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Shadow Wages and Peasant Family Labour Supply: An Econometric Application to the Peruvian Sierra

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This paper develops a methodology for estimating structural time-allocation models for self-employed households and applies it to peasant family labour supply behaviour in the Peruvian Sierra. The opportunity costs of time, or shadow wages, of household workers are explicitly estimated from an agricultural production function. Using an instrumental variables procedure, the household's structural labour supply parameters are recovered from variation in these shadow wages. The empirical results are robust to a number of alternative specifications and diagnostic tests and lend support to the rational allocation of time by peasant households.

I. INTRODUCTION

A striking feature of developing economies is the typically large proportion of the work force that is not primarily engaged in wage labour. Self-employment is particularly pervasive in agriculture, where the dominant unit of production is the family farm. Lack of widespread labour market participation can pose a major obstacle to the empirical implementation of economic models of the peasant household. Such models are important in evaluating the effects of policies directed at this poorest segment of the population. Schooling, migration and fertility choices, and even the allocation of food among household members, are thought to depend upon current or future opportunity costs of time (see, e.g. Rosenzweig and Evenson (1977) and Rosenzweig and Schultz (1982)). For labour market participants this cost is just their wage rate, which is usually taken as exogenous to the individual in empirical studies. The absence of wages for the self-employed complicates even a basic study of their labour supply behaviour, not to mention the estimation of more elaborate time-allocation models.

This paper develops a general methodology for estimating structural time-allocation models for agricultural households whose members do not work for wages, though the technique is applicable to self-employment in other contexts as well. For the self-employed, the opportunity cost of time, or "shadow wage", is determined from within the household, rather than by market forces, unless certain strong conditions hold. The methodology is closely related to the treatment of labour supply with progressive income taxes, initiated by Hall (1973). A concave budget constraint, in the form of an agricultural production function, is "linearized" at the household's optimum to obtain a set of shadow wages for different workers. At the equilibrium point, the shadow wage of each farm worker is just the marginal product of their labour in agriculture. Along with equilibrium farm profits, these shadow wages map out the structural labour supply parameters of each worker.

The empirical strategy, therefore, is to first estimate an agricultural production function, which has different types of labour (that of men, women, children and hired workers) as distinct inputs. Since this study focuses on the labour supply of men and women in the Peruvian highlands, the marginal product of adult male and female farm labour is calculated for each household. Using these marginal products in place of wages, a family labour supply model along the lines of Ashenfelter and Heckman (1974) is estimated and the restrictions implied by utility theory are tested.

Rosenzweig (1980) is the only previous attempt to confront the neoclassical family labour supply model with data from a developing country. He assumes efficient labour markets in rural India and imputes wages from market participants to the self-employed. However, labour market participation in rural India, especially in landed households, is quite limited. Rosenzweig's approach builds on the consumer-producer agricultural household models of Lau, Lin and Yotopoulos (1978) and Barnum and Squire (1979). The empirical tractability of these models derives from their "recursive" property, in which the household is viewed as first maximizing farm profit, and then maximizing utility conditional on profit. This two-stage maximization problem implies an aggregate labour supply function for the family that depends only on the market wage and on farm profit, regardless of the household's position in the labour market. Beyond maintaining that rural labour markets are efficient and free of transactions costs, these models assume that family and hired labour are perfect substitutes. Recent empirical studies in developing countries (e.g. Deolalikar and Vijverberg (1987)) call into question this perfect substitutability assumption.

The model of peasant family labour supply proposed here retains the structure and tractability of these recursive agricultural household models, but eschews their stringent assumptions.[1] Because the estimation does not rely on market wages, the implications of utility theory and the hypothesis of efficient rural labour markets need not be tested jointly. In addition, neither hired and family labour nor the labour inputs of different family members are restricted to be perfectly substitutable in agricultural production. The methodology also does not require that a value of time be imputed from a small group of wage labourers to a much larger group of self-employed workers. Finally, pure income effects on labour supply can be obtained because (shadow) farm profits capture the returns to quasi-fixed productive assets, such as land. In Rosenzweig's study no adequate measure of non-labour income for poor households is available.

The next section of the paper presents a general model of time allocation in agricultural households, containing a recursive model only as a special case. Section III discusses how such a model can be estimated and addresses the identification and selection issues. The following two sections report the empirical work, with the production function estimates in Section IV and the labour supply estimates in Section V. Section VI concludes the paper.

II. THEORETICAL FRAMEWORK

Consider an agricultural household in which men and women jointly choose the consumption of market goods (C), home produced goods (Q), their respective allocations of T

1. Lopez (1984) is the only previous attempt to estimate a non-recursive agricultural household model, where work on the family farm and market work are imperfectly substitutable in utility and production. His model is estimated on aggregate Canadian data and uses a more complicated joint estimation strategy that relies on some strong functional form assumptions, including constant returns to scale in production. Lopez ignores heterogeneity of labour within the household.

hours between own-farm work (L_i, $i=1,2$), market work (M_i), home production (S_i) and leisure ($\mathscr{L}_i$), as well as the inputs of male and female hired labour (H_1 and H_2) into own-farm production. The household has preferences over leisures and composite commodity $\mathscr{C}=C+\theta Q$ (assuming Gronau's (1977) form of perfect substitutability), maximizing $U(\mathscr{C}, \mathscr{L}_1, \mathscr{L}_2; \boldsymbol{Z})$, where $\boldsymbol{Z}$ is a vector of taste shifters, subject to the budget constraint

$$C = Y - W_1^H H_1 - W_2^H H_2 + W_1 M_1 + W_2 M_2 \tag{1}$$

where the W_i^H and W_i are the wages of hired and family labour, respectively; the strictly concave agricultural production function, $Y=F(L_1, L_2, H_1, H_2, A)$, where A is a vector of fixed inputs (e.g. land) and the price of the composite consumption good is normalized to unity and set equal to the price of farm output, Y; the strictly concave home production technology, $Q=\Phi(S_1, S_2, \boldsymbol{I})$, where $\boldsymbol{I}$ is a vector of fixed inputs; and the inequality constraints: $M_i \geqq 0$, $L_i \geqq 0$, $S_i \geqq 0$, and $H_i \geqq 0$, $i=1, 2$. All individuals are assumed to work in at least one sector ($\mathscr{L}_i < T_i$).

The first-order conditions for this problem state that each household member equates their marginal rate of substitution between consumption and leisure, or shadow wage, either to their market wage or to their marginal product (in terms of the numeraire) in either housework or farm work. A recursive model arises if each type of family labour is a perfect substitute in production with its hired counterpart (i.e. $Y=F(L_1+H_1, L_2+H_2, A)$), rural labour markets are free of transactions costs,[2] and $W_i = W_i^H$. In this case, labour supplies are determined by $U_{\mathscr{L}i}/U_{\mathscr{C}} = W_i$, own-farm labour demand functions solve $F_{Li} = W_i$, and consumption and production decisions are separated regardless of the household's position in the labour market.

