DEPARTMENT OF ECONOMICS

Working Paper

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Working Paper No. 2001-11

ISSN 1396-2426

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Off-farm Activities by Agricultural Households in Nicaragua: Exploiting Comparative Advantages or Fighting Agricultural Problems?

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November 20, 2001

Abstract

This paper considers off-farm labour activities by agricultural households in Nicaragua. It compares the role of: i) comparative advantages of households and individuals; and ii) agricultural conditions and market imperfections, in shaping off-farm labour supply. An econometric specification is developed which allows for random household-specific effects and easy estimation. Results reveal that non-agricultural off-farm work is largely determined by comparative advantages, whereas agricultural off-farm work is used extensively to deal with a number of agricultural conditions and market imperfections.

Keywords: Off-farm labour supply, household behaviour, household-specific effects.

JEL: O1, D1, J22, J43, N36, Q12.

Acknowledgements: We wish to thank Leonardo Corral, Ove Faurby, Gerald Friedman, Rasmus Heltberg, Svend Hylleberg, Helena Skyt Nielsen, Thomas Reardon, Luis Rodríguez, Peter Skott, Jos Vaessen, and seminar participants at the University of Aarhus, the University of Copenhagen, and the University of Massachusetts for useful suggestions and constructive comments. We also thank Jens Krogstrup and Anders Lunde for excellent research assistance. Financial support from the Danish Council for Development Research (Malchow-Møller) and the Danish Social Science Research Council (Svarer) is gratefully acknowledged. Finally, we wish to thank the LSMS office at the World Bank and the Instituto Nacional de Estadísticas y Censos (INEC) in Managua for providing the data.

1 Introduction

Recent empirical evidence has emphasised the importance of off-farm (and non-farm[1]) income to agricultural households in less developed countries, see e.g. Reardon, Berdegué, and Escobar (2001) for the case of Latin America, Reardon (1997) for Africa, and Reardon, Stamoulis, Balisacan, Cruz, Berdegué, and Banks (1998) for a review of global evidence.

There exist different theories of the determinants underlying labour activities by agricultural households. The benchmark story of Becker (1965) is that labour activities are determined by the relative comparative advantages of households and individuals. In other words, the time of a household member is allocated to non-agricultural wage work if the individual has a comparative advantages in this activity. Alternative and more recent theories suggest that the participation by agricultural households in off-farm activities is also influenced by agricultural conditions such as imperfections in factor input markets, credit markets, and insurance markets, see e.g. Reardon, Stamoulis, Balisacan, Cruz, Berdegué, and Banks (1998). Agricultural households not only participate in off-farm work because it is more profitable, but also because their agricultural production possibilities are influenced by market failures and risk.

So far, surprisingly little formal evidence of the role of agricultural factors has been brought forward. The purpose of the present paper is thus to compare the above theories and their explanatory power in the case of Nicaragua. The approach taken is based on a standard agricultural household model, which explains labour supply as a result of comparative advantages. This model is then extended to incorporate the effects of various agricultural conditions.

Existing econometric studies of off-farm labour supply have typically focused on settings where the household consists of only two working adults, see e.g. Sumner (1982), Huffman and Lange (1989), Kimhi and Lee (1996), and Mishra and Goodwin (1997). In the case of Nicaragua – as well as in other less developed countries – this is not an appropriate set-up. Most farm households contain more than two working members, and this extended family structure substantially increases the complexity of the analysis. The individual choice now depends on the characteristics of the entire household, instead of just own and spouse characteristics. In the present data set, this means up to 16 persons.

Previously, only two attempts have been made to appropriately address

[1]The term "non-farm" refers to non-agricultural activities, either as self-employed or as a wage labourer, whereas "off-farm" covers all wage-labour activities.

the off-farm labour-supply question in extended households. Fafchamps and Quisumbing (2000) acknowledge that reduced-form individual labour-supply functions will in principle depend on individual characteristics of all household members, which invalidates the use of the same functional forms across households of different size (and composition). They try to compensate for this by including a range of household summary statistics in the labour-supply functions. Unfortunately, they do not allow for correlation of error terms across individuals from the same household. Newman and Gertler (1994), on the other hand, estimate a structural model in the case of Peru. They divide individuals into four age-sex categories and estimate individual marginal-return functions for each of these categories. However, to make the model computationally tractable, it is assumed that the error terms entering the marginal-return functions are independent across family members.

The approach taken in the present paper builds on the one in Fafchamps and Quisumbing (2000) by focusing on reduced form labour supply functions while controlling extensively for characteristics of other household members. The problem of independent error terms is tackled by introducing household-specific random effects into the econometric specification of the labour-supply functions.

Observations on time spent in different activities are often absent or at least measured with considerable noise in household surveys in less developed countries. For this reason, the estimation of the model in this paper is based on simple categorical variables which indicate primary labour activity out of a number of different activities. The associated likelihood function is derived directly from the reduced-form labour-supply functions, and it is shown that it is equivalent to the likelihood function of a standard multinomial logit model. Hence, estimation can proceed as in the standard case. The advantage of this alternative derivation is that the estimated coefficients can now be interpreted directly in terms of the underlying labour-supply functions and not just in terms of their standard effects on regime probabilities. This allows for direct testing of the empirical hypotheses of the paper.

Maximising the likelihood function of a multinomial model with random effects has previously been cumbersome due to the fact that no statistical package allows for an easy implementation. In this paper, a recently developed idea by Chen and Kuo (2001) is used to show that the likelihood function of a multinomial logit model is equivalent to that of a Poisson non-linear model, which is easily estimated in SAS.

The data used come from the 1998 Living Standards Measurement Survey in Nicaragua. The results reveal a pattern where non-agricultural off-farm work is largely determined by comparative advantages, whereas agricultural off-farm work is used extensively to deal with a number of agricultural conditions. More specifically, it is found that uncertain land rights, production risk, imperfect commodity markets, agricultural seasons, and imperfect input markets are all important determinants of agricultural wage work.

The rest of the paper is structured as follows: Section 2 presents the theoretical framework. Labour-supply functions are derived from a household model, and it is discussed how various agricultural conditions will modify especially off-farm labour supply. Section 3 derives the econometric model from the theoretical model in Section 2. Section 4 presents the data and discusses the variables used in analysing the hypotheses of Section 2. Results of the estimations are provided and interpreted in Section 5. Section 6 concludes.

