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Shadow Wages and Peasant Family Labor Supply

An Econometric Application to the Peruvian Sierra

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No. 25	*The Demand for Urban Housing in the Ivory Coast*
No. 26	*The Côte d'Ivoire Living Standards Survey: Design and Implementation*
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No. 28	*Analysis of Household Expenditures*
No. 29	*The Distribution of Welfare in Côte d'Ivoire in 1985*
No. 30	*Quality, Quantity, and Spatial Variation of Price: Estimating Price Elasticities from Cross-Sectional Data*
No. 31	*Financing the Health Sector in Peru*
No. 32	*Informal Sector, Labor Markets, and Returns to Education in Peru*
No. 33	*Wage Determinants in Côte d'Ivoire*
No. 34	*Guidelines for Adapting the LSMS Living Standards Questionnaires to Local Conditions*
No. 35	*The Demand for Medical Care in Developing Countries: Quantity Rationing in Rural Côte d'Ivoire*
No. 36	*Labor Market Activity in Côte d'Ivoire and Peru*
No. 37	*Health Care Financing and the Demand for Medical Care*
No. 38	*Wage Determinants and School Attainment among Men in Peru*
No. 39	*The Allocation of Goods within the Household: Adults, Children, and Gender*

(List continues on the inside back cover)

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ABSTRACT

A striking feature of developing economies is the large proportion of the work force that is self-employed. Lack of widespread labor market participation in the agricultural sector can pose a major obstacle to the empirical implementation of economic models of the peasant household, whether because wage data are simply not available, or because the assumptions required to make use of wage data stretch the bounds of credulity. This paper develops a methodology for estimating a structural labor supply model for primarily self-employed peasant households, which holds under a general agricultural technology and set of labor market conditions. The unique feature of the approach is that the opportunity cost of time, or shadow wage, of household workers is explicitly estimated from an agricultural production function and is subsequently used to identify a set of structural labor supply parameters. Recent household survey data form rural Peru is employed to estimate and perform various diagnostic tests on the model. The empirical findings lend support to the hypothesis that peasant households allocate their members' time as if to maximize a family utility function, and, moreover, demonstrate the tractability of the shadow wage methodology and its usefulness in estimating more elaborate time allocation models.

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INTRODUCTION

LIST OF TABLES

I. INTRODUCTION

A striking feature of developing economies is the typically large proportion of the work force that is not primarily engaged in wage labor. Self-employment is particularly pervasive in agriculture, where the dominant unit of production is the family farm. Lack of widespread labor 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 labor 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 labor supply behavior, not to mention the estimation of more elaborate time allocation models.

This paper develops a general methodology for estimating a structural labor supply model for an agricultural household whose members are self-employed, and applies it to household survey data from rural Peru, where self-employment is the norm. The unique feature of the approach is that the opportunity cost of time, or "shadow wage", of individuals working exclusively on their own farm is determined from within the household, rather than by market forces. The endogeneity of shadow wages is presumed to result either from the imperfect substitutability of various labor inputs in the production process, or from transaction costs or other frictions in rural labor markets.

Thus, the methodology proposed here is not burdened by the unpalatable assumptions of previous studies of the peasant household.

The methodology is closely related to the treatment of labor supply with progressive income taxes (e.g., 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 a particular type of worker is just the marginal product of their labor in agriculture. Along with equilibrium farm profits, these shadow wages map out the structural labor supply parameters of each worker. The empirical strategy, therefore, is to first estimate an agricultural production function, which has different types of labor (that of men, women, children and hired workers) as distinct inputs. Since this study focuses on the labor supply of men and women, the marginal product of their farm labor is calculated for each household. Using these marginal products in place of wages, labor supply functions for men and women are estimated which are comparable to those of the neoclassical family labor supply model (e.g., Ashenfelter and Heckman 1974). The set of restrictions on the parameters of these labor supply functions implied by utility theory are then tested.

Rosenzweig [1980] is the only previous attempt to confront the neoclassical family labor supply model with data from a developing country. Under the assumption that the labor market in rural India is efficient, Rosenzweig uses the wages of men and women to estimate their joint supply of time to the market. One criticism of his approach is that in testing the signs of market wage elasticities, the controversial hypothesis of efficient rural labor markets is inevitably being tested along with the implications of utility maximization. But, perhaps more seriously, labor market participation in rural India, especially among women, is quite limited. So, even if labor markets are efficient, more assumptions are required before sex-specific market wages can be equated to the opportunity cost of time of all men and women in the sample.

Rosenzweig's model is essentially an elaboration on the highly influential consumer-producer agricultural household models exemplified in the studies by Lau, Lin and Yotopoulos [1978] and Barnum and Squire [1979]. The empirical tractability of these models derives from their invocation of the Separating Hyperplane Theorem, giving them a "recursive" property. The recursive property says that farm profit can be maximized independently of preferences, and utility can then be maximized taking profit as given. This two-stage maximization problem implies an aggregate labor supply function for the family that depends only on a single market wage and on farm profit, regardless of the household's position in the labor market. The cost of this convenience, however, beyond maintaining labor market efficiency, is that the labor of all family workers, and that of family and hired workers, must be assumed perfectly substitutable in agricultural production. Rosenzweig's model implicitly allows the labor of adult males and females to be imperfectly substitutable, but it still requires that perfect substitutes for the labor of these family workers be available on the market.

A model of peasant family labor supply is called for that retains the structure and tractability of these recursive agricultural household models, but that eschews their stringent assumptions.[1] An advantage of the proposed

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[1]Lopez [1984] is the only previous attempt to estimate a nonrecursive

model is that the implications of utility theory and the hypothesis of efficient rural labor markets do not have to be tested jointly. In addition, labor is not restricted to be perfectly substitutable in agricultural production, allowing relative variation in the shadow wages (i.e., marginal products of labor) of different workers across households, so that the labor supply parameters of these different workers can be compared. Finally, with the present approach, pure income effects on labor supply can be obtained because farm profits capture the returns to quasi-fixed productive assets, such as land. In Rosenzweig's study no adequate measure of non-labor income for poor households is available.

