-15 year old are assumed to weight 15%, 20% and 43% in the command of per capita income.

[7]Off-farm labor income is gross income, i.e. any transaction costs such as travelling costs to the workplace are not deducted from wage income.

[8]The t-ratio of the correlation index between the error terms in the HoH's and RoH's participation decision equations suggests that the participation decisions can be independently modelled. A Score test for the normality distribution of the binary dependent model (which draws on the third and fourth sample moments of the standarised residuals) suggests that the error term in the HoH's labour participation decision does not follow a normal distribution ($\chi^2_2 = 20.23$). Normality cannot be rejected in the RoH's participation model ($\chi^2_2 = 0.93$).

[9]This result is more than the 3.7% effect of an additional year of schooling reported by Taylor and Yúnez (2000) for all of Mexico. The formal education attained by HoHs and RoHs are not readily comparable as HoH (often older members), although having learned basic cognitive skills such as maths or reading, they may have become illiterate after a long time without using these skills (Yúnez-Naude, pers.comm.).

[10]A coefficient $c$ not close to zero and multiplying a dummy variable can be interpreted as a percentual change in the endogenous variable by the following calculation: $100[\exp(c) - 1]$ (Lanjouw, 2001 ).

[11]To keep log-linear estimation manageable in the presence of censored RoH's farm labour hours, a constant equal to one is added to $SCRoH$ variable following Jacoby (1993) and Skoufias (1994) .

[12]No seasonality effect is incorporated into the model. Hence the hedonic RNFE wage is assumed to reflect on-farm productivity outside peak or slack periods. While no pure slack exists in slash-and-burn in the area the increased labor use in farming when the forest need to be cleared is supplied by the HoH, RoH and sometimes by hired labour

Alderman and Sahn (1989), Olfert (1994) and Skoufias (1996) discuss the implications for labor allocation modelling under market seasonality in agriculture.

[13]The fact that the PROCAMPO subsidy appears to induce HoHs to supply more milpa labour confirms the view expressed by Sadoulet et. al. (2001) that the subsidy program should lead to visible labor reallocation effects. Unfortunately, one negative side-effect of the PROCAMPO subsidy is that, if it is encouraging household heads to allocate more labor to slash-and-burn farming, then it is also likely to lead to more forest-land clearing.

[14]The hypothesis of a hired labor shortage for the delayed households also follows from the fact that the wage rate paid to hired laborers by the 'delayed' households was on average 54% higher than the 'non-delayed' ones (at the 10% sig. level).

[15]Paraphrasing Michael Lipton (1983) *"... the poorest, are those who cannot afford to withdraw their labour supply –at once rendering 'unemployment as a bourgeois luxury' (because the poorest, if work is unavailable at the alleged going rate, must accept less) and keeping the poorest poor (because their lack of options compels them to accept even desperately low wage-rates"* (Lipton, 1983p. 93). Horton, Kanbur and Mazumdar (1994) coined this effect as the 'added worker effect'.