2 The Theoretical Framework

The theoretical framework builds on the standard agricultural household model found in the textbooks of e.g. de Janvry and Sadoulet (1995) and Bardhan and Udry (1999). In this model, the household is assumed to be a unitary decision maker.[2] It receives income from three sources: Farm production, household-enterprise production, and off-farm wage work. It allocates the time of its members to these activities in order to maximise household utility which depends on household consumption and leisure by the individual members. More formally, a household consisting of T members is assumed to undertake the following optimisation:

$$\begin{aligned}
\max \quad & U\left(C, L_1^h, ..., L_T^h\right) \\
s.t. \quad & C = Y^f + Y^e + Y^w \\
& Y^f = F\left(A, K^f, L^{fH}, L^f, \pi_f\right) - r_A A - r_K K^f - wL^{fH} \\
& Y^e = G\left(K^e, L^{eH}, L^e, \pi_e\right) - r_K K^e - wL^{eH} \\
& Y^w = \textstyle\sum_{t=1}^T w_t\left(\rho, \delta_t\right) L_t^w \\
& L^f = f^f(L_1^f, ..., L_T^f, \delta_1, ..., \delta_T) \\
& L^e = f^e\left(L_1^e, ..., L_T^e, \delta_1, ..., \delta_T\right) \\
& L_t^h + L_t^f + L_t^e + L_t^w \leq \bar{L}_t, \quad t = 1, ..., T
\end{aligned} \tag{1}$$

where C is household consumption, and L_t^h, L_t^f, L_t^e, and L_t^w are leisure (or home time), farm time, enterprise time, and off-farm time, respectively, by

[2] Collective and bargaining models where households are not required to make unitary decisions are described by e.g. Chiappori (1992), Apps and Rees (1997), Chiappori (1997), and Browning and Chiappori (1998).

household member t. Farm production, F, depends on land, A, farm capital, K^f, a measure of effective hired labour, L^{fH}, a measure of the input of effective family labour, L^f, together with local productivity of agriculture captured by π_f. Farm net income, Y^f, then equals farm production less the rental cost of land and capital together with the cost of hired labour, where w is the effective wage. Own-enterprise income, Y^e, is determined similarly. Thus, hired labour and family labour are allowed to be imperfect substitutes in production. In the literature, this is often asumed due to incentive problems for hired labour and perhaps knowledge advantages of family members. It is assumed that inputs of effective family labour, L^f and L^e, depend on time inputs of all members together with their individual-specific human capital, δ_t, given by physical attributes, education, experience, and position in the household. Wage income, Y^W, is the sum of wage income by the T members, where the available off-farm wage of individual t depends on individual-specific human capital, δ_t, and local labour-market conditions, ρ. Finally, the last inequality in (1) says that total time spent by individual t cannot exceed his or her endowment of time, $\bar{L}_t$.

The maximisation in (1) is undertaken with respect to C, A, K^f, K^e, L^{Hf}, L^{He} together with L_t^h, L_t^f, L_t^e, L_t^w, $t = 1, ..., T$. Solving the model yields labour supply functions of the following type for individual t:

$$L_t^j = L^j\left(r_A, r_K, w, \gamma, \delta_t, \delta_{-t}\right), \quad j = h, f, e, w \tag{2}$$

where $\gamma = [\pi_f, \pi_e, \rho]$, and δ_{-t} are the individual characteristics of household members other than individual t.

According to this set-up, the time spent by individual t in activity j is a function of the rental prices of land and capital, r_A and r_K, the wage rate of hired labour, w, local household characteristics, γ, as well as individual characteristics of all household members, δ_t and δ_{-t}. More intuitively, the decision of a household to let individual t participate in e.g. off-farm work is based on a comparison of his off-farm wage with his marginal productivity in farm and enterprise work, where these are influenced by the labour inputs and characteristics of other family members, and hence implicitly by their off-farm opportunities. As an example, an educated person might find it more attractive to work as a salaried worker, but less so if other family members are also educated and the local marginal return to family labour in agricultural production is high. Despite his education, it might then be optimal for the household to let him work on the farm while the other members work off the farm.

2.1 Recent Theories

Is this the whole story? The above set-up applies to a situation in which (rental) markets for land, capital and labour work perfectly, and where risk is absent or fair insurance is available. Assuming that family labour is more productive than hired labour, the model cannot explain why off-farm agricultural work is observed. Household members should always prefer to rent land and work on their own farm. Furthermore, this static framework does not allow for any role of credit constraints or dynamic considerations such as future uncertainty.

Recent theories and selective evidence suggest that agricultural "push factors" also influence the labour activities of agricultural households. It has been suggested by e.g. Reardon (1997), Reardon, Taylor, Stamoulis, Lanjouw, and Balisacan (2000), and Ruben and van den Berg (2001) that agricultural households allocate labour to the non-farm sector in response to inadequate farm output. This can be due to constraints on inputs (land and capital) or due to imperfect credit markets which prevent the purchase of inputs. In this case, off-farm labour can provide both the needed income and the liquidity to buy farm inputs. Another reason for off-farm work might be the uncertainty of agricultural income which causes households to diversify income ex-ante and react to negative shocks ex-post by participating in off-farm activities, see e.g. Reardon (1997), Reardon, Stamoulis, Balisacan, Cruz, Berdegué, and Banks (1998), Rose (2001), and Reardon, Berdegué, and Escobar (2001). In the following, it is considered in more detail how agricultural conditions can modify the off-farm labour-supply function of household members.

2.1.1 Imperfect Input Markets

The first hypothesis is that constraints in input markets affect the labour activities of the households. If households are restricted in their access to land and capital, i.e. if markets cannot be used to freely adjust inputs in accordance with the economic incentives of the model in (1), households with small endowments of land and capital must seek employment off the farm, either agricultural or non-agricultural. Hence, the amount of labour supplied to off-farm activities becomes a decreasing function of available inputs, A and K.

2.1.2 Imperfect Credit Markets

A closely related hypothesis is that markets for credit work imperfectly. A negative relationship between e.g. land and off-farm labour might then emerge because of a credit-market failure rather than a land-market failure. If some farmers are restricted in their access to credit, this might explain why they hold insufficient amounts of farm inputs and work more off the farm, even though the input markets themselves work perfectly.

Lack of access to credit might also more directly affect off-farm work. Households need liquidity, not only to finance the acquisition of farm production factors, but also to buy consumption goods. This effect will tend to reinforce the indirect effect that works through the production factors. In sum, credit-constrained households will be expected to participate less in farm activities and more in cash-generating off-farm activities.

2.1.3 Production Risk and Imperfect Insurance Markets

The third hypothesis is that off-farm labour is used as a means of managing farm-income risk. Agricultural income is highly uncertain due to production shocks and price fluctuations. This risk becomes important when insurance markest are absent, as in most less developed countries.

First, households might have different degrees of risk aversion. More risk-averse households will then be expected to undertake more diversification and therefore to participate more in off-farm work. Second, households with higher inherent farm risk, e.g. due to differences in weather variability, might be expected to participate more in off-farm work to stabilise income. Third, households facing higher costs of crop diversification can use off-farm work as an alternative means of managing farm-income risk. Diversification costs might initially be negative if e.g. intercropping increases overall output, but eventually diversification is expected to come at a cost in mean output. This cost is likely to vary across households depending on climatic conditions as well as the production structure of the household.

These three effects are all ex-ante reactions to income risk, or "portfolio effects" using the terminology of Rose (2001).[3] There might also be an ex-post effect where households that have been negatively affected by agricultural shocks try to compensate for their income loss by increasing off-farm work.

In sum, preferences, inherent farm risk, cost of diversification, and realised agricultural shocks will all be expected to affect off-farm labour supply when insurance is not available.

[3] High inherent farm risk can also give rise to a "precautionary effect", which causes households to work more today when income tomorrow is uncertain.

2.1.4 Imperfect Commodity Markets

The fourth hypothesis regards commodity markets. If these are absent or costly to use, households will be inclined to produce more for home consumption or barter. Their need for cash – either to finance consumption or to buy farm inputs – might then cause them to generate liquidity through the off-farm labour market. Thus, households that face higher costs of using commodity markets work more off the farm.