The next section of the paper fixes ideas by briefly spelling out the assumptions and implications of the standard recursive agricultural household model, before the more general shadow wage model is presented. In section III, the latter model is made operational and the identification issue is addressed. The next two sections report the empirical work, with the production function estimates in section IV and the labor supply estimates in section V. Conclusions drawn from this study appear in the final section.

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agricultural household model, where work on the family farm and market work are imperfectly substitutable in utility and production. His model is estimated using aggregate Canadian data and relies on some strong functional form assumptions, including constant returns to scale in production. Lopez ignores heterogeneity of labor by sex and age of worker.

II. THE THEORETICAL FRAMEWORK

The basic recursive model

To understand the recursive nature of the agricultural household models most often found in the literature, consider the following schematic version. The household produces agricultural output, Y, according to the strictly concave function F such that $Y = F(L^d, A)$, where A is the fixed quantity of land and L^d is the total amount of labor employed (other variable inputs are ignored without loss of generality). Embodied in this production technology is the restriction that all types of labor are perfectly substitutable; i.e., the marginal rate of transformation between these inputs is unity.

Normalizing the price of the consumption commodity, C, and setting it equal to that of farm output, and letting W be the market wage, the household's one-period[2] budget constraint is written as

$$(1) \quad C = Y - W L^d + W L^s = \Pi + W L^s.$$

where L^s is the family's supply of both on and off-farm labor and Π is farm profit. Implicit in this constraint is the assumption that the price at which the household can hire labor is equivalent to the price at which it can sell

[2]All asset accumulation decisions are presumed to have been made at an earlier stage of the family's multi-stage budgeting process.

labor; i.e., the labor market is competitive and free of transactions costs.

The single price of time, W, means that the leisure of various household members can be aggregated to form a Hicks composite commodity. Household utility can thus be expressed as a function of total family consumption and total family leisure, $\mathscr{L} = T - L^s$, where T is the family's endowment of time. In addition, a vector of taste shifters **Z** is introduced so that utility is written as $u=U(C,\mathscr{L};\mathbf{Z})$. The familiar first order conditions for the household's utility maximization problem imply,

$$\text{(2a)} \quad U_{\mathscr{L}} / U_C = W$$

$$\text{(2b)} \quad F_L = W .$$

Conditions (2a) and (2b) describe the standard neoclassical separation result or recursive property. The production, or labor demand, decision is determined solely by real factor costs (W), resource endowments (A), and the technology, entirely independently of preferences. Meanwhile, consumption depends on production only through the level of profits; that is, via the budget constraint. The recursive property becomes even clearer by setting up the equivalent two-stage maximization problem,

$$\text{(3)} \quad \Pi^*(W, A) = \max_{L^d} [F(L^d, A) - W L^d]$$

$$\max_{L^s} U(C, T-L^s) \quad \text{s.t. } C = \Pi^* + W L^s.$$

Here the maximized level of farm profits, Π^*, plays the role of nonlabor or property income in the pure consumer choice problem.

Solving the first order conditions yields explicit expressions for the demand and supply of labor as functions of the exogenous variables,

$$(4) \quad L^d = L^d(W, A)$$

$$(5) \quad L^s = L^s(W, \pi^*, Z).$$

Again, the essence of the recursive property is the absence of the taste shifters, Z, from the labor demand equation, and the fact that no variables from the production side of the model (fixed inputs or prices of variable inputs, if any) enter the labor supply equation separately. An equation based on (5) can be estimated straightforwardly by ordinary least squares, once the profit function has been estimated.

Clearly, the assumption that labor is perfectly substitutable is extremely useful, since it means that in an efficient labor market the going wage is the price of time of all workers in the household, whether they are selling their labor or not. Recent work, however, has begun to question the homogeneity of labor in peasant agriculture. Deolalikar and Vijverberg [1987], for example, reject the hypothesis that family and hired labor are perfect substitutes in a production function using two different LDC data sets, and suggest that differences in the nature and timing of tasks performed or in work incentives may be at the root of the finding.[3]

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[3] Laufer [1985] finds evidence of a division of labor between male and female workers in estimates of a flexible production function for different crops in rural India, indicating imperfect substitutability of family labor.

A shadow wage model

This section considers a more general model in which there are two types of workers (e.g., male and females, as in Rosenzweig 1980) whose time inputs are imperfectly substitutable in production, and where hired labor is not a perfect substitute for family labor. Labor heterogeneity of this form destroys the recursive property. Of course, even if perfect substitutes for each type of family worker are available for hire, transactions costs or other frictions in the labor market may drive a wedge between market wage rates and the marginal products of farm labor, and lead to a breakdown in recursiveness. The latter eventuality is explored empirically in section V. In what follows, the assumption of access to an efficient labor market is maintained, although it is important to understand that the analysis applies equally well to a household that is completely isolated from the labor market.

With labor heterogeneity, the general form of the agricultural production function is $Y = F(L_1,L_2,H_1,H_2,A)$, where H_1 and H_2 are the quantities of each type of labor hired by the household at wage rates W_1^H and W_2^H, respectively. hired labor wages Each family worker (i=1,2) allocates T_i hours between work on the family farm (L_i), work in the labor market (M_i), housework (S_i) and leisure (ℓ_i). Workers can choose not to participate in the labor market, so that $M_i \geq 0$,[4] but if they do participate they earn a wage W_i, which is not necessarily equal to W_i^H. Since off-farm wages W_1 and W_2 need not always move in unison, the family's leisure no longer forms a composite commodity, so that $u = U(C, \mathcal{L}_1, \mathcal{L}_2; Z)$.

