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# An Overview of Agricultural Household Models: Empirical Applications

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CENTER DISCUSSION PAPER NO. 451

# AN OVERVIEW OF AGRICULTURAL HOUSEHOLD MODELS: EMPIRICAL APPLICATIONS

John Strauss

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An Overview of Agricultural Household Models: Empirical Applications


## Abstract

This paper is a second, introductory chapter to Singh, Squire and Strauss, eds. Agricultural Household Models: Extensions, Applications and Policy. This paper surveys the empirical studies done on agricultural household modeling, beginning with the pioneering Stanford studies conducted by Lau, Yotopoulos and their colleagues, and the subsequent World Bank study of Barnum and Squire. More recent studies are reviewed, including those which will be in the book, which have both extended the basic methodology and made policy applications.

An Overview of Agricultural Household Models: Empirical Applications*

The previous chapter has shown that separable models have different implications than nonseparable models for the interactions between consumption and production decisions as well as for comparative statics. This is quite important especially since most models to be reviewed assume separability. If the model is separable between consumption and production decisions then, under certain circumstances to be discussed in Section 2, the empirical work can be done for each independently. If the assumptions made are wrong, so that the model is not truely separable, then the statistical results will be biased. In this case some prices will be virtual (see Chapter 1), hence endogenous to the household. The resulting comparative statics will have a second source of error, since the virtual prices will have been assumed to be fixed.

Even for separable models, there are econometric issues which need to be addressed. These are considered in Section 2. The early empirical studies are reviewed in Section 3, and subsequent extensions and application, including those in this volume, are discussed in Section 4.

## 2 Estimation Issues

Separable models are much easier to estimate empirically, since in that case all prices can be taken as exogenous to the household. Given that the model is separable, one can derive from the household's equilibrium a set of commodity demand equations (including leisure or labor supply) and a set of output supply and variable input demand functions

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(or equivalently a production function). The commodity demands are functions of commodity prices, full income and possibly household characteristics (see below). Holding full income constant they satisfy the usual constraints of demand theory: adding up to total expenditure; zero homogeneity with respect to prices and exogenous income; symmetry and negative semi-definiteness of the Slutsky-substitution matrix. The output supplies and input demands are functions of input and output prices and of farm characteristics (including fixed inputs). They are derived from a profit function which obeys the usual constraints from the theory of the firm: homogeneity of degree one in prices, and convex with respect to prices. These results can be used as a guide when specifying the model for estimation.

If estimation is to be by econometric means, errors have to be added to the model. The issues involved in sensibly specifying an error structure are outside the scope of this chapter. For simplicity, suppose the errors are added to the demand and output supply equations. If for a given household the errors on the input demand and output supply equations are uncorrelated with the errors on the commodity demand equations, the entire system of equations is statistically block recursive. In this case profits will be uncorrelated with the commodity demand disturbances so that the latter equations may be consistently estimated as a system independent from the output supply and input demand equations. The practical advantage which results from separate estimation of the demand and production sides of the model, is that far fewer parameters need to be estimated

for each side separately. This is potentially important if the equations are nonlinear in parameters and have to be estimated using numerical algorithms, since expense is greatly reduced and tractability increased. Thus models with greater detail can be estimated.

On the other hand if production and consumption side errors are correlated, then profit is correlated with the demand side errors, and its endogeneity must be accounted for to estimate the demand equations consistently, whether or not the deterministic model is separable.[1]

Even assuming that demand side and production side errors are uncorrelated it may still be that errors on different commodity demand equations are correlated, and likewise for errors on different output supply and input demand equations. This is intuitively appealing. Moreover it is necessary condition for the commodity demand equations to satisfy the adding-up constraint that expenditures add up to full income. For adding up to be met for every household, the errors, or a linear combination of them, must add up to zero for each household, resulting in nonzero correlations. This result is well known and gives one reason for estimating either the commodity demand equations or the output supply and input demand equations as a system: accounting for the error covariances will improve the statistical efficiency of the estimates. A second reason for estimating these equations as a system (or more properly two separate systems, one for the commodity demands and one for the output supplies and input demands) is to account for cross equation parameter restrictions. These will occur because these equations

are derived from a common optimizing problem. In particular the adding up and the Slutsky symmetry constraints will impose certain cross equation constraints on commodity demand parameters, which if used (and if they are correct) will again improve the statistical efficiency of the estimates. These advantages are well known and have given rise to an econometric literature on demand systems estimation (see for example, Brown and Deaton, 1972; Barten, 1977; Deaton and Muellbauer, 1980).