2.1.5 Imperfect Property Rights

The fifth hypothesis is that uncertain property rights make irreversible investments less attractive. As emphasised by Carter and Olinto (2000), this negative effect on investments can occur through two channels. First, uncertain property rights might directly decrease the demand for investments. Secondly, they might have a negative effect on credit opportunities which then indirectly affect investments. Rodríguez (1999), among others, have argued that land is the most common type of collateral used for formal loans in Nicaragua. Lacking formal property rights should therefore negatively affect the possibility of obtaining a loan. Both channels serve to decrease the marginal productivity of labour on the farm and therefore to increase off-farm supply.

A third channel can also be identified. In addition to the effect on physical investments, households with uncertain property rights are also likely to spend less time in on-farm activities such as soil and plant maintenance that increase future (and current) farm productivity. This has a direct positive effect on off-farm labour supply as well as an indirect positive effect through the lower future productivity of farm work.

2.1.6 Seasonal Fluctuations

The last hypothesis is that off-farm labour is used to smooth labour supply over the agricultural cycle. If households have preferences for smooth consumption of leisure over the year, they might engage more in off-farm activities when labour input requirements on their own farm are low.

The alternative hypothesis is that off-farm activities are at their highest when agricultural activity is high, because this generates more opportunities for off-farm work. Actually, different types of off-farm labour might be affected differently by the seasons, with non-agricultural off-farm labour peaking in the low season, and agricultural off-farm labour at its maximum in the high season.

2.2 The Final Model

Incorporating the above theories into the model in (1), the specification of the labour supply functions in (2) is replaced by:

$$L_t^j = L^j \left(r_A, r_K, w, , \gamma, \delta_t, \delta_{-t}, A, K^e, K^f, b, \eta, v, d, m, s, p \right) \qquad (3)$$

where b is a measure of credit access, η is risk aversion, v measures inherent farm risk and realised shocks, d is a measure of diversification cost, m gives the cost of using commodity markets, s is a seasonal indicator, and p captures property rights. Recognising the potential importance of these factors, agricultural off-farm work is no longer inconsistent with the theoretical model. Adverse agricultural conditions might cause households to opt for agricultural wage work. Thus, from a theoretical point of view, it might be expected that factors shape agricultural and non-agricultural wage work differently. To compare the explanatory power of comparative advantages and agricultural conditions, distinctive labour-supply functions should therefore be estimated for agricultural and non-agricultural wage work.

3 Econometric Specification

One problem of estimating individual labour-supply functions of the type in (2) and (3) is that the functional form will depend on the number of household members. As an example, L_t^w of an individual in a two-person household will depend on δ_1 and δ_2, whereas in a three-person household, it will also be a function of δ_3. Different functional specifications will therefore be needed for different household sizes, something which quickly decreases available degrees of freedom, especially when the household size varies between 1 and 16 as in the present data set.[4] Though rather obvious and intuitive, this problem has not been given much attention in the literature.

In a recent paper, Fafchamps and Quisumbing (2000) discuss the problem of estimating general individual labour-supply functions in extended households where the labour supply of individual t depends on individual characteristics of all household members. They address the problem by first estimating

[4] Furthermore, if it is believed that individual differences cannot be completely captured by the included variables, different functional specifications are needed for different types of household members as it is usually done in bivariate models of labour supply for two-person households, see e.g. Lundberg (1988), Huffman and Lange (1989), Tokle and Huffman (1991), and Kimhi and Lee (1996). One would then have to match individuals across households for a given household size. While this can be easily done in the two-person household, where type 1 is the operator and type 2 is the spouse, this mapping becomes practically impossible when the household structure gets more complex and diversified.

total labour supply by the household, replacing individual-specific characteristics with household summary statistics, e.g. average age and education for males and females, household size, and the shares of different age-sex groups in the household. Secondly, they regress individual labour shares in the different activities on: i) differences in human capital, measured by the individual deviation from average household human capital; and ii) the position of the individual in the household, e.g. head, spouse, etc. This approach does not solve the fundamental problem, however. Total labour supply of the household will depend on the entire distribution of characteristics and not just the average. Similarly, the share of individual t in a particular activity is likely to be influenced not only by his deviation from average characteristics, but by the distribution of characteristics among remaining household members.

Though not fully satisfactory, the present paper addresses this problem in a way similar to Fafchamps and Quisumbing (2000) by assuming that labour supply of individual t can be considered a function of individual characteristics as well as a diverse set of household summary statistics which are assumed to capture individual characteristics of the remaining household members. In addition, random household effects are introduced to capture unobserved correlation among individuals from the same household.

Let the households be indexed by $i = 1, ..., I$, and let T_i be the number of individuals in household i. Since the number of individuals in each household varies across households, the sample is an unbalanced panel.

First, define L_{it}^{j*} as the underlying optimal supply of labour to activity j, i.e. when labour supply is not restricted to be non-negative. Hence, L_{it}^{j*} is the solution to the household optimisation problem in (1) without imposing non-negativity constraints. Assume that L_{it}^{j*}, can be linearised as:

$$L_{it}^{j*} = x_{it}\hat{\beta}_j + \hat{u}_{ij} + \varphi\left(\varepsilon_{itj} - \varepsilon_{it0}\right) \tag{4}$$

where the vector x_{it} is the right-hand-side variables that enter the specification in (3). $\hat{u}_{ij}$ is a household- and activity-specific random effect, ε_{itj} is an activity- and individual-specific random disturbance, and ε_{it0} is an individual shock common to all labour-supply functions of the individual. φ is a scale (variance) parameter. Since observations are clustered by household, $\hat{u}_{ij}$ is included to account for potential unobserved correlation among individuals from the same household.

Secondly, since the data on participation in off-farm work activities are based on information about the week prior to the interview, it is chosen to use information on *participation* rather than *amount of time* supplied. Clearly, basing the model on information about a specific week is likely to cause some rather imprecise measures of the individual's time allocation. By using a categorical dependent variable it is attempted to reduce the impact from this noisy measurement of labour supply.

Thus, assume that the participation in J different activities is considered. Individuals can then be modelled as belonging to one of $J+1$ regimes ($j = 0, ..., J$), where regime $j = 0$ corresponds to the situation where the individual does not participate in any of the J activities. I.e. individual t is assigned to regime $j = 0$ if:

$$L_{it}^{k*} < 0, \quad k = 1, ..., J \tag{5}$$

Similarly, individual t is assigned to regime j, where $j \neq 0$, if he participates in activity j and his labour supply is higher to this activity than to each of the remaining $J-1$ activities considered:

$$L_{it}^{j*} > 0 \qquad and \qquad L_{it}^{j*} > L_{it}^{k*}, \quad \forall k \mid k \notin \{0, j\} \tag{6}$$

Using (4), the conditions in (5) and (6) can be rewritten more compactly as:

$$\varepsilon_{itk} < \varepsilon_{itj} + x_{it}(\beta_j - \beta_k) + (u_{ij} - u_{ik}), \quad k \neq j \tag{7}$$

where $\beta_k = \hat{\beta}_k/\varphi$, $u_{ik} = \hat{u}_{ik}/\varphi$, and $\beta_0 = u_{i0} = 0$.

