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ESTIMATION OF AN AGRICULTURAL HOUSEHOLD MODEL
FOR SOUTHERN MINNESOTA FARMS

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INTRODUCTION

Agricultural household models provide a methodology for integrating a farm household's production and consumption decisions into a unified theoretical and econometric framework. Such models have been widely applied for developing countries (Braverman and Hammer, 1986; Barnum and Squire, 1979; Strauss, 1984; Singh et al., 1986). In rural developing country settings, a majority of the population is typically involved in agriculture, production practices are often mono-cultural revolving around a single dominant crop, and a significant portion of the household's agricultural production is consumed at home. As a result the major emphasis of such research has been focused on marketable surplus and output-supply, input-demand type responses with respect to changing exogenous variables. Given this situation the agricultural household model is superior to traditional consumption studies which consider the effect of a food price change without taking into account the impact on farm income (Singh et al., 1986).

This study applies an agricultural household model to southern Minnesota data where only a minority of the population is actively involved in farming, but where the rural economy is highly dependent on agriculture. Furthermore, no single output dominates, but rather multiple outputs and multiple inputs are the norm; on-farm storage can represent a significant portion of output; and the amount of financial leverage can vary tremendously over farm households. These factors shift the major emphasis away from marketable surplus responses and single output price effects, to analyzing consumption expenditure responses to changing farm profits, financial flows, commodity output and factor input prices, and farm asset values.

This study uses a recursive, two-stage agricultural household model to analyze data for 1977-86 from the Southeastern and Southwestern Minnesota Farm Management Associations. The first stage of the household model involves estimating a system of net output and fixed input share equations derived from a translog restricted variable profit function. In the second stage, a system of budget share equations derived from an almost ideal demand system are estimated. The estimated parameters from these results are used to calculate elasticities for relationships on both the production and consumptions sides, as well as those elasticities linking the two. These elasticities measure the sensitivity of farm household consumption demand, input demand, and output supply with respect to changes in several important exogenous variables (commodity and input prices, rural wages, fixed asset values, and farm household demographic characteristics). Hired help is included in input demand on the production side, while household leisure time represents a category of consumption expenditure.

The estimated relationships should improve our understanding of farm household interactions in terms of analyzing the welfare or real income of farm families and the spillover effects from the farm economy to the rural non-agricultural economy via household consumption expenditures. An additional objective is to empirically examine the validity and usefulness of applying an agricultural household modeling framework in a developed country setting.

THE AGRICULTURAL HOUSEHOLD MODEL

In general, agricultural household models specify a household utility function with market-purchased goods, home-produced goods, and leisure time as the choice variables. Optimization of the utility function is subject to a "full income" constraint which includes the value of the household's stock of time, any non-wage, non-farm income, and a measure of the farm's profits. Finally, either the (short-run) production technology constraint is explicity defined or it implicitly underlies a profit, revenue or cost function (Singh et al., 1986).

The "full income" constraint in particular distinguishes agricultural household models from other approaches and highlights the interdependency between consumption and production decisions made at the farm household level. Farm technology, quantities of fixed inputs, and prices of variable inputs and of outputs affect household consumption decisions since they determine the size of the farm profit portion of the "full income" constraint. Thus, this approach permits the identification of the linkages between farm household production and consumption decisions. Singh *et al*, (1986) have shown that agricultural household models are most useful when: (a) the returns from the farm's operations comprise an important portion of the household's income (b) consumption expenditures on goods and services are sensitive to "full income"; and (c) a significant proportion of the labor input used by the farm is supplied by household members.

Under a set of simplifying assumptions, consumer demand equations and output supply and variable input demand equations can be derived by modelling the farm household's decision making process recursively as two separate stages. These assumptions are given in detail by Singh *et al* (1986). Briefly they include: (1) utility and profit maximizing behavior prevails; (2) the household is a price-taker in all markets and all markets exist; (3) production is riskless; (4) the farm household is indifferent between on-farm and off-farm employment and the use of hired labor; and (5) a static framework is appropriate.