Table 1: Variable definitions and descriptive statistics

| Variable | Description | Mean | Std. Dev. | Min. | Max. | N |
|---|---|---|---|---|---|---|
| | **Dependent variables** | | | | | |
| SCLHoH | HoH's milpa labor supply (hours) | 449.62 | 349.83 | 3 | 2,090 | 74 |
| SCLRoH[a] | RoH's milpa labor supply (hours) | 136.48 | 157.90 | 0.33 | 532 | 23 |
| DUMHIRE | 1 if HH hires milpa labor; 0 otherwise | 0.41 | 0.49 | 0 | 1 | 74 |
| SCLHIRE[b] | Total HH's hired milpa labor | 264.40 | 446.31 | 7.50 | 2,376 | 30 |
| DUSUPHoH | 1 if HoH supplies off-farm labor (OFL) | 0.59 | 0.49 | 0 | 1 | 74 |
| DUSUPRoH | 1 if HoH supplies OFL; 0 otherwise | 0.65 | 0.48 | 0 | 1 | 74 |
| OFLHoH[c] | HoH's RNFE (hours) | 1,200.64 | 914.14 | 40 | 3,360 | 44 |
| OFLRoH[c] | RoH's RNFE (hours) | 1,177.69 | 607.78 | 64 | 2,880 | 48 |
| WHoH[c] | HoH's RNFE wage rate ($/hour) | 6.67 | 5.48 | 0.50 | 25 | 44 |
| WRoH[c] | RoH's RNFE wage rate ($/hour) | 5.26 | 2.43 | 0.46 | 11.16 | 48 |
| PL1GAP[d] | HH's relative poverty gap w.r.t PL1 | -0.97 | 1.23 | -4.20 | 0.81 | 74 |
| | **Independent variables** | | | | | |
| INFANT | N. of children under 6 years | 0.66 | 0.97 | 0 | 4 | 74 |
| CHILD15 | N. of children between 6 and 15 years | 1.77 | 1.61 | 0 | 6 | 74 |
| AGEHoH | HoH's age (years) | 53.24 | 10.82 | 31.00 | 82 | 74 |
| AGERoH | RoH's average age (years) | 33.19 | 9.43 | 16.52 | 75 | 74 |
| EDUHoH | HoH's years of schooling | 2.74 | 2.38 | 0 | 9 | 74 |
| EDURoH | RoH's average years of schooling | 4.52 | 2.55 | 0 | 12 | 74 |
| SIZERoH | Active HH (non-head) members | 3.15 | 2.03 | 0 | 10 | 74 |
| DEPEN | Dependency ratio | 3.35 | 1.63 | 1 | 8 | 74 |
| PMENRoH | % of males from active HH members | 67.15 | 15.20 | 16.67 | 100 | 74 |
| FARMSIZE | Milpa area (ha) | 1.58 | 1.08 | 0.20 | 5 | 74 |
| MPROZA | % first year milpa to all milpa area | 0.73 | 0.30 | 0 | 1 | 74 |
| TECHEFF | Technical efficiency index ($x$ 100) | 57.15 | 17.42 | 11.50 | 85.60 | 74 |
| PRVLAND | Total owned land (mecates/100) | 1.22 | 4.13 | 0 | 20 | 74 |

*continued on next page*

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| | | | | | | |
|---|---|---|---|---|---|---|
| VFALLOW | Fallow years in milpa plot | 16.10 | 7.79 | 4 | 40 | 74 |
| NONLAB | Non-labour income (per. cap./1000) | 0.90 | 0.91 | 0 | 3.74 | 74 |
| HOCABA | 1 if HH lives in Hocaba; 0 otherwise (o.w.s.) | 0.66 | 0.48 | 0 | 1 | 74 |
| DUMDELAY | 1 if HH forest felling was delayed; 0 o.w.s. | 0.42 | 0.50 | 0 | 1 | 74 |
| DUMPRV | 1 if HH owns private property land; 0 o.w.s. | 0.16 | 0.37 | 0 | 1 | 74 |
| EXTENDED | 1 if HH is an extended one; 0 o.w.s. | 0.28 | 0.45 | 0 | 1 | 74 |
| ILITHoH | 1 if HoH has no schooling years; 0 o.w.s. | 0.26 | 0.44 | 0 | 1 | 74 |
| ILITRoH | 1 if RoH has no schooling years; 0 o.w.s. | 0.09 | 0.29 | 0 | 1 | 74 |
| DUMRESOW | 1 if HH could resow the crop; 0 o.w.s. | 0.64 | 0.48 | 0 | 1 | 74 |
| PROCAMPO | 1 if HH has PROCAMPO subsidy; 0 o.w.s. | 0.41 | 0.49 | 0 | 1 | 74 |
| VMONTE | 1 if forest vegetation is 'monte'; 0 o.w.s. | 0.66 | 0.48 | 0 | 1 | 74 |
| DUMHoHBU[c] | 1 if HoH worked as builder; 0 o.w.s. | 0.18 | 0.39 | 0 | 1 | 44 |
| DUMHoHEM[c] | 1 if HoH worked as other employee; 0 o.w.s. | 0.23 | 0.42 | 0 | 1 | 44 |
| DUMHoHSE[c] | 1 if HoH is self-employed; 0 o.w.s. | 0.20 | 0.41 | 0 | 1 | 44 |
| DUMARRoH[c] | 1 if RoH is not self-employed; 0 o.w.s. | 0.48 | 0.50 | 0 | 1 | 48 |

HH: Household.

[a] Calculated for those who participated in the milpa.

[b] Calculated for the HHs that hired shifting cultivating labourers.

[c] Calculated for those who participated in off-farm labour employment corrected for Rothbarth's adult equivalency.

[d] PL1 poverty line is $2,376 per capita per annum.