In the more general model, there are a variety of regimes to consider. If both family member's work in the labour market, then $U_{\mathscr{L}i}/U_{\mathscr{C}} = W_i$, regardless of the substitutability of family and hired labour, and a standard family labour supply model emerges. However, this case only applies to samples of households in which every member (or at least one member of each type) is a labour market participant. As pointed out above, such samples are likely to be very unrepresentative in many developing countries.

If either $M_1=0$ or $M_2=0$, and both family members engage in farm work ($L_i>0$), then $U_{\mathscr{L}i}/U_{\mathscr{C}} = F_{Li}$. In this case, preferences for leisure enter into the farm labour demand decision, and, conversely, labour supplies are determined by the household's agricultural technology. A similar argument applies to the case where household members engage only in home production ($L_i = M_i = 0$ and $S_i > 0$), but instead $U_{\mathscr{L}i}/U_{\mathscr{C}} = \theta\Phi_{Si}$. Since the output from home production is not observable, this tangency condition will be of no direct use in recovering preferences. The remainder of this section considers the case in which both men and women work on the family farm, though the possibility that a sample of such households may not be random is recognized in the estimation.

Under general conditions the decision of some family members not to participate in the labour market leads to a household budget constraint that is non-linear in hours worked. At the optimum, however, the gradient of the budget constraint is just the shadow wage vector ($\hat{W}_1$, $\hat{W}_2$), where $\hat{W}_i \equiv F_{Li}$. Thus, at this point the constraint is linear. In particular, define full income at the household optimum by

$$\Lambda = \Pi^*(\hat{W}_1, \hat{W}_2, W_1^H, W_2^H) + \Psi^*(\hat{W}_1, \hat{W}_2) + \hat{W}_1 T + \hat{W}_2 T, \tag{2}$$

2. Rural labour markets are often characterized by the term "rationing". However, fixed transactions costs imply that farmers may simply find it prohibitively costly to supply a small number of hours to the market.

where

$$\Pi^* = \mathrm{Max}_{L_i, H_i}\, F(L_1, L_2, H_1, H_2, A) - W_1^H H_1 - W_2^H H_2 - \hat{W}_1 L_1 - \hat{W}_2 L_2$$

and

$$\Psi^* = \mathrm{Max}_{S_i}\, \theta\Phi(S_1, S_2, I) - \hat{W}_1 S_1 - \hat{W}_2 S_2, \qquad i = 1, 2$$

(see Strauss (1986) for a similar analysis). Π^* represents "shadow" farm profit, with the opportunity cost of family labour properly deducted. Likewise, Ψ^* is the "profit" from housework. The household full income constraint evaluated at the optimum—i.e. the "linearized" budget constraint—can be written simply as

$$\Lambda = \mathscr{C} + \hat{W}_1 \mathscr{L}_1 + \hat{W}_2 \mathscr{L}_2. \tag{3}$$

Maximization of the utility function subject to (3) yields the same first-order conditions as before, but looks like a pure consumer choice model. Linearizing the budget constraint is equivalent to turning the original time allocation problem into a two-stage (recursive) maximization problem, except that full income is conditioned on the demand for leisure and, conversely, the optimal leisure choices are conditioned on the production decisions.

The solution to this revised utility maximization problem is a set of Marshallian leisure demand or labour supply functions of the form

$$h_i = L_i + M_i + S_i = h_i(\hat{W}_1, \hat{W}_2, \Lambda; \mathbf{Z}), \qquad i = 1, 2. \tag{4}$$

Since the shadow wages are the prices of pure leisure in (3), labour supply is defined as total hours in productive activities, as opposed to market hours alone (e.g. Rosenzweig (1980)). This definition avoids the usual market hours corner solution ($M_i = 0$), and is sufficient to recover preferences.[3] Also, since men and women are not necessarily perfect substitutes in production, and separability on the preference side is not imposed, male and female labour supplies will in general depend on both shadow wages. Unless the model happens to be recursive, shadow wages and full income are jointly determined with labour supply; in other words, they are endogenous.

To get standard comparative static results with respect to changes in the shadow wages, notice that the dual to the utility maximization problem, the constrained minimization of (3) with respect to $\mathscr{C}$, $\mathscr{L}_1$ and $\mathscr{L}_2$, gives the expenditure function, $\Lambda(\hat{W}_1, \hat{W}_2, u)$. The Marshallian and Hicksian labour supply functions can then be equated,

$$h_i(\hat{W}_1, \hat{W}_2, u) = h_i(\hat{W}_1, \hat{W}_2, \Lambda^*(\hat{W}_1, \hat{W}_2, u)), \qquad i = 1, 2 \tag{5}$$

and differentiated with respect to the shadow wages to give the Slutsky equations for $i = 1, 2$ and $j = 1, 2$

$$\partial h_i / \partial \hat{W}_j = \partial h_i / \partial \hat{W}_j |_u + (T - \mathscr{L}_j) \partial h_i / \partial \Lambda. \tag{6}$$

When the household cannot hire perfectly substitutable workers from the outside, it may be viewed as participating in "shadow markets" for the labour of its members. The household's net position in a particular shadow market, or its point of compensation, is just its own supply of that type of labour.[4] Utility theory implies that when $i = j$ the first term on the right-hand side of (6), the compensated own wage effect, is unambiguously

3. In contrast, Lopez (1984) considers the case where farm and market work are imperfectly substitutable in utility and derives separate supply curves for each type of labour, under the assumption of interior solutions. Because of the overwhelming importance of non-market time in Peru, the allocation of time between market and non-market activities is only a secondary issue.

4. Thus, if the family has several male workers, say, the point of compensation for each individual worker is the sum of the labour supply of all males.

positive, and that the compensated cross-wage effects are equal; i.e. $\partial h_1/\partial \hat{W}_2|_u = \partial h_2/\partial \hat{W}_1|_u$.

A final point to contend with is the possibility of savings or dissavings. In the static agricultural household model, farm profit is used as a measure of non-labour income, and Λ is replaced by Π^* in equations (4) and (6). However, if households borrow and lend, then an additional term, the net change in financial assets (physical investment is ignored), appears on the right hand side of the full income constraint (3). Under intertemporal separability of preferences, Blundell and Walker (1986) show that (4) is a legitimate within-period family labour supply model, but that it is inappropriate to condition on profits (or non-labour income). They suggest estimating (4) by exploiting the budget identity, (3), using household expenditure data. More will be said about this procedure in the next section.

III. EMPIRICAL STRATEGY

A. *The estimating model and the stochastic environment*

When both males and females work on the family farm, labour supply functions (4) can be made operational by substituting the marginal product of farm labour for the corresponding shadow wage, and, in the static case, by replacing full income with farm profits to give

$$h_i = h_i(F_{L1}, F_{L2}, \Pi^*(F_{L1}, F_{L2}, W_1^H, W_2^H); \boldsymbol{Z}), \qquad i = 1, 2. \tag{7}$$

Both the marginal products and farm profits are evaluated at the optimal—i.e. the observed—labour supply choices of each household.