Thirdly, assume that ε_{it0} and the ε_{itj}'s are all independently distributed according to a type I extreme-value distribution.[5] It is then relatively straightforward to show that the probability of individual t being assigned to regime j can be written as:

$$\Pr(y_{it} = j) = \frac{e^{x_{it}\beta_j + u_{ij}}}{1 + \sum_{k=1}^{J} e^{x_{it}\beta_k + u_{ik}}}, \qquad j = 0, ..., J \tag{8}$$

Finally, assuming that $u_i = [u_{i1} ... u_{iJ}]'$ follows a multivariate normal distribution, the likelihood contribution from household i is given by:

$$\mathcal{L}_i = \int_{u_i} \mathcal{L}_i(\cdot \mid u_i, x_{it}) f(u_i) \, du_i \tag{9}$$

where $f(u_i)$ is a multivariate normal density, and $\mathcal{L}_i(\cdot \mid u_i)$ is the conditional likelihood contribution of household i given by:

$$\mathcal{L}_i(\cdot \mid u_i, x_{it}) = \prod_{t=1}^{T_i} \frac{e^{x_{it}\beta_{j(t)} + u_{ij(t)}}}{1 + \sum_{k=1}^{J} e^{x_{it}\beta_k + u_{ik}}} \tag{10}$$

[5]The type I extreme-value distribution has density function $f(\varepsilon) = \exp(-\varepsilon - e^{-\varepsilon})$ and distribution function $F(\varepsilon) = \exp(-e^{-\varepsilon})$. The parameter φ in (4) can therefore be interpreted as a variance parameter.

where $j(t)$ is the choice made by individual t in the household. Without the random household effects, the likelihood function in (9) is equivalent to the likelihood function of a standard multinomial logit model, as derived by McFadden (1974).

In the standard multinomial framework, individuals are modelled as maximising utility by choosing between $J+1$ mutually exclusive alternatives, each associated with some random utility level, $v_{it}^{j} = x_{it}\beta_j + \varepsilon_{itj}$, where β_j is the effect on the utility of alternative j of a one unit increase in x_{it}.[6] A direct application of this interpretation does not seem particularly useful in the present set-up, and it does not allow for a test of the hypotheses in Section 2. First, there is always the risk that the sign of β_j is different from the sign of the marginal effect of x_{it} on the probability of choosing alternative j, see e.g. Greene (1993). Secondly, without the derivation given above, neither a positive β_j nor a positive marginal effect of x_{it} on the probability of choosing alternative j implies that labour supply to activity j is increasing in x_{it}. However, with the above derivation of the model, β_j can be interpreted directly as a normalised coefficient of the underlying labour-supply function for activity j. In this way, it is assured that the sign of β_j is (at least) the same as the sign of the effect of x on the labour supply to activity j. Of course, the parameters can also still be given their reduced-form interpretations through their effects on the probability in (8), as in a standard multinomial logit model.

The likelihood function is maximised with respect to β and σ_u. One problem is that the computation of the likelihood contribution in (9) involves J-dimensional integration. In the application in this paper, two different activities are modelled and consequently a 2-dimensional integral must be evaluated. Perhaps for this reason, statistical packages have not previously contained predefined procedures for the estimation of multinomial random-effects models. Recently, however, Chen and Kuo (2001) have shown how the conditional logit model, i.e. a multinomial model where the regressors are choice specific, can be estimated using a predefined procedure in the statistical software program SAS by rewriting the model as a Poisson non-linear model. In an appendix to this paper, it is shown how the multinomial model with individual-specific regressors and choice-specific random effects can likewise be rewritten as a Poisson non-linear model and estimated in SAS.

[6] The model is also often applied in a more reduced form way by simply assuming that the probability of regime j relative to the reference regime ($y_{it} = 0$) is logistically distributed. I.e. $\Pr(y_{it} = j)/[\Pr(y_{it} = 0) + \Pr(y_{it} = j)] = F(x_{it}\beta_j)$, where F is the logistic distribution function. See Maddala (1983) for a comparison of the two approaches.

4 Data

The data used come from the second Living Standards Measurement Survey (LSMS) in Nicaragua: *Encuesta de Hogares sobre Medición de Nivel de Vida 1998* (EMNV98). It was designed and implemented by el Instituto Nacional de Estadísticas y Censos with assistance from the World Bank. The survey was carried out at a national level from April through September 1998 and covered 4209 households.

The survey is representative at the national level, covering issues such as household characteristics, health, education, income and expenditures, occupation, agricultural production, other household production, and credit and savings. In the first Nicaraguan LSMS from 1993, the agricultural module was omitted due to the unstable land-ownership situation. Hence, the EMNV98 is the first nationally representative household survey in Nicaragua which includes detailed information on agricultural production as well as other household characteristics. This makes it particularly useful for the purpose of the present paper.

Geographically, Nicaragua can be divided into three major zones: The western (Pacific) lowlands, the central highlands, and the eastern (Atlantic) lowlands. The western zone is relatively flat and fertile, and it is the most densely populated region. Most of the major cities are located in this area, and the infrastructure is more developed here than in the rest of the country. The topography of the central zone is mountainous, and the infrastructure less developed than in the western zone. The eastern part of the country consists mostly of tropical rain forests and mangrove swamps. The zone is sparsely populated and the infrastructure is poorly developed. Thus, agriculture is important all over the country, but probably the most favourable conditions exist in the west. Similarly, non-agricultural work opportunities must be expected to be better in the western zone.

The Nicaraguan population is very young. About 43% of the population is younger than 15 years, and the average household size is approximately six persons. The population of interest in this paper is the population of agricultural households, defined as those households that undertake agricultural production as self-employed, using either own, rented, or borrowed land. In the EMNV98, 1469 households report that they undertake agricultural production, apart from what is produced in their back garden. Of these households, 252 (17.2%) were classified as urban, i.e. situated in villages with more than 1000 inhabitants.[7]

[7] Corral and Reardon (2001) have previously used the EMNV98 for analysing the patterns and determinants of rural non-farm incomes and activities. They focused on the rural population, which left them with 1939 households of which 62.1% were agricultural

The 1469 households correspond to a total of 9170 persons. The data set contains individual observations for 9108 of these individuals, of which 7382 are of age 6 or above. It is the behaviour of these persons which are to be analysed in the following. Missing observations for some variables will, however, decrease the actual number of individuals to be used in the analysis.

The left part of Table I reports the distribution of individuals on different work categories according to their primary occupation in the last week before the interview. The "No" category includes unemployed as well as persons undertaking only home work (cooking, cleaning, etc.). In the right part of the Table, the total off-farm participation rate is reported, i.e. individuals who report to have participated in off-farm work as either their primary or secondary activity in the last week. These individuals are then split up between agricultural and non-agricultural wage work. If an individual has participated in both types of off-farm work, he is classified according to his primary activity. In the lower part of Table I, a stratification according to consumption levels is presented.[8]

The important things to note from Table I are: Off-farm work appears to be an important economic activity for agricultural households, at least when measured by occupation rates. Furthermore, the prevalence of agricultural off-farm work indicates that agricultural factors must be important. Agricultural wage work is most important in rural regions whereas non-agricultural wage work dominates in urban regions, perhaps a sign of different local labour-market conditions. The typical off-farm worker is male, between 15 and 50 years of age, and from a small, but not necessarily poor, household.[9]

4.1 Variables

The left-hand side variable is a categorical variable, defined as in Section 3. It indicates an individual's main activity out of the activities considered,

producers. They argued that the share of agricultural income in total urban household income is low. The above figures show that the share of urban households in agricultural households is significant. Hence, from the point of view of agricultural producers, urban households should not be ignored.