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[4]Another interpretation of this inequality constraint is that, in a poorly functioning labor market, sometimes a worker is "rationed out"--unable to find any work off the farm at all at the going wage.

In Peru, for example, women who work on the family farm also spend a great deal of time in housework activities, such as cooking and cleaning (see table 4 below). To account for this phenomenon, a concave production function for housework services, Q, is postulated, of the form $Q = \Phi(S_1, S_2, I)$, where I is a vector of fixed characteristics which affect housework production. Each worker is presumed to engage in at least some housework, which is not produced jointly with farm output. It is also assumed that C and Q are perfect substitutes in utility (Gronau, 1977, makes an identical assumption), so that Q can be absorbed into the composite consumption good. Let $\mathscr{C} = C + \theta Q$ be this new composite commodity, where θ is the marginal rate of substitution in utility between C and Q.

The family is assumed to solve

$$\max_{C,Q,L_i,M_i,S_i,H_i} \quad U(\mathscr{C}, \mathscr{L}_1, \mathscr{L}_2; Z) \quad \text{subject to}$$

$$C = F(L_1,L_2,H_1,H_2,A) - W_1^H H_1 - W_2^H H_2 + W_1 M_1 + W_2 M_2$$

$$Q = \Phi(S_1,S_2,I)$$

$$T_i = \mathscr{L}_i + L_i + M_i + S_i \quad \text{and} \quad M_i \geq 0 \quad i=1,2.$$

The corresponding Lagrangian is given by

$$\begin{aligned}(7) \quad & U(C + \theta Q,\ T-L_1-M_1-S_1,\ T-L_2-M_2-S_2;\ Z) + \\ & \delta[F(L_1,L_2,H_1,H_2,A) - W_1^H H_1 - W_2^H H_2 + W_1 M_1 + W_2 M_2 - C] + \\ & \mu[\Phi(S_1,S_2,I) - Q] + \lambda_1 M_1 + \lambda_2 M_2 ,\end{aligned}$$

L_i = self-employment work
M_i = mkt work
S_i = home work

where δ, μ and λ_i are Lagrange multipliers. Maximization of (7) yields

$$\text{(8a)} \quad U_{\mathcal{L}i}/U_{\mathcal{C}} = W_i + \lambda_i/\delta = \hat{W}_i \qquad i=1,2, \quad \delta>0$$

$$\text{(8b)} \quad F_{Li} = \hat{W}_i \qquad i=1,2$$

$$\text{(8c)} \quad \theta\Phi_{Si} = \hat{W}_i \qquad i=1,2$$

$$\text{(8d)} \quad F_{Hi} = W_i^H \qquad i=1,2$$

Equations (8a-c) show that the allocation of time to leisure, farm work and housework is determined by equating the returns to each activity in terms of the numeraire to what can be interpreted as a shadow wage, $\hat{W}_i$. When the individual participates in the labor market, so that $\lambda_i=0$, condition (8a) says that the shadow wage is just the off-farm wage. Otherwise, λ_i/δ represents the amount of compensation above and beyond this market wage required to induce the individual to spend his or her marginal hour in market work or any other non-leisure activity. The shadow wage, defined by conditions (8a-c), is a function of $\underline{Z}$, $\underline{A}$, $\underline{I}$ and depends on the forms of the preference function and both of the household's technologies; i.e., it is endogenously determined.

The violation of the recursive property brought about by the decision of various family members not to work off the farm leads to a household budget constraint that is generally nonlinear in the leisure goods. At the optimum, however, the gradient of the budget constraint is just the shadow wage vector $\{\hat{W}_i\}$. Thus, at this point the constraint is linear. In particular, define full income at the household optimum by

$$\text{(9)} \quad \Lambda = \Pi^*(\hat{W}_1, \hat{W}_2, W_1^H, W_2^H) + \Psi^*(\hat{W}_1, \hat{W}_2) + \hat{W}_1 T + \hat{W}_2 T,$$

where

Z - taste shifter
I - home production technology
A - fixed inputs into self-employment production

$$\Pi^* = \max_{L_i, H_i} \; F(L_1, L_2, H_1, H_2, A) - W_1^H H_1 - W_2^H H_2 - \hat{W}_1 L_1 - \hat{W}_2 L_2 \quad \text{and}$$

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

(see Strauss 1986 for a similar analysis). Π^* again represents farm profits, with the opportunity cost of family labor 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 as

$$(10) \quad \Lambda = \mathscr{C} + \hat{W}_1\mathscr{L}_1 + \hat{W}_2\mathscr{L}_2. \geq C + \theta Q + \hat{\omega}_1\mathscr{L}_1 + \hat{\omega}_2\mathscr{L}_2$$

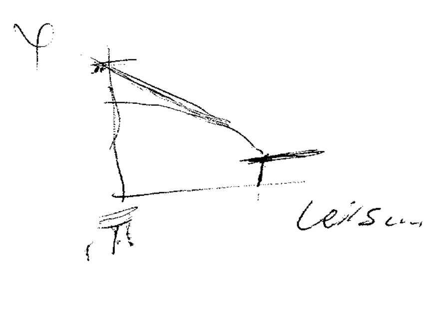
Maximization of the utility function subject to (10) yields conditions (8a-d), but looks exactly like a pure consumer choice problem. The linearization of the budget constraint is equivalent to turning (7) into a two-stage maximization problem as in the recursive model of II.A, except that full income 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 standard set of Marshallian labor supply functions

$$(11) \quad h_i = T_i - \mathscr{L}_i = h_i(\hat{W}_1, \hat{W}_2, \Lambda; Z) \qquad i=1,2 \; .$$

Observe that in contrast to the model with homogeneous labor, the labor supply of each worker would in general respond to variation in the shadow wages of both workers.