In a sample containing part-time wage earners, the market wage could be used in place of the marginal product of labour on the farm in (7), but only if working off the farm entails no transaction cost. In Section V, the restriction that the marginal product equal the wage for these workers is tested before imposing it in the estimation.

The empirical model consists of a production function specification, with functional form f, and a pair of labour supply equations,

$$Y = f(L_1, L_2, \boldsymbol{X}, \boldsymbol{A}, \beta) + \varepsilon \tag{8}$$

$$h_i = g_i(\boldsymbol{\Gamma}, \boldsymbol{Z}, \gamma_i) + u_i, \qquad i = 1, 2 \tag{9}$$

where

$$\boldsymbol{\Gamma} = (f_{L1}, f_{L2}, f - f_{L1}L_1 - f_{L2}L_2 - \boldsymbol{P}_x\boldsymbol{X})$$

and where ε and u_i are the production and labour supply disturbances, respectively, $\boldsymbol{X}$ is the vector of variable inputs with prices $\boldsymbol{P}_x$, $\boldsymbol{A}$ is a vector of fixed inputs, and β and γ_i are the production and labour supply parameters, respectively. $\boldsymbol{\Gamma}$ contains the marginal products and farm profit expressions and depends, in particular, on L_i and β. Additive disturbances are assumed for the sake of exposition.

For the production disturbance, ε, to be orthogonal to the variable inputs, it must be unknown to the farmer in advance of input decisions (Zellner, Kmenta and Dreze (1966)). Simultaneity bias in the production function estimates could result if the disturbance is anticipated, or if it contains unobservable inputs such as managerial ability. Although it is important to test for the presence of such bias, the endogeneity of the variable inputs is unrelated to the question of whether the underlying agricultural household model is recursive or not. On the other hand, the non-recursive nature of the model directly implies correlation between the labour supply disturbances, u_i, which represent unobserved heterogeneity in the preference for leisure, and shadow wages and profit. Thus, to get consistent estimates of the γ_i, instruments must be found for the elements of $\boldsymbol{\Gamma}$.

Rather than estimate the system formed by (8) and (9) jointly, a more pragmatic two-step method is adopted.[5] First the production function is estimated and $\hat{\boldsymbol{\Gamma}}$ is calculated using the estimates of β. Then instrumental variable estimates of the labour supply parameters are obtained and their covariance matrices are adjusted for the fact that $\hat{\boldsymbol{\Gamma}}$ is a function of pre-estimated regressors.

The life-cycle consistent version of equation (9) replaces profit with an estimate of full income, using a measure of household expenditures, E; i.e.

$$\hat{\Lambda} = E + \hat{f}_{L1}(T - h_1) - \hat{f}_{L2}(T - h_2). \tag{10}$$

Clearly, $\hat{\Lambda}$ must be treated as endogenous in (9), although this would be necessary in a recursive model as well.

B. *Identifying the model*

One limitation of cross-sectional data is that it is not possible to purge from the production function disturbance the so-called "fixed" effects (e.g. management ability) that may be correlated with the inputs. However, the bias due to the adjustment of variable inputs in anticipation of shocks can be rectified if instruments are available that are determined prior to the shock. For example, the fixed home production inputs, I, and taste shifters, $\boldsymbol{Z}$, are natural exclusion restrictions and are especially likely to be correlated with the family's farm labour input.

In addition, the variation across households in the number of people working on the farm can be exploited. Given that the labour inputs of family workers of a particular type are perfectly substitutable, output is just a function of the total labour input of each worker type. The number of workers is obviously highly correlated with their total labour input. At the same time, if that number is a quasi-fixed asset of the household, it is uncorrelated with the disturbance in the production function.[6]

Interpreting the number of workers in each category as resource endowments of the household also allows them to be used as instruments for the shadow wages and profits in the labour supply functions. Intuitively, another adult male farm worker in the household should affect the labour supply of adult males only by lowering their marginal product and raising the family's profit from farming. If, however, demographic variables are also taste shifters, they cannot be legitimately excluded from the labour supply equation. Moreover, if the number of household members allocated to farm work is determined by their tastes for work, then using such variables as instruments may be inappropriate. The validity of these instruments is ultimately an empirical question, which can only be resolved by testing the overidentifying restrictions supplied by the theoretical model.

5. If the production and labour supply disturbances are correlated, then greater efficiency might be achieved by employing a full-information estimation method (as in Lopez (1984)). The difficulty is that even if the production function is linear in β, and the labour supply functions are linear in γ_i, the latter functions will generally not be linear in (β, γ_i). The approach adopted here is similar to that used by McCurdy and Pencavel (1986) in an entirely different context.

6. Rather than use the number of farm workers of each type as instruments for their labour inputs, in the actual estimation of the production function the total number of household members of each type is used, since these latter variables are even less likely to be correlated with the production shock.

Additional exclusion restrictions for the labour supply functions are the fixed farm inputs and characteristics, the effects of which should already be captured in the shadow wages and farm profits through the production function. Also, the fact that the marginal product in home production equals the shadow wage ($U_{\mathscr{L}i}/U_{\mathscr{C}} = \theta\Phi_{Si}$) for individuals engaged in home work, implies that the fixed home production inputs are valid instruments for the shadow wages.

C. *Binding non-negativity constraints and selection bias*

To estimate the agricultural technology as a joint male-female production function, a sample of households is chosen with both men and women working on the farm. As a result, shadow wages will only be available for individuals in these households. If the distribution of tastes for work in this sub-sample is not a random draw from the population of agricultural households as a whole, then the resulting estimates of substitution and income effects may not reflect the true population parameters.[7]

The probability of sample exclusion is Pr ($U_{\mathscr{L}1}/U_{\mathscr{C}} > F_{L1}$ and $U_{\mathscr{L}2}/U_{\mathscr{C}} > F_{L2}$). Since the sample is selected by type of household, rather than by type of individual, the following estimation scheme is adopted. Preference heterogeneity across households is characterized by a single random error term, incorporated into which is an independently distributed optimization error. The exclusion condition then leads to the usual univariate discrete choice probability (e.g. probit under normality of the disturbance), which can be estimated on the full sample of farm households. Based on these estimates, one can form estimates of the conditional means of the disturbances in (9) and test the hypothesis of sample selection bias using Heckman's (1980) two-step procedure.[8]

Finally, on the production side of the model there is the possibility of zero input use. When non-negativity constraints, such as that on hired labour, are binding, first-order conditions cannot be exploited to estimate the technology, as with a profit or input demand function. In the next section, however, the production function is estimated directly, so the only issue is whether the functional form allows for zero inputs.

IV. ESTIMATION OF THE AGRICULTURAL TECHNOLOGY

A. *The data*

The Peruvian Living Standards Survey (PLSS) was administered by the World Bank and the Peruvian Instituto Nacional de Estadistica in 1985–86 throughout the whole of Peru, and provides detailed information on the activities of about five thousand households and the time use of their members. Only households from the highlands region, or Sierra, that worked land and reported harvesting some crops are selected for this analysis; 1549 in all. The Sierra is where most of Peru's subsistence farming is concentrated, and it is ecologically distinct from both the coast and eastern jungle. For reasons already mentioned, the final sample consists of the 1034 households in which at least one adult male and female worked on the family farm.