By assumption (4), the opportunity cost for household on-farm labor, the wages for on-farm hired labor, and the wage rates for off-farm household labor are all assumed to be subject to the same price structure (in this case the estimated off-farm wage rate). Lopez (1984, 1986) has been critical of this assumption underlying the recursive approach and, instead, has worked with a simultaneous estimation approach. However, in this study a simultaneous approach would overly complicate the estimation and detract from the initial objective of trying to identify the relationship of a large number of economic variables. With a recursive framework, the estimation reduces to a system of output supply and input demand equations on the production side and a system of demand equations on the household's consumption side. Thus, the researcher is able to draw on a growing body of literature on the properties and estimating characteristics of systems approaches, some of which include Barten (1977), Deaton and Muellbauer (1980), Phlips (1974), and Theil (1980). In particular, constraints enforcing compliance with expected theoretical restrictions are more easily applied to individual systems.

Stage I: the Production Side

Under assumptions (1)-(5) the first stage of the agricultural household model involves the production side where resource allocation decisions are made so as to optimize over a variable restricted profit function subject to a production technology, some fixed resources, and relevant household characteristics. Define the respective vectors of net output prices and net output quantities as $\mathbf{q} \in \mathbb{R}^M$ and $\mathbf{Q} \in \mathbb{R}^M$, and the vector of fixed inputs and household characteristics as $\mathbf{A} \in \mathbb{R}^F$ (with bold characters representing vectors). The vector of net output prices q, is associated with a vector of net output quantities, $\mathbf{Q}$, where Q_i is positive if it represents an output category and negative if it represents a variable input category.

Within the context of "full income" (Y*) the household's stage I problem may be seen as:

$$\underset{\{Q,T,E,D\}}{\text{MAX}} \left\{ \Pi\left(q;A\right) + wT + E + D : (Q,A,T,E,D) \in \tau\left(Q,T,E,D;A\right) \right\} = Y^{*}(q,T,E,D;A) \qquad (1)$$

where

$\tau(\cdot;A)$ = the technology or production possibility set for a given level, A, of fixed inputs and household characteristics,

wT = the value of the household's stock of time (T) multiplied by the wage rate (w),

E = off-farm, non-wage income, and

D = new borrowings minus principal payments .

But by Assumption (5) T, E, and D are fixed such that (1) may be rewritten as:

$$Y^{*}(q;E,T,D,A) = \Pi\left(q;\ A\right) + w\cdot T + E + D \qquad (2)$$

where, under the assumptions of profit maximizating behavior and a set level of fixed assets and household characteristics each period, the variable restricted profit function is defined as:

$$\Pi\left(q;\ A\right) = \underset{\{Q\}}{\text{MAX}} \left\{ q'Q \ :\ (Q) \in \tau\left(Q;\ A\right) \right\} . \qquad (3)$$

Profit (Π) is defined as the revenue from farming operating outputs minus variable input expenses. The properties of such a variable, restricted profit function are described by Diewert (1974).

This study uses a translog function to represent the variable restricted profit function. The properties and exact derivation of the translog's estimating equations are formally presented and described by McKay et al. (1983). Optimization of the translog profit function subject to assumptions (1)- (5) and certain "regularity" conditions yields a set of net output supply and fixed asset equations that are in the form of linear factor share estimating equations.

The net output supply share estimating equations for the h^{th} household and the t^{th} year as derived from the translog profit function are (see Schnepf, 1988):

$$S_{iht}(q_{ht};A_{ht}) = \alpha_i + \sum_j^M \gamma_{ij}\ln(q_{jht}) + \sum_k^F \delta_{ik}\ln(A_{kht}) + \sum_h^H \theta_{ih}D_h + u_{iht} \qquad (4)$$

$$i=1,\ldots,M$$

while the fixed asset share equations take the form:

$$R_{jht}(q_{ht};A_{ht}) = \beta_j + \sum_k^F \beta_{jk}\ln(A_{kht}) + \sum_i^M \delta_{ji}\ln(q_{iht}) + \sum_h^H \mu_{jh}D_h + \epsilon_{jht} \qquad (5)$$

$$j=1,\ldots,F$$

where

S_{iht} = the share of the i^{th} net output in total profit;

R_{jht} = the share of the j^{th} fixed input in total cost of fixed inputs;

q_{iht} = the aggregate price index or representative price for the i^{th} net supply category, i=1,...,M;

q_{ht} = the Mx1 vector of net supply prices;

A_{jht} = the j^{th} fixed asset or household characteristic, j=1,...,F;

A_{ht} = the Fx1 vector of fixed assets and household characteristics;

ϵ_{ij}, u_{ij} = additive error terms; and

D_h = zero-one dummy variable reflecting household specific fixed effects.