Estimation doesn't have to be of a system of equations, since single equations can be consistently estimated as well. This will be advantageous when the underlying model is not separable. In that case virtual prices and hence farm profits are endogenous so that the commodity demand, output supply and input demand equations are not in reduced form. To estimate these "structural" equations is expensive, since it must be done jointly (see Lopez, this volume, for such a study). As an alternative one can specify the reduced form equations. The disadvantage of that approach is that it is usually not possible to solve for the reduced form analytically. Consequently one can't take full advantage of economic theory in imposing (or testing) parameter restrictions, though some of the restrictions may be readily apparent. Nevertheless one can specify what variables belong in the reduced form, and so can estimate a least squares approximation to it. In general not imposing parameter restrictions only costs statistical efficiency, not consistency.

Even if the underlying model is separable estimating

a single equation may be advantageous because it may save on data requirements. To estimate a complete set of commodity demand, output supply and input demand equations requires an enormous amount of data. Data are needed on consumption expenditures and prices for farm and non-farm commodities, on household time allocation to on-farm and off-farm work, as well as related wage data, and on inputs and outputs of the production activities. To estimate a single equation however one only needs data on one endogenous variable and the proper exogenous variables, not on all the endogenous variables. However, a potential probelm in using the single equation approach to shortcut data requirements is that data on come of the appropriate exogenous variables may be absent, resulting in an omitted variables bias.

## 3 Empirical Studies

The first empirical studies giving estimates of agricultural household models were conducted at Stanford by Lau, Yotopoulos, and their collaborators (Yotopoulos and Lau, 1974; Lau, Lin and Yotopoulos, 1978; Yotopoulos, Lau and Lin, 1976; Kuroda and Yotopoulos, 1978, 1980; Yotopoulos, Adulavidhaya, Kuroda and Lau, 1976; Adulavidhaya, Kuroda, Lau, Lerttamrab, and Yotopoulos, 1979), and at the World Bank by Barnum and Squire (1978, 1979a, 1979b). These are all econometric studies which specify separable

models, and estimate commodity demands and either output supply and input demands, or a production function. All these studies are highly aggregative, on the demand side using one agricultural commodity produced and consumed by the household (our $X_c$, see Chapter 1), one nonagricultural commodity which can only be purchased (our $X_m$) and leisure.[2] On the production side more detail is provided, allowing for several variable and fixed inputs. Yotopoulos and Lau provide an illustration of the methodology using farm management data from India. They don't have data on household consumption of the agricultural or the nonagricultural commodity so they can't estimate a complete model. Rather they estimate a single labor supply equation as well as a joint profit and input demand function.

The subsequent studies do have sufficient data to estimate complete models. Lau, Lin and Yotopoulos use Taiwanese household data, which are averaged by farm size and by region for each of two years. Kuroda and Yotopoulos use cross-section Japanese household data, also grouped by farm size and by region. Yotopoulos, Adulavidhaya, Kuroda and Lau use cross-section Thai household data. They use different cross-sections for estimating the production and consumption sides of the model, thus assuming that the two sets of households behave identically. This is only possible since their model is separable, if it were not data on the same set of households would be necessary. Barnum and Squire use cross-section household level data from the Muda River Valley in Malaysia. The Malaysian and Thai households practiced monoculture (rice cultivation) so that aggregating

all outputs into a single aggregate does not cause aggregation problems. In the Taiwan, Japan and Thailand data sets prices vary by region (and over time for the Taiwan data), thus allowing estimates to be made of price elasticities. For the Malaysian data only wages vary, though by making sufficiently strong assumptions about preferences, price elasticities are calculated.

A difficult issue arises in the Taiwan, Japan and Thailand studies as to how to compute price indices given the high level of commodity aggregation. Both these studies assume that all households in a region face the same prices for disaggregated commodities, but allow the weights used in forming the indices to vary for each observation (household group). Thus household (or household group) specific prices are formed. There are two potentially serious problems which are thus created: spurious variation in prices, and creating a price index which is endogenous to the household. To see this suppose that every household in a market area (say a region) faced the same set of prices for each disaggregated commodity (that is for different qualities of the same aggregate commodity). Even with a common utility function different households will buy different amounts of each quality of the aggregate commodity because of differences in full income and in household characteristics. Since the weights used are the share of household expenditure on a particular commodity the weights will differ by household. Thus the researcher will see a spurious variation in prices. In addition these aggregate prices are endogenous to the household since expenditure decisions are endogenous. The endogeneity of prices would

have to be accounted for statistically in order to produce consistent econometric parameter estimates. To account for such endogeneity using maximum likelihood techniques one might add a set of reduced form equations for aggregate prices to the commodity demand equations and estimate that as a system. That may be computationally burdensome. As a compromise one could use instruments for the weights (or for the aggregate prices) and just estimate the commodity demands. This would not be a maximum likelihood procedure and would understate standard errors since the price variables would be predicted, not actual. An alternative might be to average the weights, say over the market area (see Strauss, this volume, for such an approach).