7. Note, however, that unlike the usual sample selection problem in labour supply, excluded households are not necessarily those with less taste for work on average. Given their levels of agricultural and home production inputs, these households may simply choose to allocate the same number of work hours in a different way.

8. This univariate selection bias correction is a "reduced form", in that it does not impose any of the theoretical structure implicit in the selection rule. Doing so is very complicated and beyond the scope of this paper.

Multiple crop outputs are aggregated into a single output measure using the medians of their reported prices within each village as weights. Also added in is livestock output, measured as the sales of dairy, wool and other animal products plus twenty percent of the value of the household's herd.[9]

The input of land is measured as the amount at the household's disposal in the survey year, whether owned (which constitutes about ninety percent of the land area in this sample), rented or sharecropped.[10] Land, the proportion of land irrigated, the value of farm equipment (mainly animal ploughs), the value of farm animals used for traction (oxen, horses and mules) and a dummy variable for whether or not perennial crops are grown, are all assumed exogenous relative to the one-year planning horizon. A set of season of interview dummies and regional dummies for the northern and central parts of the Sierra are also included in the production function. In addition, age and schooling of the household head enter as proxies for the management input.

Only expenditure data are available for the variable physical inputs: insecticides, fertilizer, transportation, and livestock inputs (mainly food and medicine). The use of such data in place of quantities in the production function can lead to biased estimates if input price variation is substantial. Yet, taking this route seems preferable to ignoring these inputs altogether and suffering an omitted variables problem. Finally, family farm labour is divided into four categories as seen in Table I. Hired labour, including workers received from other households in labour exchanges, is not differentiated by sex in the survey, but in the Peruvian Sierra these workers are predominantly male.

B. *Estimates of a Cobb-Douglas production function*

To keep the estimation manageable in the presence of zero inputs,[11] a Cobb-Douglas (CD) production function is chosen with a constant equal to one added to all the inputs, except land and adult male and female labour.[12] The first column of Table II displays the OLS estimates. Land, irrigation and the other physical inputs have positive coefficients, with all but fertilizer and equipment achieving significance at the 5% level. Of the labour inputs, adult males contribute the most to output, followed by hired workers (who are mostly adult males) and adult females, the latter coefficient only verging on statistical significance. The contribution of teenagers and children appears to be relatively small.[13]

Column 2 of Table II shows instrumental variables (IV) estimates of the CD production function. Insecticide, fertilizer, transportation, the livestock inputs, and the five

9. This appreciation rate is rather arbitrary and is assumed constant across households. To assess robustness, other rates of appreciation are tried below. Also, value of the herd is based only on cows, sheep, pigs, goats and llamas, since oxen, horses and mules are used for traction, which is an input into the production of crops.

10. It is not known, however, if all this land was actually cultivated. Some of the land may have been left fallow, though in Peru such land is commonly used to graze livestock, which is included in the output measure. Irrigated land is also more likely to have been cultivated.

11. None of the inputs (except land and adult male and female labour, by construction of the sample) are used by every farm in the sample. For example, labour is hired by about three-quarters of the households and only about thirty percent use any fertilizer. Also, about half of the households report zero labour inputs for teenagers and even fewer use child labour.

12. McCurdy and Pencavel (1986), for example, also add ones. When this additive constant is set at either 0·1 or 10 the resulting marginal products are almost perfectly correlated with their counterparts based on the constant set at 1 (all correlations coefficients are about 0·99). Thus, the labour supply estimates will be robust to the choice of constant.

13. Estimated marginal products of male and female labour are also very robust to the choice of livestock appreciation rate. When this rate is set at 0·3 or 0·1, the resulting marginal products are almost perfectly correlated with those derived from the estimates in column 1 of Table II, based on a rate of 0·2.

TABLE I

Definitions, means and standard deviations of production function variables and additional instruments

	Definition of production function variables	Mean	Standard deviation
Value of output	Value of all drops harvested + sales of animal by-products + 0·2 × value of livestock (see text)	8,885	55,309
Land	Land area in hectares, owned and worked by the household, or rented or sharecropped	4·6	20
Equipment	Value of farm equipment	580	8,880
Insecticide	Expenditures on insecticide	71	215
Fertilizer	Expenditures on fertilizer	142	567
Transportation	Expenditures on transportation	66	342
Livestock	Expenditures on livestock inputs	173	568
Hired labour	(Days of labour hired + days received in labour exchange) × 10	292	1,235
Adult male labour[a]	Hours farm work, all male household members, age > 19	2,354	1,491
Adult female labour[a]	Hours farm work, females age > 19	1,940	1,311
Teenager labour[a]	Hours farm work, ages 12–19	1,050	1,609
Child labour[a]	Hours farm work, ages 6–11	541	963
Farm animals	Value of oxen, horses and mules	1,541	3,414
Irrigation	Proportion of land irrigated	0·30	0·40
Head's age	Age of household head	48·1	13·5
Head's schooling	Years schooling of head	2·9	2·9
Permanent crops	Dummy: 1 if had perennial (e.g. tree) crops (0 otherwise)	0·41	0·49
Harvest season	Dummy: 1 if interviewed during harvest season	0·23	0·42
Planting season	Dummy: 1 if interviewed during planting season.	0·28	0·45
Off-season	Dummy: 1 if interviewed between harvest and planting season	0·25	0·43
North	Dummy: 1 if live in northern Sierra	0·21	0·41
Central	Dummy: 1 if live in central Sierra	0·33	0·47

Definition of additional instruments

Household composition variables: Number of males age > 19, females age > 19, males 15 < age ≤ 19, females 15 < age ≤ 19, males 11 < age ≤ 15, females 11 < age ≤ 15, all children 5 < age ≤ 11, all children age ≤ 5.
Household characteristics and housework production shifters: Fraction of land area owned, village size dummy (1 if 2000 inhabitants, 0 otherwise), home ownership dummy (1 if own, 0 otherwise), water source dummy (0 if from river, 1 otherwise), light source dummy (1 if electric, 0 otherwise), cooking fuel dummy (0 if use wood, 1 otherwise), sewage disposal dummy (0 if none, 1 otherwise).
Community level wages and prices:[b] Adult male daily field wage, adult female daily field wage, price of kerosene, price of rice.