Table 2: Determinants of RNFE participation Likelihood by the head and rest of the household

| Logit: HoH's RNFE participation | | | Probit: RoH's RNFE participation | | |
|---|---|---|---|---|---|
| Variable | Coef-ficient | Marginal Proba-bility | Variable | Coef-ficient | Marginal Proba-bility |
| *INTERCEPT* | 7.715 ** (2.460) | 1.577 | *INTERCEPT* | 2.232 (1.246) | 0.666 |
| *HOCABA* | 4.160 *** (3.070) | 0.851 | *HOCABA* | − 1.460 *** (2.612) | - 0.436 |
| *AGEHoH* | − 0.159 *** (3.220) | - 0.032 | *AGERoH* | − 0.023 (0.822) | - 0.007 |
| *EDUHoH* | − 0.172 (0.843) | - 0.035 | *EDURoH* | 0.186 * (1.676) | 0.055 |
| *ILITHoH* | − 2.926 ** (2.338) | - 0.598 | *ILITRoH* | 0.928 (1.102) | 0.277 |
| *PMENRoH* | − 0.043 + (1.499) | - 0.009 | *PMENRoH* | − 0.026 + (1.524) | - 0.008 |
| *EXTENDED* | 0.877 (0.920) | 0.179 | *EXTENDED* | 1.405 ** (2.504) | 0.419 |
| *INFANT* | − 0.529 (0.990) | - 0.108 | *INFANT* | 0.093 (0.283) | 0.028 |
| *CHILD15* | 1.304 *** (3.197) | 0.267 | *CHILD15* | 0.108 (0.563) | 0.032 |
| *NONLAB* | 0.163 (0.356) | 0.033 | *NONLAB* | − 0.066 (0.303) | - 0.020 |
| *TECHEFF* | 0.018 (0.744) | 0.004 | *TECHEFF* | 0.012 (1.030) | 0.004 |
| *DUMPRV* | − 3.311 ** (2.160) | - 0.677 | *DUMPRV* | − 0.985 (1.134) | - 0.294 |
| *PRVLAND* | 0.068 (0.023) | 0.014 | *PRVLAND* | 0.174 + (1.629) | 0.052 |
| *DUSUPRoH* | 0.085 (0.106) | 0.017 | *DUSUPHoH* | − 0.373 (0.837) | - 0.111 |
| Unrestricted Log-L | -28.62 | | | -30.38 | |
| Restricted Log-L | -49.96 | | | -47.97 | |
| LRT $\chi^2_{13}$ | 42.68 | | | 35.18 | |
| Cragg-Uhler Pseudo $R^2$ | 0.59 | | | 0.52 | |
| Normality test $\chi^2_2$ † | 20.23 | | | 0.93 | |
| Heterosk. test: | | | | | |
| LM test $\chi^2_1$ †† | 0.41 | | | 0.49 | |
| $\rho(1,2)^{\dagger\dagger\dagger}$ | | -0.017 (0.041) | | | |

No. observations: 74. Absolute-value t-ratios in parenthesis.

$***$, $**$, $*$ and $+$ are for significance levels at 1%, 5% , 10% and 15%, respectively.

† A moment based normality test. Normality is rejected for the HoH's model at any sig. level.

†† LM test for heteroskedasticity does not reject Homoscedasticity in both models.

††† $\rho(1,2)$ stands for correlation between the errors. A bivariate Probit is rejected from the low t-ratio on $\rho$.

Table 3: Hedonic RNFE wage rates for the head and rest of the household

| RNFE Wage HoH | | RNFE Wage RoH | |
|---|---|---|---|
| Variable | Coeff. | Variable | Coeff. |
| *INTERCEPT* | 2.022 *** (3.650) | *INTERCEPT* | 1.633 *** (2.849) |
| *HOCABA* | 0.172 (0.804) | *HOCABA* | 0.429 ** (2.360) |
| *AGEHoH* | − 0.028 ** (2.282) | *AGERoH* | − 0.021 ** (2.196) |
| *ILITHoH* | − 0.004 (0.015) | *ILITRoH* | − 0.190 (0.522) |
| *DUMPRV* | 1.367 *** (2.710) | *DUMPRV* | 0.025 (0.103) |
| *PRVLAND* | − 0.126 *** (3.221) | *PRVLAND* | 0.022 (0.921) |
| *TECHEFF* | 0.008 + (1.588) | *PMENRoH* | 0.004 (0.725) |
| *DUMHoHBU* | 0.493 * (1.936) | *SIZERoH* | − 0.110 ** (2.477) |
| *DUMHoHSE* | 0.756 *** (2.916) | *TECHEFF* | 0.007 + (1.606) |
| *DUMHoHEM* | 0.960 *** (4.036) | *DUMARRoH* | 0.492 *** (3.134) |
| *IMR* | − 0.197 (0.774) | *IMR* | − 0.401 (1.425) |
| Observations | 44 | | 48 |
| $\overline{R}^2$ | 0.44 | | 0.26 |
| $F$ test | $F[10,33] = 4.42$ | | $F[10,37] = 2.66$ |

Absolute value t-ratios in parenthesis.