Another problem arises when calculating wage rates. Calculating wage rates over a market area may not be appropriate if there is sufficient variation in the human capital endowment of individual workers, since that may help determine wages. However using individual wage rates which are derived by dividing earnings by time worked (which the Malaysian study does) induces a definitional relationship between time worked and wage rates, and may introduce systematic errors if there exists a standard work day which people tend to report as having worked whether or not they did (Schultz, 1980). Both problems may be avoided by using predicted wage rates from an earnings function (see Deolalikar, this volume, and Iqbal, this volume, for a similar treatment of interest rates). In addition individual (or household specific wage rates may suffer from the same problems just

discussed, since wage rates are apt to vary by season and different households will supply different proportions of labor to the market in different seasons. Again using a predicted wage will correct for this, though leaving the problem of determining the true standard errors.

All four studies use the systems approach to estimate commodity demands. Lau, Lin and Yotopoulos (1978), Kuroda and Yotopoulos (1980) and Yotopoulos, Adulavidhaya, Kuroda and Lau (1976) use the Linear Logarithmic Expenditure System (LLES), while Barnum and Squire (1979a, b) use both an LLES and a Linear Expenditure System (LES). The LLES is derived from a translog indirect utility function which is homogeneous of degree minus one in prices. This implies that every expenditure elasticity with respect to full income is one, a restrictive assumption particularly if one specifies many commodities. It is linear in parameters, however, which makes estimation simpler. The LES is derived from an additive utility function, the Stone-Geary. It has fewer parameters to estimate than an LLES, but is nonlinear in parameters. Since it is additive, Engel curves are restricted to be linear and no Hicks-complementarity between commodities is allowed for. As is true for the LLES this should be less restrictive when commodities are highly aggregated.[3]

In all of these studies household characteristics such as total size and its distribution are regarded as fixed, however, they affect commodity demands. There are different ways in which one can model the effects of demographic variables on

demand. Lau, Yotopoulos and their collaborators enter household characteristics as separate arguments into the utility function. This implies they will be independent variables in the expenditure and indirect utility functions also. Barnum and Squire use linear translation (see Pollak and Wales, 1981) to enter household characteristics. This involves subtracting commodity specific indices from each commodity in the utility function, i.e., $U(X_0 - \gamma_0, \ldots, X_n - \gamma_n)$, where the $X_i$'s are consumption of commodity i, and the $\gamma$'s are the translation parameters which depend linearly on household characteristics. The associated indirect utility function looks like $V(p, Y - \sum_{i=1}^{n} p_i \gamma_i)$, that is everywhere full income, Y, appears one subtracts the sum of the values of these commodity indices (the $p_i$'s being prices). Consequently, the effect of household characteristics comes through full income in this specification. Other specifications of household characteristics are possible and potentially preferable[4] (for an excellent review, see Pollak and Wales, 1981).

Using demographic variables an LLES share equation is given by

$$\frac{p_j X_j}{Y} = \alpha_j + \sum_{k=1}^{n} \beta_{jk} \ln\left(\frac{p_j}{Y}\right) + \sum_{\ell=1}^{r} \sigma_{j\ell} \ln a_\ell \qquad (1)$$

$$\sum_{j=1}^{n} \alpha_j = -1 \; ; \; \sum_{k=1}^{n} \beta_{jk} = 0 \; , \; \forall_j \; ; \; \sum_{j=1}^{n} \sigma_{j\ell} = 0 \; , \; \forall_\ell$$

where $p_j$, $X_j$, Y are defined as before, $a_\ell$ is the $\ell$th household characteristic and the $\alpha$'s, $\beta$'s and $\sigma$'s are parameters to be estimated. An LES expenditure equation with linear translating is given by

$$p_j X_j = p_j(\theta_j + \gamma_j) + \beta_j(Y - \sum_{i=1}^{n} p_i(\theta_i + \gamma_i)) \quad , \quad \sum_{j=1}^{n} \beta_j = 1 \qquad (2)$$

here the $\beta$'s are the (constant) marginal budget shares, the $\Theta$'s are parameters and the $\gamma$'s are the translation parameters which are a linear function of household characteristics, i.e., $\gamma_i = \sum_{\ell=1}^{r} \sigma_{i\ell} a_\ell$. For the Malaysian study only wages varied over the sample. Using an LES, however, all price elasticities can be estimated, even though not all parameters can be. This is not true of the LLES, with which Barnum and Squire can only estimate wage elasticities.

For the production side, Yotopoulos, Lau and Lin (1976), Kuroda and Yotopoulos (1978) and Adulavidhaya et.al. (1979) estimate a profit function and associated input demand functions, which are derived from a Cobb-Douglas production function. Barnum and Squire (1979a, 1978 ) estimate a Cobb-Douglas production function directly since they didn't have the necessary price data to estimate the dual functions.