Notes: All variables refer to the twelve-month period prior to the date of interview. Monetary values are expressed in June 1985 Intis.
[a] The farm labour input is "usual" annual hours as a "self employed or unpaid family worker" for all individuals identified as farmers. The questionnaire uses a seven-day recall period, asking for both hours per week and weeks per year on the main jobs. If the individual did not work in the week prior to the interview, then a 12-month reference period is used.
[b] A community questionnaire appended to the PLSS provides village level information on only about half of the present sample of households. Wage and price data are extrapolated to the whole sample by assuming that prices vary less within a geographical division, e.g. a province, than across them. Thus, households in communities with missing prices are assigned the means of community level prices for that province.

categories of farm labour are endogenous under the alternative hypothesis. The instrument set, summarized in Table I, includes community level agricultural wages and prices, and twenty quadratic terms in the instruments. OLS and IV estimates of the labour input coefficients do not differ appreciably, but the fertilizer and insecticide coefficients do. Based on a Wu-Hausman test, the joint exogeneity hypothesis is just rejected at the 5% significance level, though not at the 2·5% level. Marginal products of male and female labour derived from these two production functions are reported at the bottom of Table

II. Because the correlation between marginal products across columns is very high, about 0·8 for male labour and 0·95 for female labour, the OLS and IV estimates are unlikely to lead to perceptibly different labour supply parameter estimates in the next stage of the analysis, though the ones based on the OLS estimates would be more efficient.

C. *Estimates of a translog production function*

To identify own and cross shadow-wage elasticities in equation (9), the marginal product of men must vary relative to that of women. But the CD production function imposes

TABLE II

Production function estimates

(Dependent variable: log value of output)

Independent variable	Cobb-Douglas		Translog (OLS)	
	OLS	IV[a]	I	II
Log land	0·221	0·217	0·221	0·217
	(0·020)	(0·029)	(0·020)	(0·020)
Log equipment	0·004	0·001	−0·006	−0·006
	(0·013)	(0·015)	(0·013)	(0·013)
Log insecticide[b]	0·062	0·301	0·000	0·006
	(0·016)	(0·079)	(0·024)	(0·024)
Log fertilizer[b]	0·023	−0·122	0·009	0·007
	(0·015)	(0·075)	(0·015)	(0·015)
Log transportation[b]	0·093	0·117	0·068	0·074
	(0·016)	(0·062)	(0·016)	(0·016)
Log livestock inputs[b]	0·054	0·074	0·048	0·049
	(0·013)	(0·044)	(0·012)	(0·012)
Log hired labour[b]	0·107	0·081	0·125	0·127
	(0·012)	(0·040)	(0·015)	(0·015)
Log adult male labour[b]	0·150	0·167	0·202	0·209
	(0·033)	(0·096)	(0·045)	(0·045)
Log adult female labour[b]	0·069	0·077	0·099	0·108
	(0·036)	(0·103)	(0·041)	(0·042)
Log teenager labour[b]	0·015	0·026	0·014	0·014
	(0·008)	(0·017)	(0·008)	(0·008)
Log child labour[b]	0·009	0·013	0·010	0·011
	(0·009)	(0·016)	(0·009)	(0·009)
Log farm animals	0·042	0·027	0·051	0·053
	(0·009)	(0·012)	(0·009)	(0·009)
Irrigation	0·186	0·235	0·215	0·197
	(0·071)	(0·089)	(0·069)	(0·070)
Head's age	0·000	0·001	0·001	0·001
	(0·002)	(0·003)	(0·002)	(0·002)
Head's schooling	0·043	0·047	0·041	0·041
	(0·011)	(0·015)	(0·011)	(0·011)
Permanent crops	0·166	0·144	0·185	0·185
	(0·059)	(0·076)	(0·058)	(0·058)
Log insecticide squared			0·030	0·029
			(0·009)	(0·009)
Log hired labour squared			0·016	0·015
			(0·006)	(0·006)
Log adult male labour squared			0·044	0·045
			(0·018)	(0·018)
Log adult female labour squared			0·057	0·047
			(0·023)	(0·023)
Log farm animals squared			0·017	0·017
			(0·004)	(0·004)

TABLE II—continued

Independent variable	Cobb-Douglas OLS	Cobb-Douglas IV[a]	Translog (OLS) I	Translog (OLS) II
Log adult male labour × log farm animals			−0·018	−0·024
			(0·009)	(0·009)
Log adult female labour × log land			−0·076	—
			(0·020)	
R^2	0·048	0·036	0·51	0·49
Marginal products:[c]				
Male labour	0·47	0·59	—	0·44
	(1·23)	(1·47)		(0·62)
Female labour	0·26	0·35	—	0·28
	(0·60)	(0·90)		(0·44)

Notes: Standard errors in parentheses. Season of interview dummies, regional dummies and a constant are included in all regressions.
[a] The value of the Wu-Hausman statistic for the joint exogeneity test is 19·0, while $\chi^2_{(9,\,0\cdot05)}=16\cdot9$ and $\chi^2_{(9,\,0\cdot025)}=19\cdot0$.
[b] Endogenous under the alternative hypothesis.
[c] These are calculated using the formula $MPL_i=\hat{\beta}_i\hat{Y}/L_i$, where $\hat{\beta}_i$ is the coefficient on $\log(L_i)$ and $\hat{Y}$ is predicted value of output. Means over the sample of 1034 households are reported, except in the last column, where negative marginal products are thrown out leaving a sample of 1015. Units are June 1985 Intis per hour. The standard errors do not take into account the sampling distribution of the estimate.

the restriction that the marginal rate of transformation (MRT) between male and female labour (i.e. the ratio of the marginal products) depends only on (the ratio of) the male and female labour inputs and not on the level of any other input; this is known as strong separability. To see if the labour supply estimates are robust to this separability assumption, the flexible translog functional form is estimated and used to derive the shadow wages.

Interpreting the translog as a second-order approximation to some unknown arbitrary production function (see Denny and Fuss (1977)), restrictions implied by strong and weak separability are tested and, if not rejected, imposed sequentially to obtain a parsimonious translog specification (details of this procedure can be found in Jacoby (1992)). Column 3 of Table II shows the OLS estimates of the resulting production function, with the inputs scaled at their geometric means. The last two terms of translog I indicate that the underlying technology exhibits non-separability of male and female labour with respect to both land and the value of farm animals.[14]

The female labour-land interaction term in translog I leads to a large number of violations of positive and diminishing marginal product.[15] Dropping this term alleviates the problem, but at the loss of a source of relative shadow wage variability. The correlation coefficients between the marginal products of labour derived from the resulting production function, translog II in column 4 of Table II, and those derived from its counterpart in column 1 are not significantly different from zero, indicating that translog II still yields quite a different shadow wage structure than the CD.

14. Both of these negative interaction terms are plausible consequences of the sexual division of labour in the Peruvian Sierra. Oxen, horses and mules are used in the primarily male tasks of ploughing and transport. Hence, animal power would tend to be *relatively* more substitutable with male labour than with female labour, even though complementary with both. As for land, Deere (1982) argues that in small farms of the Peruvian Sierra men spend more time off the farm in market work, leaving women to do the heavier chores involving agricultural implements. Thus, the kinds of tasks performed by women, and consequently the slope of the isoquant between male and female farm labour, changes with farm size.

15. This is a common problem with flexible functional forms. While in all but five households the male marginal products are positive, two hundred or nearly 20% of the households show a negative marginal product of female labour.