If both workers participate in the labor market (i.e., $\lambda_i=0$, $i=1,2$), then



(11) reduces to the two worker analog of recursive labor supply function (5) in II.A. If either one of the workers fails to participate in the labor market (e.g., $\lambda_1=0$, $\lambda_2>0$), then immediately the recursive property breaks down. Although each labor supply function would still depend on the exogenous W_1, they would also each depend on $\hat{W}_2$ and Λ, which are determined by preferences and the technology. When neither worker participates in the market, all the arguments of the labor supply functions 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 (10) 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 labor supply functions can then be equated,

$$(12) \quad h_i(\hat{W}_1, \hat{W}_2, u) = h_i(\hat{W}_1, \hat{W}_2, \Lambda^*(\hat{W}_1, \hat{W}_2, u)) \quad i=1,2$$

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

$$(13) \quad \partial h_i/\partial \hat{W}_j = \partial h_i/\partial \hat{W}_j|_u + (T_j - \mathscr{L}_j)\partial h_i/\partial \Lambda .$$

When the household cannot hire perfectly substitutable workers from the outside, it can be thought of as participating in "shadow markets" for the labor 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 labor.[5] Utility theory implies that when i=j the first term on the right hand

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[5]Thus, if the family has several type 1 workers, say, the point of

side of (13), the compensated own wage effect, is unambiguously positive, and that the compensated cross wage effects are equal; i.e., $\partial h_1/\partial \hat{W}_2|_u = \partial h_2/\partial \hat{W}_1|_u$.

III. THE EMPIRICAL STRATEGY

The estimating model and the stochastic environment

Labor supply functions (11) can be made operational by substituting the marginal product of farm labor for the corresponding shadow wage, using condition (8b), and by replacing full income with farm profits to give

$$(14) \quad h_i = h_i(F_{L1}, F_{L2}, \Pi^*(F_{L1}, F_{L2}, W_1^H, W_2^H); Z) \qquad i=1,2.$$

Why farm profit?

Both the marginal products and farm profits are evaluated at the optimal--i.e., the observed--labor supply choices of each household. Note that in a sample containing part-time wage earners it may be desirable to use the market wage, when available, rather than the marginal product of farm labor in equation (14). But, before imposing the restriction that the marginal product equal the wage for these workers, that restriction should be tested (see below).

The general empirical model consists of a production function and a pair

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compensation for each individual worker is the sum of the labor supply of all type 1 workers. Note also that the derivative of labor supply with respect to Λ could just as well be replaced by the derivative with respect to Π^*.

Is this because at optimum, $F_{L_i} = \theta \phi_{s_i}$?

of labor supply equations,

$$(15) \quad Y = \psi[f(L_1, L_2, \mathbf{X}, \mathbf{A}, \beta), \varepsilon)$$

$$(16) \quad h_i = g_i(\Gamma, \mathbf{Z}, \gamma_i, u_i) \qquad i=1,2$$

$$\text{where} \quad \Gamma = (f_{L1}, f_{L2}, f - f_{L1}L_1 - f_{L2}L_2 - \mathbf{P}_x\mathbf{X})$$

and where ε and u_i are the production and labor supply disturbances, respectively, $\mathbf{X}$ is the vector of variable inputs with prices $\mathbf{P}_x$, $\mathbf{A}$ are the fixed inputs, and β and γ_i are the production and labor supply parameters, respectively. Γ contains the marginal products and farm profit expressions and depends, in particular, on L_i and β. The functions ψ and g_i permit either additive or multiplicative disturbances.

The interpretation of the error term in an agricultural production function is an old question. Zellner, Kmenta and Dreze [1966] regard the disturbance (e.g., a weather shock) as orthogonal to the variable inputs, as long as it is not revealed to the farmer in advance of his input decision. If the shock is anticipated, or if the error contains unobservables, such as managerial ability, which are known to the household, simultaneity bias in the production function estimates could result. Although it is important to test for the presence of such bias, it should be noted that the endogeneity of the variable inputs is unrelated to the question of whether the underlying agricultural household model is recursive or not.

Whereas nothing in the theoretical model says that ε is necessarily correlated with the regressors in the production function, that is certainly not the case of u_i in the labor supply functions (16). These disturbances can be interpreted as unobserved differences in the preference for leisure. The correlation between u_i and the shadow wages is a direct consequence of the nonrecursive nature of the model. Thus, in order to get consistent estimates of the γ_i, instruments must be found for the elements of Γ.

Rather than estimate the system formed by (15) and (16) jointly, a more pragmatic two-step method is adopted.[6] First the production function is estimated and Γ is calculated using the estimates of β. Then instrumental variable estimates of the labor supply parameters are obtained and their covariance matrices are adjusted for the fact that Γ is a function of pre-estimated regressors.

Identifying the model

Ideal instruments for variable inputs in a production function are the prices of those inputs. In the absence of such data, variables which proxy indirect costs (such as remoteness of the village or the degree of modernity) can be employed. Instruments for the family's own labor input are those variables which covary with the returns to other uses of time, such as housework and leisure; the housework inputs, I, and taste shifters, Z, are natural choices.

In addition, the variation across households in the number of people working on the farm can be exploited. Given that the labor inputs of family

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[6] If the production and labor 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 labor 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 MaCurdy and Pencavel [1986] in an entirely different context.

workers of a particular type are perfectly substitutable, output is just a function of the total labor input of each worker type. The number of workers is obviously highly correlated with their total labor 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. Thus, the number of farm workers of each type in the household should make excellent instruments for their various farm labor ~~inputs.~~ household members?