Various elasticities, computed at the sample means, are provided in Tables 1, 2, 3, and 4 for the Taiwan (Lau, Lin and Yotopoulos), Malaysia (Barnum and Squire), Japan (Kuroda and Yotopoulos), and Thailand (Yotopoulos, Adulavidhaya, Kuroda and Lau) studies respectively. For changes in the price of the agricultural output, wage rate, fixed inputs, and the technology, the elasticities are reported both allowing profits to vary and holding them fixed. This corresponds to equations (8B) and (8A) in Chapter 1 respectively, both put in elasticity form. The

reader can see that a sizeable difference exists when the household is modeled as an agricultural household. For the Taiwan study (  ) out of six possible (the responses of consumption of the farm output, consumption of the nonfarm commodity and labor supply to farm output and labor prices) signs change. Even in the cases for which signs do not change the magnitudes do. For instance consumption of the non-agricultural good responds weakly (.13) to agricultural good price when profits are held fixed but strongly (1.18) when profits vary. For the Malaysian study all six possible sign changes occur, for the Thailand study -- do, and for the Japan study--out of eight signs change.[5] In general then, the profit effect of a change in agricultural output price is strongly positive for the demand for consumption commodities, and negative for labor supply. The same with opposite signs is true for changes in the agricultural wage rate.

In two out of the four studies consumption of the agricultural good responds positively, though inelastically, to its own price once profits are allowed to vary. Marketed surplus of the agricultural commodity responds positively and elastically to own price, the smallest elasticity being .66 for the Malaysian study. It tends to respond in a strongly negative fashion to wage rate and fairly positively to changes in land or to technological improvement.

Labor supply responds positively to wage except for off-farm worker labor supply in the Japanese study, which responds negatively to off-farm wage rates. In all cases, however,

labor supply is reasonably inelastic, by far the largest supply elasticity being .45 for farm workers in the Japanese study. Farm labor demand responds very elastically to both wage rate (a negative response) and to output price (a positive response) in all four studies. The labor demand and supply responses would suggest that net farm demand for labor responds quite negatively to wage, somewhat more so than does gross labor demand. This is of some importance for the demand for off-farm labor. Net labor demand responds in a very positive way to output price in all four studies as well as to land or a technological change.

Also all four studies find that numbers of workers and dependents affect consumption significantly. Number of workers directly affect full income, but may also change the composition of consumption holding full income constant. In the Malaysia, Taiwan and Thailand studies household labor supply increases strongly with increases in working members, and it increases, but much less so, when dependents are increased.[6] In the Japan study more dependents also cause farm labor supply to rise, but labor supply responds negatively to increases in working members. In three of the studies the addition of family members tends to reduce the marketed surplus of output by a small amount through increased consumption, with changes in dependents having a slightly larger effect in two of the studies. In the Thailand study, however, more dependents have a small positive effect on marketed surplus, since less is consumed in the household.

## 4. Extensions and Applications of Empirical Work

Since the pioneering Stanford and World Bank studies interest in agricultural household models has grown, resulting in numerous extensions and applications of the empirical methodology, many of which appear in this volume. One set of extensions has been to incorporate more commodity detail into the models on both the production and demand sides. Another set of extensions has involved building two-period models, in one case in order to add risk considerations. Progress has also been made, incorporating household production activities into these models, as it has for households facing quantity constraints on their activities. Finally a number of policy applications have been pursued, some of them involving the construction of limited general equilibrium models, which are interesting in their own right.

Singh and Subramaniam (this volume) summarize two studies in which multiple outputs are allowed for: one for Korean households (Ahn, Singh and Squire, 1981) which produce several outputs in pure stands, and one for Nigerian households which intercrop. Both studies use linear programming techniques to estimate the production side of the model, integrating that with econometric estimates of a linear expenditure system for the demand side. Linear programming is well suited to handle multiple outputs, in particular zero production of some outputs.

Strauss (this volume) summarizes a study of rural Sierra Leone households in which several commodities are also specified.

His major interest is in exploring household calorie availability so he disaggregates food consumption. Nonfoods (Z-goods) are also included in both production and consumption. Commodity demands are estimated using a quadratic expenditure system, which allows for quadratic Engel curves (and inferior commodities). This is found to be more suitable than specifying linear Engel curves, given the level of food disaggregation. The production side is estimated econometrically, in contrast to the Korea and Nigeria studies, as a system of output supplies and input demand. Because of household specialization in production, data censoring (zero production) is a problem. Strong assumptions on both the technology and the statistical errors are made to make the Tobit computational method tractable. Results are reported separately for different income groups, in contrast to some of the other studies.