$***$, $**$, $*$ and + are for sig. levels at 1%, 5% , 10% and 15%, respectively.

Table 4: Labor allocation in slash-and-burn by the head and rest of the household

| OLS | | Tobit | |
|---|---|---|---|
| ln (SCLHoH) | | ln (SCLRoH) | |
| Variable | Coeff. | Variable | Coeff. |
| *ln (SCLRoH)*$^{\mp}$ | 0.028 (0.478) | *ln (SCLHoH)*$^{\mp}$ | $-0.804^{*}$ (1.668) |
| *INTERCEPT* | $4.234^{***}$ (3.172) | *INTERCEPT* | $-1.960$ (0.822) |
| *HOCABA* | $-0.208$ (0.413) | *HOCABA* | $-0.469$ (1.073) |
| *AGEHoH* | 0.011 (0.552) | *PMENRoH* | $0.042^{***}$ (3.125) |
| *ILITHoH* | 0.331 (0.964) | *ILITRoH* | $-1.586^{**}$ (2.149) |
| *EXTENDED* | $-1.015^{***}$ (2.710) | *EXTENDED* | $-2.134^{***}$ (3.379) |
| *INFANT* | $0.352^{*}$ (1.787) | *DEPEN* | $-0.036$ (0.268) |
| — | — | *SIZERoH* | $0.411^{***}$ (3.746) |
| *DUMPRV* | 0.651 (0.934) | *DUMPRV* | $1.329^{*}$ (1.762) |
| *PRVLAND* | $-0.191^{***}$ (2.883) | *PRVLAND* | $-0.281^{**}$ (2.139) |
| *FARMSIZE* | $0.395^{*}$ (1.896) | *FARMSIZE* | $1.085^{***}$ (3.567) |
| *MPROZA* | 0.038 (0.069) | *MPROZA* | 0.579 (0.682) |
| *VFALLOW* | 0.006 (0.286) | *VFALLOW* | $0.040^{*}$ (1.665) |
| *VMONTE* | 0.343 (0.897) | *VMONTE* | 0.334 (0.865) |
| *TECHEFF* | 0.005 (0.495) | *TECHEFF* | $-0.002$ (0.164) |
| *PROCAMPO* | $0.464^{+}$ (1.531) | *PROCAMPO* | $-0.052$ (0.164) |
| *ln (WHoH)*$^{\mp}$ | $-0.261$ (0.936) | *ln (WHoH)*$^{\mp}$ | $-0.598^{*}$ (1.878) |
| *ln (WRoH)*$^{\mp}$ | 0.113 (0.287) | *ln (WRoH)*$^{\mp}$ | $0.773^{*}$ (1.807) |
| ULL | -94.81 | | -85.81 |
| RLL | -116.57 | | -97.38 |
| LRT† | $\chi^2_{16}$: 43.52 | | $\chi^2_{17}$ 23.14 |
| BP statistic†† | $\chi^2_{16}$=106 | | |

ULL: Unrestricted Log-likelihood (LL); RLL: Restricted LL; LRT: Likelihood ratio test.

No. observations: 74. Absolute value t-ratios in parenthesis.

$***$, $**$, $*$ and $+$ are for sig. levels at 1%, 5% , 10% and 15%, respectively.

†: Loglikelihood ratio test calculated prior to VCM had been adjusted.

††: Breush-Pagan test cannot reject heteroskedasticity

OLS standard errors are corrected using White's formula.

$\mp$ Predicted variable.

Table 5: Hired labor in slash-and-burn: Logit for the probability of hiring farm labor and sample selection for (log) hired farm labor hours