This specification includes dummy variables to account for "fixed effects" across households.

McKay *et al* (1983) have shown that several relationships in the form of elasticities are derivable from this framework. However, only two such elasticities are presented here, which later are used in constructing the elasticities linking production variables to consumption behavior. The partial elasticity of variable net ouput (Q_i) with respect to variable net price (p_j) is:

$$\epsilon_{ij}(q;A) = \frac{\partial Q_i}{\partial q_j}\cdot\frac{q_j}{Q_i} = S_j + \left(\gamma_{ij}/S_i\right) - \lambda_{ij} \qquad \lambda_{ij} = \begin{cases} 1 \text{ if } i = j \\ 0 \text{ if } i \neq j \end{cases} \qquad (6)$$

$$i,j=1,\ldots,M$$

The partial elasticity of variable net output (Q_i) with respect to fixed input (A_k) is:

$$\xi_{ik}(q;A) = \frac{\partial Q_i}{\partial A_k}\cdot\frac{A_k}{Q_i} = R_j + \delta_{ik}/ S_i \qquad \begin{matrix} i=1,\ldots,M \\ k=1,\ldots,F \end{matrix} \qquad (7)$$

Stage II: the Consumption Side

The second stage pertains to the consumption side of the household where resource allocation decisions are made subject to the "full income" constraint (2). Further, this second stage problem accepts the first stage choices as given or fixed. This implies that household leisure time is merely the remainder of total household time minus the on- and off-farm household labor time allocations made in the first stage. Define the respective vectors of prices and consumption expenditure categories as $p \in \mathbb{R}^N$ and $\mathbf{X} \in \mathbb{R}^N$ where $\mathbf{X}$ includes a category for household leisure, X_L.

The household's utility function is described by $U = U(\mathbf{X};m)$ where m represents household adult equivalent units. The household budget constraint is defined as:

$$\sum_i^{N-1} p_i X_i + p_L \cdot X_L \leq \Pi\left(q;\ A\right) + w\cdot T + E + D = Y^* \qquad (8)$$

where p_L equals w, i.e., the off-farm wage rate. The household's problem is to maximize U subject to (8). Since utility maximization implies expenditure minimization for a fixed level of utility under certain regularity conditions, e.g., local nonsatiation (see Varian, 1984), the household's consumption problem may be stated using an expenditure function as:

$$C(p,\bar{U}) = \underset{\{X\}}{\text{MIN}} \left\{ \sum_{i}^{N-1} p_i X_i + p_L \cdot X_L : U(X) \geq \bar{U} \right\} \tag{9}$$

The properties of such an expenditure function are described by Diewert (1982). The household's equilibrium is obtained when total expenditure is equal to full income:

$$C(p,\bar{U}) \equiv Y^*(q;T,A,E,D) \, . \tag{10}$$

Under the specification of a cost minimizing framework this study has chosen to utilize the almost ideal demand system (AIDS) model (Deaton and Muellbauer, 1980). There exists a growing body of literature involving the AIDS model, for example, Blanciforti and Green (1983); Braverman and Hammer (1986). Deaton and Muellbauer have shown that the AIDS estimating equations are easily transformed into a linear system of equations by adopting Stone's price index as the income deflator. In situations where the independent variables are identical over all equations, the estimation reduces to simple ordinary least squares (OLS). An additional transformation whereby consumption expenditure prices are normalized with respect to household specific adult equivalent units is adopted from Ray (1980 and 1982). The resulting linearized budget share estimating equations for the AIDS model are of the form:

$$w_{iht} = \alpha_i + \sum \gamma_{ij} \ln(p_{jht}) + \beta_j \ln\left(Y_{ht}/P^*_{ht}\right) + \theta_i \ln(m_{ht}) + u_{iht} \tag{11}$$

where (again h and t run over households and years, respectively):

w_{iht} = budget share of the i^{th} expenditure category;

p_{jht} = price of the i^{th} expenditure category;

m_{ht} = household adult equivalent units;

Y_{ht} = nominal total household expenditures in per adult equivalent units;

= Y^*_{ht}/m_{ht};

Y^*_{ht} = nominal total household expenditures;

$\ln(P^*_{ht})$ = $\sum_i w_i \ln(p_i)$, i.e., Stone's price index;

u_{iht} = error term.