Interpreting the number of workers ~~in each~~ category as resource endowments of the household also allows them to be used as instruments for the marginal products or shadow wages in the labor supply functions. Intuitively, the presence of another adult male in the household should affect the labor 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 labor supply equation. Moreover, if the number of household members allocated to farm work is part of the short run labor supply decision, 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.

Additional exclusion restrictions for the labor supply functions are the fixed farm inputs and characteristics, the effects of which should already be captured in the shadow wages and farm profits via the production function. Also, condition (8c), equating the marginal returns from housework to the shadow wage, implies that the housework production shifters, I, are valid instruments for the shadow wages.

do you instrument for H before running the production fn.?

No - instrument after computing MP - only use exogenous stuff in estimating MP

IV. ESTIMATION OF THE AGRICULTURAL TECHNOLOGY

The data

The Peruvian Living Standards Survey (PLSS) was administered by the World Bank between 1985 and 1986 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. It is in the Sierra where most of Peru's subsistence farming is concentrated, and this region is ecologically distinct from both the coast and eastern jungle. Since this study focuses on the productivity and joint labor supply decisions of adult males and females, the final sample consists of the 1,034 households in which at least one adult male and female worked on the family farm (thus dropping about 500 agricultural households). Sample statistics are reported in table 1.

Because most farm households in the Sierra grow several crops and raise livestock as well, and since data on all inputs (particularly labor and land) are not broken down by crop or activity, the different crop outputs are aggregated using the medians of their reported prices within each village as weights. Obtaining the value of output from livestock production (e.g., cattle or sheep herding) poses a problem because of the difficulty of measuring the appreciation in the value of the herd over the year. Thus, in what follows, livestock output is taken to be the sales of dairy, wool and other animal products, plus some fraction of the value of the household's

TABLE 1

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 crops harvested + sales of animal by-products + .2 x value of livestock (see text)	8885	55309
Land	Land area in hectares, owned and worked by the household, or rented or sharecropped	4.6	20
Equipment	Value of farm equipment	580	8880
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 labor	(Days of labor hired + days received in labor exchange) x 10	292	1235
Adult male labor	Hours farm work, all male household members, age>19	2354	1491
Adult female labor	Hours farm work, females age>19	1940	1311
Teenager labor	Hours farm work, ages 12-19	1050	1609
Child labor	Hours farm work, ages 6-11	541	963
Farm animals	Value of oxen, horses and mules	1541	3414
Irrigation	Proportion of land irrigated	.30	.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)	.41	.49
Harvest season?	Dummy: 1 if interviewed during harvest season	.23	.42
Planting season?	Dummy: 1 if interviewed during planting season.	.28	.45
Off-season?	Dummy: 1 if interviewed between harvest and planting season	.25	.43
North?	Dummy: 1 if live in northern Sierra	.21	.41
Central?	Dummy: 1 if live in central Sierra	.33	.47

TABLE 1--*Continued*

Definition of additional instruments
I. 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.
II. Household characteristics and housework production shifters: Fraction of land area owned, village size dummy (1 if 2,000 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). I
III. Community level wages and prices: 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.

herd,[7] under the assumption that the appreciation is proportional to this value. The constant of proportionality is set, rather arbitrarily, at .2 throughout the analysis, though other values are tried to assess the robustness of the estimates to this choice.

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. It is not known,

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[7]Oxen, horses and mules are excluded from this calculation since animal traction is an input into the production of crops, leaving only cows, sheep, pigs, goats and llamas.

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. Furthermore, the proportion of land irrigated is known. Irrigated land is more likely to have been cultivated and is usually more fertile than dry land. Land and irrigation along with the value of farm equipment (mainly animal plows), 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 taken as exogenous relative to the one-year planning horizon. Dummies for the agricultural season in which the household was interviewed, and a set of regional dummies for the northern and central parts of the Sierra are also included in the production function. In addition, two characteristics of the household head, his or her age and years of schooling, 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.

Farm labor is divided into five categories: adult (age twenty and older) male and female, teenage (twelve to nineteen), child (under twelve),[8] and

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[8] The questionnaire uses a seven day recall period, asking for both the actual and the "usual" hours per week, and weeks per year, spent working in the main jobs. If the individual did not work in the week prior to the interview, then a 12 month reference period is used. If the person identifies himself as a farmer who is a "self-employed or unpaid family worker," his usual hours in that job, calculated on an annual basis, are taken as the farm labor input.

non-family labor. The latter category includes both hired labor and labor received from other households in labor exchanges. The survey does not differentiate such labor by sex, but in the Peruvian Sierra non-family agricultural workers are predominantly male.

Estimates of a Cobb-Douglas production function

The Cobb-Douglas (CD) production function imposes imperfect substitutability between the labor inputs.[9] Despite its parsimony in parameters and log-linearity, the CD has the drawback that it does not allow inputs to take on a value of zero. None of the variable physical inputs are employed by every farm in the present sample, and many households report zero labor inputs for teenagers and children, either because they have no members of that age, or because they choose not to work them on the farm. Following MaCurdy and Pencavel [1986], for example, the constant one is added to all the inputs, except land and adult male and female labor, which are always positive by construction of the sample.[10]

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[9] But a CES production function is estimated in Jacoby [1989], and the nested hypothesis that adult male family labor and hired labor are perfect substitutes is rejected at the 5% level.

[10] The choice of the additive constant is arbitrary and the CD parameter estimates are fairly robust to different choices within an order of magnitude or so around unity, except for the coefficient on the hired labor variable, which is substantially more sensitive.