| Logit: Employment of hired labor | | | ln (SCLHIRE) | |
|---|---|---|---|---|
| | Coeff. | Marginal Probability | Variable$^{\dagger}$ | Coeff. |
| *INTERCEPT* | $-1.680$ (0.251) | -0.352 | *INTERCEPT* | $9.578^{***}$ (5.915) |
| *HOCABA* | $-2.440$ (1.437) | -0.511 | *HOCABA* | $-0.476$ (0.973) |
| *AGEHoH* | 0.068 (1.137) | 0.014 | *WHoH* $^{\mp}$ | $-0.043$ (0.155) |
| *EDUHoH* | 0.312 (1.160) | 0.065 | *WRoH* $^{\mp}$ | $-0.336$ (0.747) |
| *ILITHoH* | $-1.491$ (1.023) | -0.312 | *SCHoH* $^{\mp}$ | $-0.717^{***}$ (2.787) |
| *PMENRoH* | $-0.090^{**}$ (2.185) | -0.019 | *SCRoH* $^{\mp}$ | $0.272^{*}$ (1.727) |
| *FARMSIZE* | 0.533 (1.077) | 0.112 | *DUMDELAY* | $-1.185^{***}$ (2.713) |
| *MPROZA* | 0.258 (0.186) | 0.054 | *IMR* | 0.217 (0.547) |
| *DUMPRV* | $-1.349$ (0.685) | -0.282 | | |
| *PRVLAND* | 0.300 (1.246) | 0.063 | | |
| *VMONTE* | $-0.879$ (0.682) | -0.184 | | |
| *VFALLOW* | $-0.022$ (0.347) | -0.005 | | |
| *DUMRESOW* | 1.091 (1.344) | 0.228 | | |
| *DUMDELAY* | $-1.928^{**}$ (1.960) | -0.404 | | |
| *TECHEFF* | $-0.063^{+}$ (1.484) | -0.013 | | |
| *AGERoH* | $-0.006$ (0.093) | -0.001 | | |
| *EDURoH* | 0.179 (0.947) | 0.037 | | |
| *SIZERoH* | $-0.088$ (0.288) | -0.018 | | |
| *ln (WHoH)*$^{\mp}$ | 1.369 (1.348) | 0.286 | | |
| *ln (WRoH)*$^{\mp}$ | $3.299^{**}$ (1.928) | 0.690 | | |
| UR Log-L | -25.63 | | UR Log-L | -38.85 |
| R Log-L | -49.96 | | R Log-L | -50.47 |
| LRT $\chi^2_{19}$ | 48.66 | | LRT $\chi^2_{7}$ | 23.24 |
| Cragg-Uhler $R^2$ | 0.65 | | $\overline{R}^2$ | 0.17 |
| Normality test $\chi^2_2$ | 9.40 | | | |
| Observations | 74 | | | 30 |

t-ratios in parenthesis. $^{\dagger}$ Variables are in logs; $^{\mp}$ Predicted variable.

White corrected standard errors reported in the Heckman model.

$***$, $**$, $*$ and $+$ are for sig. levels at 1%, 5% , 10% and 15%, respectively.

Table 6: Determinants of RNF labor allocation by the head and rest of the household

| | Tobit | |
|---|---|---|
| | Off-farm labor† | |
| Variable† | HoH | RoH |
| *INTERCEPT* | 16.661*** (3.354) | 4.833** (2.174) |
| *HOCABA* | −0.023 (0.029) | −0.537+ (1.502) |
| *WHoH* ∓ | −0.133 (0.353) | −0.492*** (2.850) |
| *WRoH* ∓ | 1.333** (1.962) | −4.808*** (9.938) |
| *SCLHoH* ∓ | −2.094*** (3.932) | 1.060*** (4.287) |
| *SCLRoH* ∓ | 0.512+ (1.632) | −0.448*** (3.289) |
| *SCLHIRE* ∓ | −0.749+ (1.546) | 0.495** (2.134) |
| *NONLAB* | −0.335** (1.967) | −0.491*** (6.288) |
| *PL1GAP* ∓ | 0.058 (0.160) | −2.250*** (11.278) |
| Unrestr. Log-likelihood | -155.62 | -142.60 |
| Restr. Log-likelihood | -162.65 | -169.82 |
| LRT†† | $\chi^2_8 : 14.04$ | $\chi^2_8 : 54.43$ |

No. observations: 74. t-ratios in parenthesis.

∗∗∗, ∗∗, ∗ and +: Sig. levels at 1%, 5% , 10% and 15%.

† All variables are in logs except PL1GAP.

†† Calculated before adjusting the VCM

∓: Predicted variable.

Table 7: Own and cross wage elasticities of labor in slash-and-burn farming, RNFE and leisure for the head and rest of the household

| Wage | Household member | Elasticities $M$ | $F$ | $l^\dagger$ |
|---|---|---|---|---|
| HoH's $w$ | HoH: | $\approx -0$ | $\approx -0$ | $\approx +0$ |
| | RoH: | -0.49 | -0.60 | 0.08 |
| RoH's $w$ | HoH: | 1.33 | $\approx +0$ | -0.20 |
| | RoH: | -4.80 | 0.77 | 0.72 |