For estimation purposes it is assumed that m_{ht} is independent of Y^*_{ht} and prices.

Expenditure and price elasticities, in addition to an elasticity measure with respect to the household's size, can be derived from the linear specification in (11).

The household size elasticity is:

$$\Omega_i = \frac{\partial X_i}{\partial p_j} \cdot \frac{p_j}{X_i} = \frac{\theta_i - \beta_i}{w_i} \qquad (12)$$

THe full income elasticity is:

$$e_i = \frac{\partial X_i}{\partial Y^*} \cdot \frac{Y^*}{X_i} = 1 + \frac{\beta_i}{w_i} \qquad (13)$$

The uncompensated price elasticities are:

$$e_{ij} = \frac{\partial X_i}{\partial p_j} \cdot \frac{p_j}{X_i} = \frac{1}{w_i} \cdot \left(\gamma_{ij} - \beta_j \cdot w_j \right) - \delta_{ij} \quad \forall\ i,j = 1,\ldots,N \qquad (14)$$

where δ_{ij} is the Kronecker delta.

The final step is to evaluate the impact of the production side on consumption via the linking full income term. Under the comparative static, short-run framework described by the household model of this study two particular sets of relationships appear accessible. The elasticity of a change in consumption expenditure on a particular category, X_i, with respect to a change in the price of a net output, q_j, is:

$$\Psi_{ij} = \frac{\partial X_i}{\partial q_j} \cdot \frac{q_j}{X_i} = e_i \cdot \left(\frac{\partial Y^*}{\partial \Pi} \cdot \frac{\Pi}{Y^*} \right) \left[\sum_l S_l \cdot \left(\frac{\partial Q_l}{\partial q_j} \cdot \frac{q_j}{Q_l} \right) \right] . \qquad (15)$$

The elasticity of a change in consumption expenditure on a particular category, X_i, with respect to a change in the value of a fixed input, A_k, is:

$$Z_{ik} = \frac{\partial X_i}{\partial A_k} \cdot \frac{A_k}{X_i} = e_i \cdot \left(\frac{\partial Y^*}{\partial \Pi} \cdot \frac{\Pi}{Y^*} \right) \left[\sum_l S_l \cdot \left(\frac{\partial Q_l}{\partial A_k} \cdot \frac{A_k}{Q_l} \right) \right] . \qquad (16)$$

These linking elasticities sum the effect of a change in an ouput price in (15) and in the value of a fixed asset in (16) on the quantites of net outputs weighted by their respective profit shares, and then trace the impact through farm profits and full income to the different consumption categories.

DATA

Generally, the use of detailed agricultural household models is limited by the extensive data requirements involved. The data utilized in this study are from farms participating in the Southeastern and Southwestern Minnesota Farm Management Associations. For several decades, the members of these two Associations have been providing their financial records to the University of Minnesota for individual analysis and summarization. Detailed records are kept of farm incomes, production activities and expenses, asset purchases and sales, and liabilities. In addition, a number of members have kept records of their household consumption expenditures and nonfarm income. To ensure the consistency and reliability of the data, the fieldmen of each association assist the farmers in maintaining accurate records and decide which records are complete and accurate.

The Associations' data have two apparent weakenesses. First, participation in the financial records study is on a voluntary basis and does not pretend to represent a random survey of farmers in these two areas of Minnesota. In spite of this, the data still possess much valuable information and can be used to demonstrate the potential of agricultural household models to analyzing U.S. farms. The second weakness of the data is that membership and participation in the financial records study changes from year to year; however, there is enough consistency over the most recent several years to establish a relevant working set of panel data.