[8]The stratification variable is annual household consumption per capita, adjusted for differences in geographic prices. Due to variability of income, consumption is often used as a more reliable estimator of the underlying income level of the household, see e.g. Deaton (1995).

[9]Distinguishing between agricultural and non-agricultural wage work, the typical agricultural off-farm worker is male, between 15 and 24 years, and from a small and *poor* rural household. The typical non-agricultural wage worker, on the other hand, is male or female, between 25 and 50 years, and from a small and *wealthy* urban farm household.

which are: Agricultural off-farm work and non-agricultural off-farm work. More specifically, an individual is considered as participating primarily in, say, agricultural off-farm work, if this was either his primary or secondary work activity in the last week – given that non-agricultural off-farm work was not the primary activity. He is considered as not participating in any of the activities, if none of them was the primary or the secondary activity.[10]

The choice of explanatory variables is based on the theoretical discussion in Section 2 and on previous findings in related studies. The variables are grouped into: i) individual variables, capturing individual characteristics (human capital); ii) household variables, capturing summary statistics of households members; iii) regional variables, capturing local differences in agricultural and enterprise profitability together with local labour-market conditions; and iv) agricultural variables. Summary statistics are provided in Table II.

Individual variables: *Male*, *head*, and *spouse* are indicator variables taking the value one if the person is a male, the household head, and the spouse of the head, respectively. *Age* gives the age of the individual in years, and *education* is an imputed measure of completed years of individual education.[11]

Household variables: *Age of head* gives the age of the household head in years. The variable is used as a proxy for overall household and farm experience. A wide range of other summary variables were tried out but found insignificant, as will be discussed below.

Regional variables: *Rural* takes the value one if the household lives in a rural area; *road access* takes the value one if the home can be accessed directly by either a road or a trail; and *electricity* is a dummy for whether the household has electricity in the home. Again, a number of additional variables were tried out.

In order to examine the role of land and farm-capital markets in the off-farm participation decision, the variables *land size* and *capital* are included. *Land size* gives the size of the household farm in manzanas per adult household member, and *capital* measures the value of physical farm capital, such as equipment and installations, in Córdobas.[12]

[10] Note that this classification of regimes corresponds to the one used in the right part of Table I.

[11] The variable *education* is imputed as in Corral and Reardon (2001). Completed preschool was associated with 3 years; primary school, 6 years; secondary school, 11 years; basic technical school, 6 years; middle technical school, 9 years; superior technical school, 12 years; and university, 16 years. To these years, the number of completed years at the current education level was added.

[12] 1 manzana is approximately equal to 0.7 hectare, and 1 Córdoba = 10.28 US $ as of April 1, 1998.

Since observations on "access to credit" are not available, observations on "use of credit" are relied on instead. If credit-market failures prevent some households from obtaining credit and force them to work off the farm, a relationship between use of credit and off-farm labour should arise.

With respect to risk, observations on preferences (risk aversion), inherent farm risk, cost of crop diversification, and realised shocks would be optimal from a theoretical point of view. Previous studies based on panel data have used measures of historical rainfall variability in different regions, as in Rose (2001), or historical on-farm income variability, as in Mishra and Goodwin (1997), to measure the inherent farm risk.[13] In addition, Rose (2001) used yearly observations on rainfall to address ex-post responses to risk. The cross-sectional nature of the present data does not allow for the construction of such measures, nor does it allow for a distinction between ex-ante and ex-post responses as in Rose (2001). Instead, the approach taken is to use a measure of on-farm crop diversification as a proxy for cost of diversification. Households with high cost of crop diversification will diversify less and use off-farm work as an alternative means of diversifying risk.

The *crop diversification* index is computed as an inverse Simpson index:

$$crop\ diversification_i = \frac{q_i^2}{\sum_{s=1}^{n_i} q_{is}^2} \leq n_i$$

where n_i is the number of different crops harvested by household i over the last twelve months, q_{is} is the value of crop s, and $q_i = \sum_{s=1}^{n_i} q_{is}$. The range of the index is $[1, n_i]$. A higher number of crops and/or more equally distributed income between crops will cause a higher value of the index.[14]

The data does not allow us to infer differential costs of using commodity markets across households. Instead, a measure of market integration is constructed to analyse the potential role of commodity-market failures in shaping off-farm behaviour. The variable *marketed share* gives the value of marketed crops relative to the total value of produced crops by the household.

[13] A slightly different approach taken by Kanwar (1999) is to use a panel to estimate a farm production function from which to obtain a measure of the conditional variance of farm income.

[14] Such a measure has previously been used by e.g. Valdivia, Dunn, and Jetté (1996) in the case of Bolivian households to compute a measure of household diversification over all types of income. To construct the index, values of the different crops harvested by households are needed. The survey collected information on both the marketed and non-marketed amounts of crops for each household, but values were only reported for the marketed crops. Hence, observed values of marketed crops are used to construct average prices of crops. These are subsequently used to compute the values of the non-marketed crops. Households are allowed to report a maximum of 14 different harvested crops, thereby in practice bounding *crop diversification* from above by 14.

The idea is that households with higher costs of using commodity markets will have a lower marketed share.

In Nicaragua, the agricultural year consists of three cropping seasons: *Primera* starts with the onset of the first part of the rainy season in June and lasts until July/August where crops are harvested. *Postrera* lasts from the beginning of September where the second part of the rainy season begins and until November/December. The last cropping season, *Apante*, runs from December to March/April, but production in this cycle can only take place in some areas of the eastern and central zones. In the case of Nicaragua, agricultural activity must therefore be expected to be most intensive from June to December. To capture seasonal fluctuations, an indicator variable, *rainy season*, that takes the value 0 if the interview took place in April and May, and the value 1 if it took place in June, July, August, or September is included.

The various land reforms under the Sandinist government in the 1980s and the subsequent legal disputes over land rights between former owners and current users of the land have created a highly uncertain land-rights situation, where many peasants lack formal claims on their land.[15] To investigate the effects of uncertain property rights, the dummy variable *property right* takes the value one if the household holds some formal document of ownership on their land and if this document is recorded in the public register. In order to distinguish between the investment, credit and direct labour effects of uncertain property rights, as discussed in Section 2, measures of formal credit use are included. In addition, physical farm capital is controlled for via *capital*.

5 Results

Estimation results are presented in Table III. A large amount of different specifications were estimated along the way, as will be discussed below. The Table presents only the resulting preferred specification, where all insignificant variables have been left out. The inclusion/exclusion of these variables does not affect the estimated coefficients of the included variables.

In Table III, both the estimated coefficients, the β's, and the "relative risks" are reported. The relative risk measure is only relevant if the standard multinomial logit interpretation is applied. The measure is computed as the exponential value of the estimated coefficient, and it gives the change in the relative probability of the alternative (relative to the reference alternative, which in this case is no participation in off-farm work) for a one unit increase

[15] See e.g. Corral (1999) for a description of the reforms and the conflicts.

in the explanatory variable, i.e. the change in "odds". In the following, an interpretation of the coefficients in terms of the labour supply functions is offered.

The first thing to note from Table III is the significance of the variance of the random household effect. This justifies the use of a random effects model.