Another way in which more commodity detail can be entered is by making labor heterogeneous. Rosenzweig (1980) using Indian household data distinguishes between male and female labor. He is interested in explaining the net supply of each type of labor to the market (off-farm labor).[7] While one can obtain elasticities of off-farm labor supply from the labor supply and labor demand elasticities obtained by estimating an entire agricultural household model, the necessary data are not available so Rosenzweig derives the off-farm labor elasticities from a reduced form equation. This equation relates off-farm labor directly to its determinants: male and female wage rates, output prices, nonlabor input prices, farm characteristics,

and household characteristics. In addition he tests the agricultural household model by comparing the off-farm labor supply responses of landless households with landed ones. Assuming the model to be separable, if a landless household faces the same prices, and has the same full income and household characteristics as an agricultural household, the landless household will respond less (in numerical value) in its off-farm labor to wage than would the agricultural household.[8] The response of off-farm labor to wage, given a separable model, is[9]

$$\frac{\partial(T - X_L - R_L)}{\partial p_i} = \frac{-\partial R_L}{\partial p_L} - \frac{\partial X_i}{\partial p_L} - (T - X_L - R_L)\frac{\partial X_L}{\partial Y} \qquad (3)$$

where, as in Chapter 1, T is total household time available for work or leisure, $X_L$ is leisure, $R_L$ is total labor demand (family plus hired), and $p_L$ is the wage rate. Equation (3) has three terms: $-\frac{\partial R_L}{\partial p_L}\Big|_{p_c^*}$ is the negative of the response of the labor demand to wage, which is positive; $-\frac{\partial X_L^c}{\partial p_L}$ is the negative of the response of compensated leisure demand to wage, also positive; and $-(T-X_L - R_L)\frac{\partial X_L}{\partial Y}$ is the negative income effect. For a landless household the income effect is weighted by $-(T-X_L)$, labor supply. If its response to wage is subtracted from the agricultural household's response two positive terms are left: $-\frac{\partial R_L}{\partial p_L}$ and $R_L\frac{\partial X_L}{\partial Y}$.

In his empirical work Rosenzweig is forced to use gross, not net, off-farm work since data on labor hired is not available. This introduces censoring into the data, which is handled using

a Tobit model. However, the model itself explains net, not gross, off-farm work. The two may be different if a household sells labor during a slack season and hires during peak season. As an alternative one might hypothesize family and hired labor to be imperfect substitutes in which case the gross supply of off-farm labor would be the appropriate endogenous variable. However the model would then not be separable for households supplying no off-farm labor since they would be at a corner at which household labor supply equaled household labor demand, (see Chapter 1, Section 5).

Rosenzweig finds that the differential responses of off-farm labor for landless and landed households generally conform to predictions derived from the agricultural household model. Surprisingly, off-farm supply of male labor responds negatively to male wage and positively to female wage,[10] however, female off-farm labor responds positively to the female wage and negatively to the male wage.

Yotopoulos (this volume) also disaggregates labor, but he distinguishes child from adult labor. His data, on households in Mindanao, Philippines, are complete enough to estimate an entire agricultural household model, which he does separately for tenant and landowning households. While estimating production functions for different types of agricultural households has a long history it does raise several methodological issues. The biggest potential porblem so introduced is inconsistency of econometric parameter estimates. This would occur if the sample was selected based on random variables correlated with

the endogenous variables, since in that case the statistical disturbances would no longer have mean zero. Yotopoulos also has data on fertility related variables and tries to relate the results from the agricultural household model to the household demand for children. The connections can only be drawn indirectly, however, since the agricultrual household model he uses assumes children are fixed exogenously, while the idea of a demand for children makes them endogenous. Despite this limitation Yotopoulos finds some support for the hypothesis that fertility is inversely related to farm endowments.

Lopez (this volume) distinguishes family from hired labor using aggregate Canadian data. He also hypothesizes differential disutility is derived from working on the family enterprises versus working for someone else. As shown earlier these two assumptions result in a nonseparable model. Rather than estimate one reduced form equation Lopez estimates commodity demand, output supply and input demand equations jointly. He also specifies a separable model, but assumes demand and production side errors to be correlated, so again he estimates the two sides jointly. The two models are not nested so Lopez uses a non-nested statistical test to discriminate between them and strongly rejects his specification of a separable model. He also rejects, less strongly, the hypothesis of zero correlation between demand and production side errors. His results thus cast some doubt on the assumptions used in the bulk of the empirical work with agricultural household models. It should be born in mind that his model is very small, and even then is

very expensive to estimate. Whether the results are so different as to merit the extra expense is not completely clear. In addition, it should be noted that Lopez is using aggregate, not household, data, and that non-nested tests of the type Lopez uses may not lead to unambiguous results.[11]

Deolalikar (this volume) builds a two period agricultural household model in order to explore investment (particularly in irrigation) and savings (hence borrowing) decisions, in addition to current period consumption and production decisions, for Indian households in Gujarat. Given perfect markets including for the capital market (possibly a dubious assumption), and given no bequest motives, multiperiod agricultural household models are separable between production and consumption decisions, with investment treated as part of the production block and savings as part of the consumption block. As is true for the early neoclassical models of investment (Jorgenson, 1963) the model itself only determines desired capital stock. Some (ad hoc) rule has to be invoked to determine investment, the dynamic paths of capital stocks not being determined within the model. Between time periods the production decisions are separable but the consumption decisions are not. Although Deolalikar has data for two periods, it is incomplete so he has to resort to estimating a one period model treating capital as endogenous. He uses an extended linear expenditure system (ELES) to do this. While the ELES can be derived from a dynamic optimizing problem (Lluch, 1973), it can also be derived from a purely static model in which savings provides utility (Howe, 1975). It does not, then, correspond to a truely dynamic model.