The data are in the form of a time series of cross-sectional observations that comprise a panel. Cross-sectional observations which represent individual households will bear the subscript h ranging from 1 to H; whereas, the times-series observations will be designated by the subscript t and range from 1 to T. The total number of observations then will be H*T. The data used cover the ten-year period from 1977 through 1986, thus T = 10.

The size of H is less obvious since not all households have observations running over the entire ten year period. Only 23 households have both the necessary production and consumption data for all ten years. However, another 21 households have data for nine out of the ten years, while 13 more have eight years of data. Including those with at least eight years of data provides a cross-section of 57 households for a total sample size of 523. Examination of the data revealed no particular pattern to the missing observations; thus, no corrective statistical measures were felt necessary to account for the possibility of a nonrandom omission of data and the subsequent bias that this would introduce.

Household expenditure data are divided into nine categories. The use of a household model approach necessitates the inclusion of the value of household leisure time as a tenth category of household expenditure. The categories are: X_F = food and meals purchased; X_M = medical expense and hospitalization insurance; X_C = clothing and cloth materials; X_H = housing, household furnishings and equipment; X_T = transportation; X_R = recreation; X_O = other goods and services;[1] X_D = donations and gifts; X_K = capital investments;[2] and X_L = leisure time.

Prices for all categories but capital, donations, and the value of leisure time are represented by their corresponding Minneapolis-St.Paul CPI-W (urban wage earners and clerical workers) values. Capital is priced by the annual average interest rate charged on intermediate non-real-estate loans for the Ninth Federal Reserve District. Donations are priced by the marginal tax rate for married taxpayers filing jointly which, in accordance with Reece (1979), is the relevant opportunity cost. The actual taxes paid (income taxes paid minus any income tax refund) by a household were fitted to the relevant tax table to obtain a marginal tax rate. If no taxes were paid or tax refunds exceeded tax withholdings a zero marginal tax rate was used. Finally, household leisure is valued at the off-farm wage rate confronting each particular household.

Household Off-farm Wage Estimation

Wages or the information on time allocation necessary to calculate wage rates were not available in the data set. However, a procedure was devised for deriving a county level off-farm wage using Bureau of Economic Analysis (BEA) data for Minnesota counties on personal income from wage & salaries and employment. A fully employed individual was assumed to work 50 forty-hour work weeks for a total of 2,000 per year. The county aggregate for wages & salaries was divided by the county aggregate for employment multiplied by 2,000.

Wage rates vary geographically because of the location of major cities, industries, and transportation routes. The major example in the study area is Olmsted county where the city of Rochester and the Mayo Clinic are located. Since the BEA county level data were not available for 1985-86, a simple OLS regression was used regressing the county off-farm wage estimate for 1975-84 on BEA Minnesota state personal income (wages and salary) for those same years. The underlining concept is that off-farm wages are related to the level of economic activity as reflected by state personal income. This OLS regression was performed for each of the counties in the two farm management areas in order to estimate their 1985-86 off-farm wage rates.

Production Side

On the production side, six aggregate net output categories were identified. These include: Q_1 = crop output; Q_2 = livestock and dairy output; Q_3 = livestock operating expenses; Q_4 = crop operating expenses; Q_5 = land rent and leases; and Q_6 = hired labor. Price indexes were developed for Q_1 - Q_4, while the average cash rent for southern Minnesota was used for Q_5 and the off-farm wage rate estimate was used to price Q_6. All prices were deflated using the Minneapolis-St.Paul all-items CPI.

For simplification, the fixed asset categories were limited to four aggregate groups: A_B = buildings; A_L = land; A_M = machinery and equipment; and A_Q = on-farm household labor (as explained later). A_B, A_L, and A_M represent the value of their ending inventories, while A_Q is the estimated on-farm household labor time valued at the estimated off-farm wage rate. See Schnepf (1988) for a detailed description of the composition of these categories and the relevant prices. In addition, three household characteristics were included in the production side model: A_5 = household size; A_6 = age of operator; and A_7 = weather index. A Stalling's index (Stallings, 1960) based on county level corn and soybean yields was used for the weather index.