TABLE 2

PRODUCTION FUNCTION ESTIMATES
(DEPENDENT VARIABLE: LOG VALUE OF OUTPUT)

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

TABLE 2--*Continued*

Independent variable	Cobb-Douglas OLS	Cobb-Douglas IV	Translog (OLS) I	Translog (OLS) II
Permanent crops?	.166 (.059)	.144 (.076)	.185 (.058)	.185 (.058)
Log insecticide squared			.030 (.009)	.029 (.009)
Log hired labor squared			.016 (.006)	.015 (.006)
Log adult male labor squared			.044 (.018)	.045 (.018)
Log adult female labor squared			.057 (.023)	.047 (.023)
Log farm animals squared			.017 (.004)	.017 (.004)
Log adult male labor X log farm animals			-.018 (.009)	-.024 (.009)
Log adult female labor X log land			-.076 (.020)	....
R^2	.48	.36	.51	.49
Marginal products:[c]				
Male labor	.47 (1.23)	.59 (1.47)	...	.44 (.62)
Female labor	.26 (.60)	.35 (.90)	...	.28 (.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 $\chi^2_{(9,.05)} = 16.9$ and $\chi^2_{(9,.025)} = 19.0$.

[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 1,034 households are reported, except in the last column, where negative marginal products are thrown out leaving a sample of 1,015. Units are June 1985 Intis per hour. The standard errors do not take into account the sampling distribution of the estimate.

The first column of Table 2 displays OLS estimates of the CD production function, and shows that it explains about half of the variation in the value of output. Land has the largest and most significant coefficient, while irrigation and the other physical inputs have positive coefficients as well, with all but fertilizer and equipment achieving significance at the 5% level. The coefficients on the labor inputs also seem to make sense; adult males contributing the most to output, followed by hired workers (who are mostly adult males) and adult females. The coefficient on this latter category of labor verges on 5% statistical significance.[11] The contribution of teenagers and children appears to be relatively small, though only 42% of the households in this sample put any children under 12 years old to work on their farms.

To test the hypothesis that the variable inputs are exogenous, the CD technology is estimated by the instrumental variables (IV) method. Nine inputs are endogenous under the alternative hypothesis: insecticide, fertilizer, transportation, the livestock inputs, and the five categories of farm labor. Based on the discussion in section III, variables included in the instrument set (summarized in table 1) are the number of family members in various age-sex categories, characteristics of the household, community level

[11]When livestock appreciation is set at either .3 or .1 times the value of the herd, most parameters are not significantly affected. Not surprisingly, the coefficient on livestock input expenditures increases with this fraction, but the change is not very dramatic. Also, when the fraction is set at .3, adult female labor is significant, but when set at .1, that coefficient is only weakly positive. This change is probably due to the fact that women spend relatively more of their time than men in tending livestock, an indication of labor heterogeneity.

agricultural wages and prices,[12] and quadratic terms in the instruments (twenty are used here).

IV estimates of the CD production function are reported in the second column of table 2. A comparison of the OLS and IV estimates reveals no appreciable differences between the coefficients on the labor inputs, though the fertilizer and insecticide coefficients differ quite substantially. Based on a Wu-Hausman test, the joint exogeneity hypothesis is just rejected at the 5% significance level, however not at the 2.5% level. Marginal products of male and female labor derived from these two production functions are reported at the bottom of table 2. The correlation coefficient between the marginal products across columns is very high, about .8 for male labor and .95 for female labor, suggesting that the OLS and IV estimates should not lead to perceptibly different labor supply parameter estimates in the next stage of the analysis, though the ones based on the OLS estimates would be more efficient.

Estimates of a translog production function

Identification of all the elements of γ_i in equation (16) requires that the shadow wages of men vary relative to those of women. Since the relative shadow wage is just the marginal rate of transformation (MRT) between male and female labor (i.e., the ratio of the marginal products of these two inputs),

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[12] 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 can be extrapolated to the whole sample, however, if it is assumed 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.

the restrictions that the chosen functional form of the technology imposes on the MRT must be carefully considered. The CD production function imposes strong separability, the restriction that the MRT depends only on (the ratio of) the male and female labor inputs and not on the level of any other input. In order not to impose separability a priori, a flexible functional form such as the translog must be estimated. Shadow wages derived from a nonseparable technology might lead to estimates of the labor supply parameters that are quite different from those based on the CD technology.

Using a procedure, based on Denny and Fuss [1977], that interprets the translog as a second order approximation to some unknown arbitrary production function, restrictions implied by strong and weak separability are tested and, if not rejected, imposed sequentially to obtain a parsimonious translog specification.[13] Column 3 of table 2 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 nonseparability of male and female labor with respect to both land and the value of farm animals.

Both of these negative interaction terms are plausible consequences of the sexual division of labor in the Peruvian Sierra. Oxen, horses and mules are used in plowing and transport, which are tasks performed primarily by men. Hence, animal power would tend to be *relatively* more substitutable with male labor than with female labor, though it may be complementary with both. As for the interaction between land and female labor in translog I, Deere [1982]

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[13]Details of this procedure can be found in Jacoby [1989].

argues that in households of the Sierra with little land, 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 labor, changes with farm size.[14]

A well known feature of translog production functions, and other flexible functional forms, is that they do not guarantee positive or diminishing marginal products at every data point. The strong negative coefficient on the female labor-land interaction term in translog I is a source of a large number of violations of the regularity conditions.[15] Dropping this term from the translog alleviates the problem to a great extent, but at the loss of a source of relative shadow wage variability. The correlation coefficients between the marginal products of labor derived from the resulting production function, translog II in column 4 of table 2, and those derived from their counterparts in column 1 are not significantly different from zero, indicating that translog II still yields quite a different shadow wage structure than the CD.

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[14] See Rosen [1978] for an elaboration of the relationship between the division of labor and substitutability. Clearly, data on the hours of each task performed by males and females would be informative in this regard.

[15] 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 labor.