V. LABOUR SUPPLY ESTIMATION

A. *The specification of labour supply*

The samples used in the labour supply analysis are composed of the men and women (age twenty and up) who work on the 1034 family farms selected in the previous section. Total hours worked are calculated by summing the yearly hours spent in farm work, off-farm self-employment, wage employment and housework. Table III shows means for these separate categories and, for purposes of comparison, includes the hours of individuals whose households were excluded from the sample. These individuals appear to work a little less overall but work more for wages. Notice the extent to which women, whether farm workers or not, engage in housework, raising their total labour supply far above that of men on average. Also, though women spend much less time in wage employment than men do, they work more in family enterprises.[16]

TABLE III

Yearly hours of men and women in Peruvian sierra

(Participation rates in parentheses)

	Included households		Excluded households	
Mean yearly hours in	Men	Women	Men	Women
Farm self-employment	1873 (0·95)	1497 (0·92)	1233 (0·69)	921 (0·55)
Wage employment	362 (0·33)	58 (0·05)	748 (0·40)	218 (0·15)
Non-farm self-employment	215 (0·26)	345 (0·42)	297 (0·27)	486 (0·40)
Housework	356 (0·66)	1505 (0·95)	418 (0·66)	1517 (0·92)
Total hours	2807	3405	2696	3142
Standard deviation of total hours	1126	1265	1301	1437
Sample size	1299	1340	442	534

Note: Households are "included" if they contain at least one adult male and one adult female working on the farm.

For purposes of estimation, the relatively few individuals who worked exclusively for wages or in non-farm self-employment are omitted from consideration, leaving a sample of 1229 men, and a sample of 1233 women. In the male sample, there are 287 individuals who report that the job they worked the most hours at in the reference period is for wages (virtually none of the females participate in the labour market). The theory says that the wage of these workers should equal their marginal product on the farm,[17] a restriction that can now be tested.

Under the assumption that the estimated marginal products of labour are in fact the pre-harvest expected marginal products, they can be regressed on wages for the sub-sample

16. In terms of the regimes discussed in Section II, 60% of the 1034 households in the sample have men and women working exclusively on the farm, about 37% have either men or women, but not both, engaged in both farm and market labour, and only 3% have both men and women working in the farm and in the market.

17. Wage jobs reported as "secondary" occupations in the survey are more likely to be seasonal or temporary. Thus, the relationship between the wage in these jobs and the marginal product on the farm is more tenuous.

of labour market participants as follows.

$$MPL_i = a + bW_i + e_i. \tag{11}$$

The disturbance term e_i consists of errors in measurement of the marginal product and random optimization errors. The implications of utility maximization and an efficient labour market are embodied in the null hypothesis $(a, b) = (0, 1)$. Notice that, according to the theory, e_i is independent of the taste for work. That is, for individuals in the sub-sample the allocation of time between farm and market is made purely on efficiency grounds. So, even though the sample may be non-random with respect to the taste for work, the mean of e_i conditional on sample inclusion is still zero and sample selection bias in (11) is not a concern.

Since the wage is calculated as reported yearly cash and value of in-kind payments divided by yearly hours in that job, it is likely to be correlated with the measurement error in the marginal product. Hence, in the estimates of equation (11) in Table IV, the wage is instrumented using the worker's age, years of schooling and quadratic terms in these variables. Regardless of which production function is used to derive the marginal products, and in spite of a strong positive relationship between wages and marginal products, an F-test emphatically rejects the null hypothesis.

TABLE IV

Tests of the equality of wages and marginal product for labour market participants: instrumental variables estimates

$(N = 287)$

MPL derived from:	$\hat{a}$	$\hat{b}$	R^2	F-test[a]	Wu-Hausman[b]
Cobb-Douglas (OLS)	−0·06	0·37	0·10	136	7·5
	(0·17)	(0·07)			
Translog II	−0·041	0·58	0·14	62	31
	(0·22)	(0·08)			

Note: Standard errors in parentheses. The R^2 for the first-stage wage equation is 0·34.
[a] Null hypothesis: $(a, b) = (0, 1)$. The 5% critical point for $F(2,287) = 3$.
[b] Null hypothesis: No measurement error in wages. $\chi^2_{(1,\,0\cdot05)} = 3\cdot8$.

Two explanations for this rejection, beyond "irrationality" on the part of farmers, come to mind. First, the estimated marginal products may in fact be systematically biased so that the IV method does not lead to consistent estimates of (a, b). Alternatively, as alluded to earlier, the equality of marginal products and wages may fail to hold in reality because of some transaction cost or imperfection in the labour market. For example, a commuting cost or disutility associated with off-farm work (see Lopez (1984)), or a binding restriction on hours worked in the market, would drive a wedge between the shadow wage and the market wage. The marginal product, however, would still theoretically equal the shadow wage under these circumstances.[18] Therefore, (under the assumption that they are unbiasedly estimated) the marginal products of labour are used even for part-time wage earners in the labour supply functions.

Log-linear labour supply functions for men and women are first estimated based on the OLS estimates of the CD production function and then using the translog II parameters.

18. But, if market and farm work are imperfect substitutes in utility, it may not be appropriate to aggregate the different types of labour anymore.

As discussed in Section III, instruments for the marginal products and farm profit[19] include the number of adult male and female farm workers, housework production shifters (availability of electricity, plumbing, etc.) and exogenous agricultural production variables. Sample selectivity is ignored for now to focus on testing the validity of these instruments, which is easier to do without a conditional mean correction term. Also, any intra-household correlation between the u_i is ignored, an oversight which at worst leads to a loss of efficiency. However, as pointed out above, the covariance matrices of the labour supply parameters must be adjusted for the fact that marginal products and farm profits are estimated quantities; conventional standard errors would understate the true sampling variation.[20]

Included in the labour supply specifications are age and schooling variables, as well as some family composition variables; the number of children in various categories and the number of adults not working on the farm. Village size and regional dummies along with community level prices for rice and cooking fuel are used to proxy geographic variation in labour supply behaviour and the cost of living. Season of interview dummies may help redress any biases caused by seasonality in reported hours worked.

B. *Labour supply estimates with the Cobb-Douglas technology*

Initial estimates of the labour supply functions, with a full set of regressors, reveal that many of the non-budget constraint variables do not significantly affect labour supply.[21] Thus, to obtain more efficient estimates of the variables of primary interest, those non-budget constraint variables (except the age and schooling terms) not significant at least at the 10% level are omitted, leaving the specifications in Table V.

Uncompensated own-wage elasticities (the own-wage coefficients in Table V) are positive for both men and women. In contrast, Rosenzweig (1980) estimates a backward-bending market labour supply function for Indian males. In fact, gross own-wage elasticities here are slightly higher for men than for women. U.S. labour supply studies generally find women have a greater gross labour supply response than men (though Mroz's (1987) study disputes this), and argue it is because women have more margins of substitution out of market time. But, since the definition of labour supply used here includes home production, a greater response by women to changes in their shadow wage should not be expected, *a priori*. Both the male and female coefficients on farm profits

19. Two types of expenses are subtracted from the predicted value of farm output in addition to the shadow value of adult male and female farm labour (the shadow value of child and teenager labour is considered exogenous income and is thus not netted out): (a) the shadow rental payments on the land not owned by the household (i.e. the estimated marginal product of land times and hectares rented or sharecropped), and (b) actual expenses on the purchased inputs (insecticide, fertilizer, transportation, livestock inputs and hired labour). With the CD parameters there are 25 cases of negative profits, which are assigned the value of fifty to avoid numerical problems.