Separability of a two-period model can easily be destroyed. If bequests are important then accumulated net investments will appear in the household's utility function and separability will be lost. Of importance for developing countries is the likelihood that capital markets are imperfect, or at least that households face an upward sloping supply curve for loans. In that case the interest rate is endogenous to the household and the model is no longer separable. Iqbal (this volume) estimates net borrowing and interest rate functions for a set of Indian households, the net borrowing function being explicitly derived from an agricultural household model. Net borrowing is defined as investment minus savings, thus it includes self-financing in addition to external borrowing. Iqbal shows that such a difference in definition makes a difference in the empirical results. Using an interest rate function is one way to accomodate the large variation in interest rates charged often found in empirical investigations, as well as to impute interest rates to households which don't borrow on the market. However it still does not measure effective interest rates, which is the more relevant price in view of the oftentime large transaction costs (Adams and Graham, 1981).

A somewhat different approach to a two-period model is taken by Roe and Greene. They are interested in introducing risk considerations, in particular into full income (price risk on the consumption side is not considered). They hypothesize that households maximize expected utility subject to a stochastic full income constraint, which they set up as a dynamic programming

problem. Under certain circumstances their model is separable, which they exploit in their empirical work for Dominican Republic households using programming techniques to estimate the production side and econometric techniques for the demand side.

Rosenzweig and Pitt (this volume) introduce a household production activity, health, into an agricultural household model by making health an input into both utility and farm production. Health is in turn produced by inputs, some of which result from household choices (eg. foods). The resulting model is still separable provided hired and family labor are perfect substitutes in farm production. Rosenzweig and Pitt estimate reduced form profit and labor supply equations for Indonesian households, and find evidence to support separability. They also estimate reduced form equations for health supply, and for demand for a health input (clean water). Finally a structural equation is estimated for the health production function of individuals.

Earlier empirical papers by Rosenzweig and others have estimated reduced form equations for the demand for children, and for education within the context of multiperiod agricultural household models (see Rosenzweig, 1977, Rosenzweig and Evenson, 1977; Rosenzweig, 1982a, b). More recently, Huffman and Lange (1982) have estimated reduced form equations for off-farm, farm, and household production labor use, for household services from durable capital goods, and for demand for farm inputs for a set of Iowa agricultural households.

A very different extension from the foregoing is made by Sicular (this volume). She considers the effects of various

quantity constraints on household sales and purchases, and applies her model to a commune production team in the Peoples Republic of China. Her treatment of such a large unit (the production team) as a household is quite different from other formulations which focus on the interactions between team members (intra household distribution, see for instance Sen, 1966; Chinn, 1979), but it seems to be fruitful empirically. Because she only has data on one production team for one year she cannot use econometric techniques to estimate her model, and instead uses programming techniques. The difficulty is that consumption choices cannot easily be modeled in this way, so she concentrates on the production side. Introducing quantity constraints makes an otherwise separable model nonseparable, however, given knowledge of the optimum consumption bundle, the household's production choices can be modeled as maximizing profits subject to the production function, quantity constraint(s), and to optimal consumption. By using actual consumption as a proxy for optimal consumption Sicular is able to use programming techniques to model production decisions despite their dependence on household preferences. Unfortunately she is not able to empirically derive proper comparative statics since there is no way to know what levels optimal consumption will take on as independent variables are varied.

In addition to these extensions of agricultural household models a number of policy applications have been made. Lane and Benito (this volume) look at the effects of food subsidies on the nutritional status of low income agricultural households

in Egypt. They also use LP to estimate their model. In order to do this they assume an unusual form for the household utility function, that it is lexicographic with food "needs" being met first. Minimum food requirements are allowed to be a function of income, but the parameters in this function are not empirically determined.

Other applications are at the macro level and allow for the endogeneity of some variables, usually market prices, which are taken as given by households. Lau and Yotopoulos (1974) suggest some types of macro models which might be useful. Barnum and Squire (1979b) made some calculations for the Malaysian study which assume that world markets determine prices for all commodities except labor, with the wage rate adjusting to equilibriate net labor demand by agricultural households with net labor supply by the rest of the economy. Smith and Strauss (this volume) simulate Strauss' Sierra Leone results at the household level, then projecting them to the national level. They also allow rural wages to adjust to changes in exogenous variables. Because the simulations are at the household level, they can derive very detailed distributional results, which is done for household caloric availability. Lau, Yotopoulos, Chou and Lin (1981) project their Taiwan household level predictions to the aggregate level, but do not allow for any general equilibrium effects. They simulate different policy scenarios, paying attention to the distributional impact.