V. LABOR SUPPLY ESTIMATION

The specification of labor supply

The samples used in the labor supply analysis are composed of the men and women (age twenty and above) who work on the 1,034 family farms selected in the previous section. The relatively few individuals who worked exclusively for wages or in nonfarm self-employment are omitted from consideration, leaving a sample of males numbering 1,229, and a sample of females numbering 1,233. Among the male farmers there are still 287 whose primary job is for wages (virtually none of the females are in the labor market). The theoretical model states that for these workers the wage should equal the marginal product on the farm, a restriction that can now be tested.

Under the assumption that the estimated marginal products of labor are in fact the pre-harvest expected marginal products, subject to a random measurement error, they can be regressed on wages for the subsample of labor market participants as follows,

$$(17) \quad MPL_i = a + b\, W_i + e_i \ .$$

The disturbance term e_i consists of errors in measurement and random optimizations errors. The implications of utility maximization and an efficient labor market are embodied in the null hypothesis $(a,b)=(0,1)$. 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 (17) in table 3, 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 3

TESTS OF THE EQUALITY OF WAGES AND MARGINAL PRODUCT FOR LABOR 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)	-.06 (.17)	.37 (.07)	.10	136	7.5
Translog II	-.41 (.22)	.58 .08)	.14	62	31

Note: Standard errors in parentheses. The R^2 for the first stage wage equations is .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. $\chi^2_{(1,.05)} = 3.8$.

Two explanations for this rejection, beyond simple 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 labor market. For example, a commuting cost or disutility associated with off-farm work, 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. Therefore, (under the assumption that they are unbiasedly estimated) the marginal products of labor are used even for part-time wage earners in the labor supply estimation to follow.

To estimate the labor supply function derived in section II, the hours worked by each adult are calculated by summing the yearly hours spent in farm work, off-farm self-employment, wage employment and housework. The first part of table 4 breaks down these non-leisure hours of men and women into the different categories. Notice especially the extent to which women who work on the farm engage in housework, raising their total labor supply far above that of men on average. Although women spend much less time in wage employment than men do, they work more in rural family enterprises, e.g., selling farm produce in local markets.

TABLE 4

CHARACTERISTICS OF MEN AND WOMEN WORKING ON FAMILY FARMS

Variable definition	Adult males (N = 1229) Mean	Adult males (N = 1229) Std. dev.	Adult females (N = 1233) Mean	Adult females (N = 1233) Std. dev.
Yearly hours in:				
Family farming	1980	994	1627	915
Wage employment	317	718	31	225
Non-farm self-employment	217	592	346	608
Housework	359	439	1534	832
Total work	2863	1032	3537	1396
Age	43.1	15.3	41.5	14.6
Years schooling	3.5	3.2	1.7	2.6
Married? (1=yes, 0=no)	.63	.48	.62	.49
Household head?	.78	.42	.05	.21

The individual level variables listed in the second half of Table 4 are likely to capture some of the variation in hours worked that the household level marginal products and profit variable[16] cannot account for. Age and

[16] To construct farm profits, 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 labor (the shadow value of child and teenager labor 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 the hectares rented or sharecropped), and (b) actual expenses on the purchased inputs (insecticide, fertilizer, transportation, livestock inputs and hired labor). With the CD parameters there are 25 cases of negative profits, which are assigned the value of fifty to avoid numerical problems.

schooling pick up idiosyncratic productivity differences as well as possible cohort and taste effects. Also included in the labor supply functions are 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 labor supply behavior and the cost of living. Season of interview dummies may help redress any biases caused by seasonality in reported hours worked. As discussed in section III, the number of adult male and female farm workers are excluded from the labor supply equations, as are housework production shifters (availability of electricity, plumbing, etc.) and the exogenous agricultural production variables.

A log-linear version of labor supply function (16) is estimated below (quadratic and linear functions are found to yield similar labor supply elasticities and are not reported here). The disturbances in (16) are presumed to possess all of the classical properties, including homoscedasticity, except that they are correlated with the marginal products and farm profit variable. No account is taken of the covariance between the disturbances of members of the same household, an oversight which at worst leads to a loss of efficiency. Finally, as pointed out above, the covariance matrices of the labor 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. A general formula for the covariance matrix of a sequential estimator can be found in Newey [1984]. The particular formula used here is somewhat simpler owing to the linearity of the labor supply functions in parameters and the homoscedasticity assumption.[17]

Labor supply estimates with the Cobb-Douglas technology

Estimates of log-linear labor supply functions for men and women based on shadow wages derived from the OLS estimates of the Cobb-Douglas production function are presented in table 5. Initial estimates, with a larger set of regressors, reveal that many of the nonbudget constraint variables do not significantly affect labor supply.[18] Thus, to obtain more efficient estimates of the variables of primary interest, those nonbudget constraint variables (except the age and schooling terms) not significant at least at the 10% level are omitted, leaving the specifications in table 5.

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[17] Suppressing the subscript, write (16) 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

Covariance matrix

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

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

[18] 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 5

ESTIMATES OF LOG-LINEAR MALE AND FEMALE LABOR 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	.102 (.039)	.006 (.031)	.030 (.029)	.062 (.037)
Log female shadow wage	-.010 (.034)	.079 (.036)	-.020 (.046)	.157 (.088)
Log farm profit	-.058 (.033)	-.082 (.029)	.004 (.034)	-.109 (.085)
Age	.025 (.005)	.021 (.005)	.028 (.005)	.020 (.006)
Age squared	-.00029 (.00006)	-.00027 (.00005)	-.00032 (.00005)	-.00026 (.00005)
Years schooling	.009 (.014)	.005 (.016)	.018 (.011)	.007 (.028)
Years schooling squared	-.0024 (.0009)	-.0028 (.0015)	-.0025 (.0008)	-.0027 (.0035)
Married?	....	.076 (.029)	....	.084 (.041)
Household head?	....	.162 (.064)	....	.191 (.072)
Number non-farm adult males	-.108 (.053)	....	-.070 (.049)	....
Number males age 12-15	-.060 (.027)	....	-.060 (.024)	....
F-test[a]	8.0	8.6	10.6	8.6
GMM χ^2 test[b]	22.4 [30.1]	43.4 [38.9]	23.3 [30.1]	37.8 [38.9]

TABLE 5--*Continued*

	Cobb-Douglas		Translog II	
	Males (N=1229)	Females (N=1233)	Males (N=1203)	Females (N=1211)
Compensated effects:				
Own shadow wage	901 (338)	1578 (598)	187 (217)	2646 (1625)
Cross shadow wage	203 (492)	486 (338)	-218 (625)	85 (520)

Notes: Standard errors in parentheses, χ^2 critical values in square brackets. 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 1 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]Joint significance test, based on adjusted covariance matrix.