20. See Newey (1984) for the general covariance adjustment for a sequential estimator. Linearity of the labour supply functions in parameters and homoscedasticity of u_i simplifies the formula. Suppressing the subscript, write (9) as $\log(h) = \hbar = V\gamma + u$, where $V = (\log(\Gamma), Z)$. The standard instrumental variables covariance matrix for $\hat{\gamma}$ is given by $\hat{\sigma}_u^2\Sigma = s_u^2(V'W(W'W)^{-1}W'V)^{-1}$, where W is the matrix of instruments and s_u^2 is a consistent estimate of the variance of u. If the error terms u and ε are independent, then the adjusted covariance matrix is

$$\mathrm{Var}(\hat{\gamma}) = \hat{\sigma}_u^2\Sigma + \Sigma V'W(W'W)^{-1}W'\hat{\hbar}_\beta \, \mathrm{Var}(\hat{\beta})\hat{\hbar}'_\beta W(W'W)^{-1}W'V\Sigma,$$

where $\hat{\hbar}_\beta = \Sigma\hat{\gamma}_k \partial \log(\Gamma_k)/\partial\beta|_{\hat{\beta}}$, k indexes the columns of Γ, and $\hat{\beta}$ is the estimated production function parameter vector.

21. Particularly interesting is that the number of children five years old and under does not depress women's hours worked, which includes housework, though not child care per se. Rosenzweig (1980) finds no impact of young children on the supply of market hours by rural Indian women.

TABLE V

IV estimates of log-linear male and female labour supply functions

Independent variable	Cobb–Douglas Males ($N=1229$)	Cobb–Douglas Females ($N=1233$)	Translog II Males ($N=1203$)	Translog II Females ($N=1211$)
Log male shadow wage[a]	0·102	0·006	0·030	−0·062
	(0·039)	(0·031)	(0·029)	(0·037)
Log female shadow wage[a]	−0·010	0·079	−0·020	0·157
	(0·034)	(0·036)	(0·046)	(0·088)
Log farm profit[a]	−0·058	−0·082	0·004	−0·109
	(0·033)	(0·029)	(0·034)	(0·085)
Age	0·025	0·021	0·028	0·020
	(0·005)	(0·005)	(0·005)	(0·006)
Age squared	−0·00029	−0·00027	−0·00032	−0·00026
	(0·00006)	(0·00005)	(0·00005)	(0·00005)
Years schooling	0·009	0·005	0·018	0·007
	(0·014)	(0·016)	(0·011)	(0·028)
Years schooling squared	−0·0024	−0·0028	−0·0025	−0·0027
	(0·0009)	(0·0015)	(0·0008)	(0·0035)
Married	—	0·76	—	0·084
		(0·029)	—	(0·041)
Household head	—	0·162	—	0·191
		(0·064)	—	(0·072)
Number non-farm adult males	−0·108	—	−0·070	—
	(0·053)		(0·049)	
Number males age 12–15	−0·060	—	−0·060	—
	(0·027)		(0·024)	
F-test[b]	8·0	8·6	10·6	8·6
GMM χ^2 test[c]	22·4	43·4	23·3	37·8
Compensated own shadow-wage effect	901	1578	187	2646
	(338)	(598)	(217)	(1625)
Compensated cross shadow-wage effect	203	486	−218	85
	(492)	(338)	(625)	(520)

Notes: Standard errors in parentheses. Male equations includes a constant, village size dummy, prices of kerosene and rice, off-season dummy and five regional dummies based on department of residence. Female equations include a constant, village size dummy and the kerosene price. All instruments in Table I are used in the estimation, except the number of adult farm workers replaces number of adult household members. Polynomials in age are also used as instruments.

[a] Endogenous variable.

[b] Joint significance test, based on adjusted covariance matrix.

[c] Critical value is 30·1 in male equation and 38·9 in female equation.

are negative, hovering around significance, and, as with many U.S. studies, the income elasticities are greater for women than men.

Compensated own and cross shadow-wage effects—i.e. the Slutsky matrix—are reported at the bottom of Table V, evaluated at the sample means of the shadow wages, farm profits and compensation points.[22] Standard errors are calculated using the corrected covariance matrices. The positive and significant compensated own wage effects are highly supportive of the utility maximization hypothesis. Because of their larger income effect, women's compensated own wage effect is larger than the male counterpart. Compensated cross shadow-wage effects in both the male and female equations are positive, though small relative to the own-wage effects, and not significant. A t-test cannot reject

22. Means of the points of compensation are 3649 hours for men and 4495 hours for women, and the mean of farm profits is 2373 Intis.

the equality of the compensated cross-wage effects implied by utility maximization (in contrast to U.S. studies, where it is often resoundingly rejected).[23]

A Generalized Method of Moments (GMM) specification test (Hansen, 1982) cannot reject the joint null hypothesis that the instruments in the male labour supply equation are uncorrelated with the residual at the 5% level. Meanwhile, the same test in the female case yields a weak rejection, but since exogeneity of the instruments was not rejected when a larger set of regressors was included in the female labour supply equation, it appears that the rejection now is due to some omitted variables.

To test the exogeneity of certain subsets of the instruments, a variant of the Wu-Hausman test is used.[24] As reported in Table VI, the hypothesis that the number of adult male and female farm workers are valid exclusion restrictions cannot be rejected in either the male or female labour supply equation. Thus, the number of farm workers in a given year does not seem to be correlated with their taste for leisure. Similarly, the joint exogeneity of the farm worker variables and the housework production shifters cannot be rejected. The orthogonality of the housework production shifters lends support to the time-allocation model presented above.

TABLE VI

Estimates of labour supply parameters with varying instrument sets and tests of overidentifying restrictions

	Log male shadow wage	Log female shadow wage	Log farm profits	Exclusions tested[a]	χ^2 test[b]
Males:					
(1)	0·201	−0·109	−0·04	Z_2	1·08
	(0·098)	(0·090)	(0·061)		[16·9]
(2)	0·167	−0·107	−0·201	Z_1	2·47
	(0·074)	(0·072)	(0·040)		[6·0]
Females:					
(1)	−0·028	0·82	−0·064	Z_2	0·38
	(0·057)	(0·044)	(0·037)		[16·9]
(2)	−0·036	0·075	−0·053	Z_1	2·64
	(0·045)	(0·042)	(0·030)		[6·0]

Note: Standard errors in parentheses and chi-square critical values (degrees of freedom equal to number of overidentifying restriction tested) in square brackets. Labour supply specifications are identical to those in the first two columns of Table V.

[a] $Z_1 = \{$No. of adult male farm workers, No. of adult female farm workers$\}$, $Z_2 = \{Z_1$, the six housework production shifters$\}$.

[b] Test of the significance of the difference between these estimates and those using the full set of instruments in Table V.