Braverman, Ahn and Hammer (this volume) report what is by far the most ambitious macro level model with an agricultural household model embedded in it. Their work is a limited general

equilibrium model designed to analyze policy-oriented questions in Senegal, specifically what effects different agricultural pricing policies may have on government revenues, farm and non-farm incomes disaggregated by region, and other aggregate measures. The model has rural, urban, and government sectors. Commodity demands, output supplies and input demands are derived from agent optimizing behavior, an agricultural household model for the rural sector. Commodity demands are generated by an Almost Ideal Demand System (AIDS, see Deaton and Muellbauer, 1980), which allows for inferior goods and some limited nonlinearity in Engel curves, but which forces the Engel curves to have zero intercepts. The government sector is modeled as part of the market clearing conditions. In this way the impact of various policies on government revenues is permitted. Commodity demand equations are linked to utility functions so as to assess the welfare implications of consumer price changes involving a number of goods simultaneously by computing real price indices. Different regions are distinguished so as to trace policy effects on regional inequality, and an Atkinson (1970) social welfare function employed to measure the changes on aggregate welfare. The model itself is highly non-linear, thus is expensive to solve.

In macro modeling the question arises how to compute the macro-functions. Most studies have multiplied the micro (household level) functions evaluated at the sample average by the number of households in the agricultural sector. That is the macro functions are derived using the concept of a representative household. This raises the question of whether the functional forms used for the commodity demands, output

supply and input demands aggregate perfectly (Deaton and Muellbauer, 1980 -- they do for both the LES and the AIDS). As Smith and Strauss show there may be substantial differences between using the representative household approach and summing the relevant microfunctions when functional forms are used which don't aggregate perfectly.

## 5. Summary

Clearly many useful empirical applications of agricultural household models have been made. The pioneering studies of Lau, Yotopoulos and their collaborators, and Barnum and Squire have shown that modeling the production-consumption interactions of farm households does make an important empirical difference. Subsequent studies have made some useful extensions, and have examined several interesting policy questions. The remaining chapters in this volume comprise many of those extensions.

FOOTNOTES

1. Uncorrelatedness of the error terms can be tested statistically. One could use a Lagrange Multiplier test which only requires restricted parameter estimates (i.e., separate estimates of the consumption and production blocks). Alternatively one could use a Hausman-type test using maximum likelihood estimates of the demand parameters treating profits as fixed and a (nonlinear) three-stage least squares estimator treating profits as endogenous (see Lopez, this volume, for a different, Wald, test of uncorrelatedness).

2. Kuroda and Yotopoulos decompose leisure into leisure of family members who work on the farm and leisure of those working off the farm. They thus assume that those working off the farm are different people with different labor quality than those working on farm. To make the model separable they also implicitly assume hired labor is used on the farm.

3. Though Deaton (1978) thinks even in that case additivity should be rejected.

4. In particular scaling (see Pollak and Wales) which involves dividing quantities in the utility function by commodity specific indices, i.e., $U\left(\frac{X_0}{\gamma_0}, \ldots, \frac{X_n}{\gamma_n}\right)$, seems to work a little better empirically than translating.

5. Recall Kuroda and Yotopoulos specify off-farm worker and farm worker labor supply.

6. In the Taiwan study the effect of workers comes only by changing full income. Dependents, however, change the commodity composition of demand.

7. Huffman (1980) and Sumner (1982) also estimate off-farm labor supply functions, though for U.S. farm households.

8. Rosenzweig derives other differential responses, for example with respect to education or age variables.

9. See equation (28) of Chapter 1 for a similar expression for the marketed surplus of the agricultural commodity.

10. Presuming that hired male labor responds negatively to wage; had the net rather than gross off-farm labor supply been measured,the response to male wages would have been less negative, or perhaps even positive.

11. In particular it is possible both of his hypothesized models are false and some other specification of a separable model might have been found to be true.

Table 1

Taiwan: Selected Household Response Elasticities with Farm Profits Exogenous and Endogenous[a]

| Variables | | Elasticities | | | | |
|---|---|---|---|---|---|---|
| | | Consumption of Farm Good | Consumption of Non-farm Good | Household Labor Supply | Farm Labor Demand | Marketed Farm Surplus |
| Price of farm good | Profits Constant | -0.72 | 0.13 | 0.21 | 2.25 | |
| | Profits Variable | 0.22 | 1.18 | -1.54 | | 1.03 |
| Wage rate | Profits Constant | | | | | |
| | Profits Variable | -0.03 | -0.12 | 0.17 | -1.98 | -0.95 |
| Number of family workers | | 0.84 | 0.84 | 1.27 | -- | -0.13 |
| Number of dependents | | 0.43 | 0.0 | 0.20 | -- | -0.07 |
| Land quantity | Profits Constant | 0.0 | 0.0 | 0.0 | | |
| | Profits Variable | 0.46 | 0.46 | -0.77 | 0.93 | 1.00 |

[a] From Tables V and VI, Lau, Lin and Yotopoulos (1978) and Table 6, Yotopoulos, Lau and Lin (1976). The elasticities in Table V of Lau, Lin and Yotopoulos holds full income constant, not profits. These elasticities are identical except for wage rate changes, in which case . (the proportion of the value of time in full income) is added to those holding full income constant.