With respect to the individual variables, being a *male* is found to significantly increase agricultural off-farm labour, whereas it has no effect on non-agricultural labour. Similar results are found by de Janvry and Sadoulet (2001) and Ruben and van den Berg (2001) for Mexico and Honduras. *Age* has a concave effect on labour supply to both off-farm activities, implying that both agricultural and non-agricultural wage work are maximised at approximately 44 years of age. *Education* increases non-agricultural off-farm work but does not affect agricultural off-farm work significantly. Thus, age and sex are interpreted as important determinants of returns to agricultural wage work, whereas age and education are more important for the non-agricultural wage. Finally, being the *head* or the *spouse* is found to negatively affect both types of work. This is probably because the head and the spouse undertake special functions in farm and own-enterprise work and therefore face relatively higher marginal returns in these activities.

Turning to household characteristics, only *age of head* was found to be significant. Interpreting this variable as a proxy for farm experience, households with less experience and hence a lower return to agriculture are more inclined towards non-agricultural off-farm work. A vast number of additional household summary statistics were included in early estimations, including average education, age, and measures of household composition. None of these were found to affect the results.

Of the regional variables, infrastructure as captured by *road access* and *electricity* hook-up are positively correlated with off-farm work. This is interpreted as more developed areas having more (especially non-agricultural) off-farm opportunities; perhaps a more developed local labour market with reduced cost of searching for employment. Living in a *rural* area increases agricultural wage work and decreases non-agricultural wage work. Again, this is taken as evidence of varying local labour market conditions with better opportunities for agricultural wage work in a rural area and non-agricultural work in an urban area. Decomposing the rural variable into finer regional measures did not add anything. This was somewhat surprising, bearing in mind the huge infrastructural and climatic variations across the country. Other measures of local conditions, such as distances to various locations and local availability of technical assistance, were included at earlier stages but did not have any effect on the results.

These findings all seem uncontroversial and relate well to previous studies of Nicaragua, see Corral and Reardon (2001), and other countries and regions, see e.g. the surveys in Reardon, Berdegué, and Escobar (2001) and Reardon, Stamoulis, Balisacan, Cruz, Berdegué, and Banks (1998).

Now, focusing on the agricultural variables, the results in Table III suggest that individuals from households with a smaller *land size* and less *capital* work more outside the farm. This supports the raw figures in Table I.[16] Similar results have been found by e.g. Ruben and van den Berg (2001) in the case of Honduras and Elbers and Lanjouw (2001) for Ecuador, in addition to early studies by Bardhan (1979) and Rosenzweig (1980) using Indian data. Note, however, that these results must be interpreted with some caution. If the simple correlation between land size and the amount of off-farm work is considered, a negative relationship must be expected to emerge, even in the case of perfectly functioning land markets. Households that have a comparative advantage in off-farm work, perhaps due to highly educated members, will also most likely choose to operate a smaller farm. Hence, simply observing a negative relationship does not make land a determinant of off-farm labour supply. Both off-farm work and the operational land size might be determined by the underlying individual and household characteristics. Only if it is believed that there has been controlled appropriately for individual and household characteristics, can a negative relationship be taken as an indication of a an effect of constrained access to capital and land for some farmers. The present study has explicitly attempted to do so by including random household effects and a wide range of individual and household variables before assessing the role of agricultural conditions. Hopefully, more confidence can therefore be put in the present results than in previous findings.

The negative relationships between land and capital on the one hand and off-farm work on the other could of course also emerge as a consequence of credit market constraints. However, none of the included credit variables turned out to have any explanatory power and did not affect the coefficients on *land size* and *capital*. Hence, differential use of credit could not explain why small farmers work more off the farm.[17]

The fact that the coefficient on *crop diversification* is significantly nega-

[16] In the regressions, the natural logarithm of *land size* was used because of large outliers in the sample, and because the indicated relationship between land size and off-farm participation in Table I seems to reveal a non-linear pattern which could be captured by using ln(*land size*).

[17] As above, it is important to distinguish between the effects caused by individual and household characteristics and those caused by market failures. Households with a smaller comparative advantage in farming might also be the households that choose to borrow less.

tive with respect to agricultural off-farm work indicates that this activity is used as a means of diversifying income risk. Those households that diversify less in farm production diversify more through off-farm work. As mentioned in Section 2, this effect is hypothesised to work through differential costs of diversification. Households with high costs will diversify less and prefer to use off-farm work as a stabilising device.

If differences in risk aversion and or inherent farm risk were more important determinants of risk behaviour, one would expect a positive relationship between crop diversification and off-farm work to appear. Risk averse households or households facing high uncertainty would diversify more (in all directions) than other households.[18] However, it cannot be ruled out that ex-post reactions to shocks are also to some extent captured by *crop diversification*. Negative shocks to some crops will result in a lower value of the index, and one would expect that households experiencing adverse shocks would try to compensate through off-farm work.[19]

In sum, off-farm work seems to be an important component of risk management strategies of agricultural households. This supports existing evidence for India, as found by Saha (1994), Kochar (1999), and Rose (2001), and for the US, as documented in Sumner (1982), Mishra and Goodwin (1997), and Mishra and Goodwin (1998). So far, however, evidence for other countries, in particular less developed countries, has not been available.

Agricultural off-farm work is also found to be negatively correlated with *marketed share*. That is, individuals from households that market a larger share of their crops participate less in off-farm work. Though this does not directly imply anything about the imperfect functioning of commodity markets, it indicates that off-farm work is traded off against cash crop production as a means of generating liquidity. The authors are not aware of any related empirical evidence of this result.[20]

Furthermore, both agricultural and non-agricultural off-farm work are found to be lower during the *rainy season* where input requirements on the family farm are higher. It is a bit surprising that also agricultural wage work is lower in the dry season, where agricultural labour demand must be

[18] In the case of perfect markets, on the other hand, one would not expect a relationship to emerge.

[19] In order to attempt to distinguish between ex-ante responses due to cost differences and ex-post responses due to realised shocks, a qualitative measure of experienced negative shocks to production were included in the regression. It turned out to have no effect on the results.

[20] An alternative explanation might be that larger farms in general market a larger share of their production. Hence, the relationship between *marketed share* and off-farm work could actually be a relationship between farm size and marketed share. However, since *land size* is already included in the regression, this possibility seems unlikely.

expected to be higher. The results therefore strongly support the idea that off-farm work is used to smooth labour supply over the year.

Finally, legal rights are negatively correlated with off-farm work. Since controlling for credit and capital does not change this, the negative coefficient on *property right* is interpreted as a direct labour effect. Households with uncertain property rights spend less time in activities such as land and plant maintenance that increase the value and productivity of the farm. This interpretation is supported by additional evidence from the survey: Among those households that did not hold any document on their land, 94.5% indicated that they would prefer having a document. Out of these, 71.3% said that it was due to security reasons, whereas only 14.9% said that it was in order to improve their access to credit.

Previous studies have focused almost exclusively on the effects of property rights on capital investments, see e.g. Carter and Olinto (2000), where the evidence has been mixed. In a recent study of the northwestern region of Nicaragua, Foltz, Larson, and Lopez (2000) found that uncertain property rights positively influenced off-farm income, whereas they were unable to find any effect on physical investments. The results of the present paper provides a possible interpretation of their result.

In sum, there are clear cut differences between the determinants of agricultural and non-agricultural off-farm work. Whereas nonagricultural off-farm work seems to be largely determined by comparative advantages such as education, age, and infrastructure, there is considerable evidence supporting the hypothesis that agricultural off-farm work serves an important role in mitigating various unfortunate agricultural conditions. It seems as if agricultural off-farm work is used both to manage risk, generate liquidity, compensate for insecure property rights, and perhaps also to overcome input constraints in land and capital markets.