C. *Labour supply estimates with the translog technology*

Columns 3 and 4 of Table V display estimates of the labour supply equations based on translog II, which places fewer restrictions on shadow wage variability.[25] Although the

23. Another implication of utility maximization is that the determinant of the Slutsky matrix is positive (see Ashenfelter and Heckman (1974)). This restriction is satisfied at the sample means, though the standard error of the determinant is not calculated here.

24. To tell whether two IV estimates, based on alternative instrument sets, are significantly different from each other, the variance of their difference must be calculated, which, unlike Wu-Hausman, must take into account the covariance between the estimates (see Mroz (1987)).

25. To avoid dealing with negative shadow wages, those few observations with either a negative male or female marginal product are dropped (twenty-six cases in the male sample and twenty-two in the sample of women).

overall fit of the male equation is better than in the CD case, the budget constraint variables are estimated with less precision. Farm profit, in fact, has a very slightly positive coefficient. For females, the coefficients on shadow wages and farm profit all have the same signs as in the CD case, but the uncompensated cross-wage elasticity is much larger in magnitude.[26] Also note that now the GMM test finds no evidence of specification error in the female equation, as it did in the CD case.

Notwithstanding the large gross effect of the male shadow wage in the female equation, the compensated cross-effect for women is essentially zero, as is the cross-effect for men, again making it impossible to reject symmetry. Note also that the gap between the male and female compensated own-wage effects increases in the translog case. Overall, while the quantitative results are sensitive to the form of the agricultural production function, the broad qualitative conclusions do not change dramatically. Although cross-wage effects were of no importance in the CD case, the translog case shows that it may be inappropriate to ignore the joint maximization framework and restrict such effects to be zero in individual labour supply equations.

D. *Sample selectivity and life-cycle consistency*

The male and female labour supply functions based on the CD and translog production functions are now re-estimated to control for possible biases due to sample selectivity and savings behaviour. Instead of conditioning on shadow farm profits, the life-cycle consistent model includes an estimate of full income based on a measure of total household expenditures calculated from the PLSS data.[27] With the time endowments for men and women set at 5840 hours,[28] mean full income in the sample is 4012 Intis, as compared with an estimated average farm profit of 2373 Intis.[29]

Table VII displays the estimated shadow-wage and income elasticities for the eight selectivity corrected models.[30] The hypothesis of no sample selectivity cannot be rejected in any of the female specifications by virtue of the insignificant coefficient on the inverse Mill's ratio, but it is rejected in all of the male specifications. The new results for males

26. It is also interesting that the adjustments to the standard errors to correct for pre-estimated regressors are extremely large for females in the translog case. For example, the uncorrected standard errors for the male wage, female wage and farm profit coefficients are 0·026, 0·035 and 0·025, respectively.

27. Expenditure items include (1) regularly purchased non-food items and food consumed outside the household within the last two weeks; (2) clothing, household goods and maintenance, medicines and other irregular expenditures within the last three months; (3) food expenditures within the last two weeks; (4) estimated rental value of durable goods (based on depreciation of reported present value); (5) value of food produced and consumed by the household in the last three months; (6) value of payments in kind (food and non-food) received by household members; and (7) actual housing rental payments or imputed rents for owner occupied housing based on hedonic rent equations. To obtain real expenditures, nominal expenditures for each household extrapolated to the full year are deflated using regional monthly price indices in order to correct for Peru's rampant inflation over the survey period, and then normalized by a regional price level. See Glewwe (1987) for details.

28. When time endowments are set at 8760 hours, the labour supply estimates are virtually identical. For example, the parameter estimates corresponding to the second row of Table VII are 0·088, −0·002, −0·074, and 0·136.

29. The mean of measured expenditures is actually only about 1400 Intis, which is less than average profit. Thus, either expenditures are underestimated, profits are overestimated, or households are saving an enormous amount. In light of the likelihood of large measurement error in profits and full income, it is encouraging to find that the alternative income elasticity estimates are fairly similar.

30. The inverse Mill's ratio is calculated from probit estimates of the decision to work both males and females on the farm. Regressors include all the household level instruments used in the labour supply equations (see the note to Table V). The selectivity term is included in initial regressions of shadow wages and profit on all of the instruments. Using these estimates, the conditional means of the first stage disturbances are subtracted from shadow wages and profit. Finally, the labour supply functions, including the selectivity correction, are estimated by instrumental variables. Standard errors are not adjusted for pre-estimated regressors.

TABLE VII

Tests of sample selectivity and life-cycle consistency

	Log male shadow wage	Log female shadow wage	Log farm profits	Log full income	Inverse Mills' ratio
Males					
Cobb-Douglas					
	0·078	−0·025	−0·017	—	0·136
	(0·036)	(0·032)	(0·037)		(0·053)
	0·084	−0·005	—	−0·075	0·137
	(0·031)	(0·033)		(0·057)	(0·046)
Translog II					
	0·020	−0·038	0·038	—	0·170
	(0·028)	(0·046)	(0·035)		(0·047)
	0·030	0·045	—	−0·087	0·153
	(0·030)	(0·030)		(0·055)	(0·045)
Females					
Cobb-Douglas					
	0·009	0·077	−0·083	—	0·025
	(0·030)	(0·027)	(0·028)		(0·043)
	0·025	0·060	—	−0·147	0·054
	(0·029)	(0·023)		(0·046)	(0·037)
Translog II					
	−0·059	0·149	−0·102	—	0·033
	(0·026)	(0·037)	(0·028)		(0·040)
	0·011	0·086	—	−0·170	0·064
	(0·027)	(0·023)		(0·047)	(0·036)

Notes: See notes to Table V. Standard errors are not adjusted.

are still reasonably close to the estimates in Table V, although the income elasticity is somewhat smaller than before. Nevertheless, the compensated own male shadow-wage effect calculated from the first row of Table VII is 567 hours per Inti, which is within a standard deviation of its counterpart in Table V. In fact, this case represents the largest discrepancy found between the two tables, indicating that sample selectivity does not have statistically significant consequences for either males or females.

Finally, as was the case with sample selectivity, the female labour supply estimates are quite robust to the replacement of farm profits with full income. While the life-cycle consistent specifications show larger income elasticities, the actual income effects are about the same for women (because full income exceeds profits). Similarly, for men the income elasticity based on full income is more negative, and in the translog case even has a different sign than the elasticity based on farm profit. Here, as in all previous cases, the estimates of the male labour supply parameters are considerably less robust than the female estimates to alternative assumptions. However, these different specifications do not lead to any strong rejections of the utility maximization hypothesis.

VI. CONCLUSION

The statistical evidence just presented suggests that Peruvian farm households indeed allocate their members' time as if to maximize a family utility function. In particular, work effort is higher among peasants who are more productive at the margin and who thus face a higher opportunity cost of time. Beyond lending support to peasant rationality, this paper demonstrates the tractability of the shadow-wage methodology and its usefulness in estimating time-allocation models in a variety of contexts where wage data are simply not available, or when the assumptions required to make use of wage data stretch the bounds of credulity.

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