Table 3

Japan: Selected Household Response Elasticities with Farm Profits Exogenous and Endogenous[a]

| Variables | | Elasticities: Consumption of Farm Good | Consumption of Non-farm Good | Household Farm Labor Supply | Household Off-farm Labor Supply | Farm Labor Demand | Marketed Farm Surplus |
|---|---|---|---|---|---|---|---|
| Price of farm good | Profits Constant | -0.87 | 0.08 | 0.16 | 0.06 | | |
| | Profits Variable | -0.35 | 0.61 | -1.00 | -0.05 | 1.98 | 2.98 |
| Farm wage rate | Profits Constant<br>Profits Variable | 0.15 | 0.25 | 0.45 | 0.11 | -1.55 | -0.77 |
| Off-farm wage rate | | 0.32 | 0.50 | -1.97 | -0.16 | -- | -0.33 |
| Number of family farm workers | | 0.07 | -0.12 | -0.89 | 0.21 | -- | -0.03 |
| Number of dependents | | 0.14 | 0.02 | 0.34 | -0.06 | -- | -0.06 |
| Land quantity | Profits Constant | 0.0 | 0.0 | 0.0 | 0.0 | | |
| | Profits Variable | 0.19 | 0.19 | -0.43 | -0.04 | 0.73 | 0.96 |

[a] From Tables 4.2 and 4.3, Kuroda and Yotopoulos (1980) and Table 4.2, Kuroda and Yotopoulos (1978). Table 4.2 in Kuroda and Yotopoulos holds full income, not profit, constant. Those wage elasticities have . (the proportion of the value of time in full income) added to them in order to obtain the elasticities reported here.

Table 2

Malaysia: Selected Household Response Elasticities with Farm Profits Exogenous and Endogenous[a]

| Variables | | Elasticities | | | | |
|---|---|---|---|---|---|---|
| | | Consumption of Padi | Consumption of Non-farm Goods | Household Labor Supply | Farm Labor Demand | Marketed Padi Output |
| Price of padi | Profits Constant | -0.04 | -0.27 | 0.08 | | |
| | Profits Variable | 0.38 | 1.94 | -0.57 | 1.61 | 0.66 |
| Wage rate | Profits Constant | 0.06 | 0.29 | -0.07 | | |
| | Profits Variable | -0.08 | -0.35 | 0.11 | -1.47 | -0.55 |
| Number of family workers | | 0.44 | -0.06 | 0.62 | -- | -0.09 |
| Number of dependents | | 0.23 | -0.05 | 0.12 | -- | -0.50 |
| Neutral technical efficiency parameter[b] | Profits Constant | 0 | 0 | 0 | | |
| | Profits Variable | 0.42 | 2.21 | -0.65 | 1.61 | 1.85 |

[a] From Tables 15 and 16, Barnum and Squire (1979a).

[b] The intercept of a Cobb-Douglas production function.

Table 4

Thailand: Selected Household Response Elasticities With Farm Profits Exogenous and Endogenous[a]

| Variables | | Consumption of Farm Good | Consumption of Nonfarm Good | Household Labor Supply | Farm Labor Demand | Marketed Farm Surplus |
|---|---|---|---|---|---|---|
| Price of farm good | Profits Constant | -.82 | .06 | .18 | | |
| | Profits Variable | -.37 | .51 | -.62 | 1.90 | 8.10 |
| Wage Rate | Profits Constant | | | | | |
| | Profits Variable | .47 | .52 | .26 | -1.57 | 3.62 |
| Number of family workers | | .70 | .69 | .94 | -- | -1.72 |
| Number of dependents | | -.16 | -.29 | -.28 | -- | .39 |
| Land quantity | Profits Constant | 0.0 | 0.0 | 0.0 | | 0.0 |
| | Profits Variable | .11 | .11 | -.19 | .54 | 1.48 |

[a] From Tables 6 and 8, Yotopoulos, Adulavidhaya, Kuroda and Lau (1976), and Table 6.4 Adulavidhaya, Kuroda, Lau, Lerttamrab, and Yotopoulos (1979). Table 6 in Yotopoulos et. al holds full income, not profit, constant. Those wage elasticities have. -- . (the proportion of the value of time in full income) added to them, in order to obtain the elasticities reported here.

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