[b]Joint exogeneity test, degrees of freedom equal to number of overidentifying restrictions.

Uncompensated own wage elasticities (the own wage coefficients in table 5) are positive for both men and women. In contrast, Rosenzweig [1980] estimates a backward bending market labor supply function for Indian males. In fact, gross own wage elasticities here are slightly higher for men than for women. U.S. labor supply studies generally find women have a greater gross labor supply response than men (see Killingsworth 1983 pp. 103-104), and argue it is because women have more margins of substitution out of market time. But, since the definition of labor supply used here includes housework, 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 are negative, hovering around significance. One finding in agreement with many U.S. studies is that the income elasticities are greater for women than men. There is, however, the possibility of omitted variable bias here, in that households may have other sources of nonlabor income which are correlated with their farm profits, and with the instruments as well.

Compensated own and cross shadow wage effects--i.e., the Slutsky matrix--are reported at the bottom of table 5, evaluated at the sample means of the shadow wages, farm profits and compensation points.[19] 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 the equality of the compensated cross wage effects implied by utility maximization (in contrast to U.S. studies, where it is often resoundingly rejected). Still, the judgment about whether symmetry holds for this data must be reserved until a more flexible underlying agricultural production function is considered.[20]

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[19] Means of the points of compensation are 3,649 hours for men and 4,495 hours for women, and the mean of farm profits is 2,373 Intis.

[20] 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.

A Generalized Method of Moments (GMM) specification test (Hansen 1982) cannot reject the joint null hypothesis that the instruments in the male labor 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 labor supply equation, it appears that the rejection now is due to some omitted variables.

The exogeneity of certain subsets of the instruments can be assessed using a more powerful test. A variant of the Wu-Hausman test[21] is employed to test whether the number of adult male and female farm workers are valid exclusion restrictions in each of the labor supply equations. As can be seen in table 6 this exogeneity hypothesis cannot be rejected in either the male or female labor supply equation. Similarly, the joint exogeneity of these latter instruments and the housework production shifters is not rejected. It can be concluded, therefore, that the decision about how many adult household members to send out into the fields in a given year is not correlated with their taste for leisure. Furthermore, the orthogonality of the housework production shifters lends support to the time allocation model presented above.

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[21] 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).

TABLE 6

ESTIMATES OF LABOR 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)	.201	-.109	-.04	Z_2	1.08
	(.098)	(.090)	(.061)		[16.9]
(2)	.167	-.107	-.021	Z_1	2.47
	(.074)	(.072)	(.040)		[6.0]
Females:					
(1)	-.028	.082	-.064	Z_2	.38
	(.057)	(.044)	(.037)		[16.9]
(2)	-.036	.075	-.053	Z_1	2.64
	(.045)	(.042)	(.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. Labor supply specifications are identical to those in the first two columns of table 5.

[a]Z_1= {# of adult male farm workers, # 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 5.

Labor supply estimates with the translog technology

Calculating the budget constraint variables from translog II in table 2 allows shadow wages of men and women to vary relative to one another as a function of the value of the stock of farm animals. The robustness of the estimated wage effects to this change can now be evaluated. But first, 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).

The new labor supply estimates are displayed in the third and fourth columns of table 5. Although the overall fit of the male equation is better than in the CD case, the budget constraint variables are estimated with conspicuously less precision. Farm profit, in fact, has a very slightly positive coefficient. Meanwhile, the results for females are quite striking. While the coefficients on shadow wages and farm profit all have the same signs as in the CD case, the male shadow wage coefficient, which is just the uncompensated cross wage elasticity, is much larger in magnitude. It is also interesting that, while for males the adjustments to the standard errors to correct for pre-estimated regressors are rather small, the same corrections in the female translog case are extremely large. For example, the uncorrected standard errors for the male wage, female wage and farm profit coefficients in the female equation are .026, .035 and .025, respectively. Finally, observe that with the budget constraint variables derived from translog II the GMM test does not find evidence of any misspecification 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 shown in column 4 of table 5 is essentially zero. So to is the cross effect in the male equation, making it impossible once again, to reject the symmetry restriction. Note also that the compensated own wage effect of women is larger and that of men is smaller with the translog than with the CD. Overall, while some of the quantitative results appear to be sensitive to the functional form of the agricultural technology, the broad qualitative conclusions are not dramatically altered by it. 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 labor supply equations.

VI. CONCLUSIONS

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 when wage data are simply not available, or when the assumptions required to make use of wage data stretch the bounds of credulity.

In developing countries, typically very few women and children participate in the wage labor market. Yet, many of the important issues in development--most notably, fertility demand--hinge precisely upon the opportunity cost of time of these agents. Rosenzweig and Schultz [1982], for example, argue that differences in infant mortality rates by sex might be a parental response to differing lifetime earning capacities of males and females. They test this hypothesis using data on employment rates of men and women in rural India as proxies for earnings potentials. A much more convincing empirical case could be made, though, if the actual productive contribution of men and women in agriculture were estimated, as they have been in this paper.

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