The fact that agricultural and non-agricultural off-farm work is affected differently by agricultural conditions is interpreted as follows: Households that have a comparative advantage in agriculture are also those households affected by imperfect agricultural conditions such as missing markets, high risk, and imperfect property rights. Hence, these households try to compensate through off-farm work. But having a comparative advantage in agriculture, they turn to agricultural wage work.

All of these findings turned out to be extremely robust to changes in the individual and household variables included in the model. Furthermore, including an extra activity such as own-enterprise work did not affect the parameter estimates of the already included activities, supporting the robustness and validity of the model.

6 Conclusion

The purpose of this paper has been to analyse the determinants of off-farm labour activities by agricultural households in Nicaragua. The paper has simultaneously investigated a number of hypotheses about the role of different agricultural conditions in shaping off-farm labour supply, comparing their effects to those of underlying comparative advantages of individuals and households.

Initially, labour supply functions for a range of activities were derived from a theoretical agricultural household model, explaining differences in labour supply among individuals as a result of differences in their comparative advantages. It was then considered how various agricultural conditions, such as production risk, market failures, and property rights uncertainty would lead to modifications of these supply functions.

Linearised versions of the supply functions were subsequently used for the specification of the econometric model, where a random-effects specification was applied to account for unobserved random household effects. A likelihood function was derived based on categorical observations on primary labour activity, and it was shown that the resulting function was equivalent to that of a multinomial logit model. However, the random household effects prevented estimation of the model using a predefined statistical software procedure. Instead, a recently developed idea was applied to rewrite the model as a non-linear Poisson model and estimate it in SAS. The model was estimated using data from the 1998 Living Standards Measurement Survey in Nicaragua.

A general finding was that non-agricultural wage work seems largely to be determined by comparative advantages, most importantly age, status in the household, education, and local infrastructure. Agricultural wage work, on the other hand, is seriously influenced by agricultural conditions. More specifically, agricultural wage work was found to be used by agricultural households to diversify risk in farm production, to substitute for cash crops in generating liquidity, to smooth labour supply over the year, and possibly to substitute for constraints in land and capital markets. In addition, uncertain property rights where found to increase off-farm work by reducing incentives for on-farm labour investments. Somewhat surprisingly, credit was not found to have an effect on off-farm work. These findings all turned out to be extremely robust. Inclusion of additional individual and household variables to control for underlying comparative advantages did not affect the results.

Thus, it appears that individuals having a comparative advantage in agriculture are also those affected negatively by different agricultural conditions. Given their comparative advantage in agriculture, they turn to agricultural wage work as the solution to their problems. From a policy point of view, this is extremely important. As an example, limiting the demand for agricultural wage labour, e.g. through the often advocated land reforms, is likely to have a significant negative impact on agricultural households, unless the conditions leading to off-farm supply are dealt with at the same time.

The present paper has attempted to provide a more structural and theoretically founded analysis of off-farm work than has usually been the case within the literature on off-farm work. This is highly important if anything is to be inferred about underlying mechanisms and incentives. Still, the analysis of the off-farm work decision could be even more structural. Marginal return functions could be estimated along the lines of Newman and Gertler (1994), while allowing for a more complex error structure as in the present paper. This is left for future research.

A Appendix

This appendix shows the equivalence between the likelihood function of the multinomial logit model with random effects and that of a non-linear Poisson model. Furthermore, it is sketched how this equivalence can be exploited in estimating the multinomial model in SAS.

From (9), the contribution to the log-likelihood function from household i is given by:

$$\log \mathcal{L}_i = \log \left[\int_{u_i} \left(\prod_{t=1}^{T_i} \frac{e^{x_{it}\beta_{j(t)}+u_{ij(t)}}}{1+\sum_{k=1}^{J} e^{x_{it}\beta_k+u_{ik}}} f(u_i) \right) du_i \right]$$

where the different regimes are indexed by $j = 0, ..., J$, and $j(t)$ is the choice made by individual t, $t = 1, ..., T_i$. β_k, $k = 0, ..., J$ are the parameter vectors associated with the $J + 1$ different regimes, where β_0 equals zero. x_{it} is the vector of regressors which are individual specific. u_{ij} is the random-effects term, which is constant across individuals from the same household. It is assumed that $u_i = [u_{i1}...u_{iJ}]'$ follows a multivariate normal distribution with density function $f(u_i)$, and that $u_{i0} = 0$.

Then turn to the non-linear Poisson model. Define the following indicator variable:

$$W_{itj} = \begin{cases} 0 \text{ if } Y_{it} \neq j \\ 1 \text{ if } Y_{it} = j \end{cases}$$

I.e. the variable W_{itj} takes on a value for each regime choice that individual t from household i faces. This increases the total number of observations with a factor $(J + 1)$. Assume that:

$$W_{itj} \sim Poi(\lambda_{itj})$$

where:

$$\lambda_{itj} = \frac{e^{x_{it}\beta_j+u_{ij}}}{1+\sum_{k=1}^{J} e^{x_{it}\beta_k+u_{ik}}}$$

with β, x, and u defined as above. Now, use the fact that if $v \sim Poi(\lambda)$, then $f(v = 0) = e^{-\lambda}$ and $f(v = 1) = e^{-\lambda}\lambda$ to write the conditional likelihood of observing W_i for household i as:

$$\begin{aligned}
\hat{\mathcal{L}}_i\left(\cdot\,|u_i, x_{it}\right) &= \prod_{t=1}^{T_i}\prod_{j=0}^{J} f\left(W_{itj}|\,u_i, x_{it}\right) \\
&= \prod_{t=1}^{T_i}\prod_{j=0}^{J} e^{-\frac{e^{x_{it}\beta_j+u_{ij}}}{1+\sum_{k=1}^{J} e^{x_{it}\beta_k+u_{ik}}}} \cdot \left(\frac{e^{x_{it}\beta_j+u_{ij}}}{1+\sum_{k=1}^{J} e^{x_{it}\beta_k+u_{ik}}}\right)^{W_{itj}} \\
&= \prod_{t=1}^{T_i} e^{-1} \cdot \frac{e^{x_{it}\beta_{j(t)}+u_{ij(t)}}}{1+\sum_{k=1}^{J} e^{x_{it}\beta_k+u_{ik}}} \\
&= e^{-T_i}\prod_{t=1}^{T_i} \frac{e^{x_{it}\beta_{j(t)}+u_{ij(t)}}}{1+\sum_{k=1}^{J} e^{x_{it}\beta_k+u_{ik}}}
\end{aligned}$$

The unconditional log-likelihood contribution of household i then becomes:

$$\begin{aligned}
\log\hat{\mathcal{L}}_i &= \int_{u_i} \hat{\mathcal{L}}_i\left(\cdot\,|u_i, x_{it}\right) f\left(u_i\right) du_i \\
&= \log\left[e^{-T_i}\int_{u_i}\left(\prod_{t=1}^{T_i} \frac{e^{\beta'_{j(t)}x_{it}+u_{ij(t)}}}{1+\sum_{k=1}^{J} e^{\beta'_k x_{it}+u_{ik}}} f\left(u_i\right)\right) du_i\right] \\
&= -T_i + \log\mathcal{L}_i
\end{aligned}$$

where $\mathcal{L}_i$ is given by (9). This implies that maximising $\log\mathcal{L}$ is equivalent to maximising $\log\hat{\mathcal{L}}$, and that $\log\mathcal{L}$ can be found by computing $\log\hat{\mathcal{L}}$ and then adding $\sum_{i=1}^{I} T_i$.

The advantage of this equivalence is that $\log\hat{\mathcal{L}}$ is easily maximised in SAS. To do this, one has to expand the data set from $\sum_{i=1}^{I} T_i$ observations to $(J+1)\cdot\sum_{i=1}^{I} T_i$ observations, corresponding to one observation for each potential choice of each individual, instead of just one observation per individual. At the same time, the indicator variable W_{itj} must be defined. Then, the NLMIXED procedure in SAS is used to maximise the likelihood of the corresponding non-linear Poisson model. Finally, $\log\mathcal{L}$ is computed from $\log\hat{\mathcal{L}}$, while the parameter estimates are obtained directly. The program can be obtained on request from the authors. While it is easy to implement, the estimation time becomes considerable with more than three different regimes.

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TABLE I
PRIMARY OCCUPATION RATES AND TOTAL OFF-FARM PARTICIPATION

		Primary Occupation					Total Off-farm Participation			
	obs	No	On	Off	Own	Total	pct	obs	Aw	Naw
Total	6927	54.54	29.67	11.74	4.06	100	12.92	895	58.44	41.56
Regions										
Atlantic urban	316	58.86	22.47	11.39	7.28	100	12.97	41	39.02	60.98
Atlantic rural	1468	55.04	36.58	5.93	2.45	100	7.49	110	83.64	16.36
Central urban	433	56.12	23.56	14.78	5.54	100	15.94	69	30.43	69.57
Central rural	2692	53.23	33.21	10.88	2.67	100	11.89	320	71.25	28.75
Managua	180	54.44	11.11	25.56	8.89	100	26.67	48	32.33	66.67
Pacific urban	332	55.72	18.37	16.57	9.34	100	17.17	57	29.82	70.18
Pacific rural	1506	54.78	24.57	15.41	5.25	100	16.60	250	58.44	41.56
Sex										
Females	3237	81.87	5.53	6.83	5.78	100	6.98	226	23.01	76.99
Males	3690	30.57	50.84	16.04	2.55	100	18.13	669	70.40	29.60
Age groups										
6-14 years	2305	80.78	16.18	2.17	0.87	100	2.30	53	81.13	18.87
15-24 years	1748	46.11	33.30	18.08	2.52	100	19.62	343	63.27	36.73
25-50 years	1991	36.56	37.57	17.68	8.19	100	19.64	391	48.59	51.41
>50 years	883	43.26	39.86	10.76	6.12	100	12.23	108	67.59	32.41
Land strata										
0-2 mzs	2338	55.52	23.57	16.25	4.66	100	17.62	412	57.52	42.48
2-5 mzs	1437	54.77	29.44	11.48	4.31	100	12.46	179	58.66	41.34
5-20 mzs	1460	53.22	33.77	9.04	3.97	100	10.21	149	59.06	40.94
20-50 mzs	835	54.49	33.89	7.90	3.71	100	9.58	80	62.50	37.50
>50 mzs	857	53.79	35.59	8.17	2.45	100	8.75	75	57.33	42.67
Total	6867	54.48	29.75	11.68	4.09	100	12.87	884	58.14	41.86
Income strata										
1st quintile	1373	58.34	30.15	9.76	1.75	100	11.43	157	75.80	24.20
2nd quintile	1373	56.88	31.25	9.98	1.89	100	11.58	159	68.55	31.45
3rd quintile	1374	54.15	28.97	12.95	3.93	100	13.83	190	61.05	38.95
4th quintile	1373	54.26	29.35	12.02	4.37	100	12.96	178	52.25	47.75
5th quintile	1374	48.76	29.04	13.68	8.52	100	14.56	200	38.50	61.50

"No" = no work in the last week,
"On" = on-farm as primary activity in the last week
"Off" = off-farm as primary activity in the last week,
"Own" = own enterprise as primary activity in the last week

"Off" as primary or secondary activity
"Aw" = agricultural wage work,
"Naw" = Non-agricultural wage work

Table II
Explanatory Variables and Summary Statistics

	Variable Name	Obs	Mean	Std. Dev.	Min	Max
Individual	Male	6927	0.5327	0.4989	0	1
	Head	6927	0.1991	0.3993	0	1
	Spouse	6927	0.1601	0.3667	0	1
	Age	6927	26.5251	18.5942	6	97
	Education	6927	2.5958	2.9776	0	16
Household	Age of head	6927	48.2090	14.5039	17	97
Regional	Rural	6927	0.8350	0.3712	0	1
	Road access	6927	0.8884	0.3149	0	1
	Electricity	6927	0.2860	0.4519	0	1
Agricultural	Land size	6927	7.9214	23.7265	0.00175	495
	Capital	6927	3,771.638	119,148.2	0	3,244,100
	Crop diversification	6927	2.1333	0.9723	1	7.26
	Marketed share	6927	0.2752	0.3047	0	1
	Rainy season	6927	0.6578	0.4746	0	1
	Property right	6927	0.4032	0.4906	0	1

Variable definitions in the text.

Table III

Estimation Results

	Variables	Agri. wage work coef	st.er	p-val	risk	Non-agri. wage work coef	st.er	p-val	risk
individual	Male	2.7407	0.2236	0.000	15.4978	0.0427	0.1574	0.786	1.0436
	Head	-1.3322	0.2440	0.000	0.2639	-1.1515	0.2546	0.000	0.3162
	Spouse	-2.0929	0.3605	0.000	0.1233	-1.6830	0.2630	0.000	0.1858
	Age	0.2801	0.0219	0.000	1.3233	0.3209	0.0264	0.000	1.3784
	Age squared	-0.0032	0.0003	0.000	0.9968	-0.0037	0.0003	0.000	0.9963
	Education	-0.0424	0.0283	0.134	0.9585	0.2174	0.02258	0.000	1.2428
Household	Age of head	-1.0062	0.7622	0.187	0.3656	-2.5904	0.7217	0.000	0.0750
Regional	Rural	0.9329	0.3055	0.002	2.5419	-0.3774	0.1910	0.048	0.6856
	Road access	0.9183	0.3398	0.007	2.5050	1.1671	0.3973	0.003	3.2127
	Electricity	0.0615	0.2418	0.799	1.0634	0.8977	0.1807	0.000	2.4540
Agricultural	ln(Land size)	-0.2204	0.06923	0.002	0.8022	-0.1973	0.0575	0.001	0.8209
	Capital	-0.0883	0.1343	0.511	0.9155	-0.3276	0.1193	0.006	0.7207
	Index	-0.2832	0.1064	0.008	0.7534	-0.0413	0.0798	0.605	0.9595
	Market share	-1.1109	0.3357	0.001	0.3293	-0.2174	0.2535	0.391	0.8046
	Rainy season	-0.4461	0.2021	0.027	0.6401	-0.4876	0.1604	0.002	0.6141
	Property right	-0.6930	0.2188	0.002	0.5001	-0.2234	0.1765	0.206	0.7998
	Sigma	5.1940	1.0696	0.000		1.3522	0.3528	0.000	

"Risk" is the exponential value of the coefficient

Number of observations = 6927

Log likelihood = -2444.80

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