Full Income

The full income term encompasses the value of all the resources available to the consumption side of the household. This includes the opportunity cost of household time whether used in farm production activities or as leisure time. Given the available data, the measure of household full income was obtained using the following formula:

$$Y^{*} = \Pi(q;A) - INT - TAX - w \cdot Q_L + D + E + w \cdot T - \Delta K - \Delta C - \Delta INV \qquad (17)$$

where

Π = (Gross income from sales of crops, livestock, and dairy products) + ΔINV - (Total current cash expenses),

INT = Interest charges for the year;

TAX = Property and real estate taxes;

$w \cdot Q_L$ = the value of the household's on-farm labor time;

D = New Borrowings - Principal Payments - DIFF; (Where DIFF represents the difference between the apparent cashflow available for household expenditures and the reported household expenditures);

E = Nonfarm, nonwage income;

$w \cdot T$ = the value of the household's stock of time;

ΔK = Farm asset purchases - sales;

ΔC = change in cash-on-hand (includes checking); and

ΔINV = change in inventory holdings of crops.

In order to adapt the theoretical concept of full income to the available data a number of modifications were necessary. In particular, results from the translog function's profit share estimating equations proved to be highly sensitive to having profits at or near zero. Profit observations near zero give too heavy a weight to those particular household observations' activities; thus distorting the picture of general farm household behavior.

As a result, all observations on the production side having household full income of $10,000 or less were deleted from the data set in order to avoid over-weighting the influence of those particular observations. Thus, the production side had only 483 observations, whereas the consumption side estimation used a total of 518 observations.

In calculating the variable restricted profit function, it became necessary to remove interest charges (INT), property and real estate taxes (TAX), and the opportunity cost of household on-farm labor time (wQ_L) from the variable inputs expense categories and to include them instead as additive fixed costs for the following two reasons. First, neither taxes nor interest charges in any given year are necessarily related to that given year's prices, but rather, are more likely to be functions of decisions made in previous years, e.g., land and equipment purchase decisions. Secondly, without their removal, nearly a fourth of the initial 523 observations on farm household profit were negative. Under this framework, the fixed cost nature of household on-farm labor permits its inclusion among the fixed inputs in the input share estimating equations as described earlier.

The term ΔINV appears twice in the "full income" formula, (17). The first time is in Π where it accounts for unsold crop production resulting from production activities and for which current expenses have been incurred. The second time, it is subtracted to account for the foregone income (i.e., opportunity cost) of storing rather then selling the product. The prices used to value the beginning and ending inventory are not necessarily the same; thus, the change in inventory includes a possible price change as well as a quantity change.

Given the available data with no specific detail on capital expenditures and methods of financing capital purchases, all capital or fixed asset purchases are treated as expenses (or investment costs) to full income in the year in which they are incurred. Depreciation is ignored until time of sale or disposal when depreciation is reflected in the resale or disposal price.

With respect to the allocation of the household's stock of time, only the value of the household's off-farm labor time is available. Therefore, to utilize a household model it is necessary to approximate one of the remaining two components of household time, i.e., $w \cdot Q_L$ (the value of on-farm labor time) or $w \cdot X_L$ (the value of leisure time), with the third component then representing the residual of the first two from the value of the total stock of household time. It was decided to estimate $w \cdot Q_L$ since there is a larger amount of information available upon which to base such an estimate. Under a set of simplifying assumptions regarding the levels of productivity over both crop and livestock activities a procedure was established whereby the types and level of production activities were used to determine the required on-farm labor time based on historical farm management data (see Schnepf, 1988). The household's leisure time then remained as a residual from the total stock of time. Although this procedure was highly restrictive, data shortcomings precluded any other possibilities.

Descriptive Statistics

Table 1 presents the means and standard deviations for the production side variables. Table 2 provides similar statistics for the consumption side.[3]

ESTIMATION PROCEDURE

All the systems of estimating equations specified in this study (i.e., the net output, fixed input, and budget share equations) have the same error structure specification:

(i) $$u_{iht} \sim N\left(0;\ \sigma_{\phi ii}\right) \qquad \phi = S,\ R,\ \text{or}\ W;$$

(ii) $$E(u_{iht}u_{jkt-r}) = \begin{cases} \sigma_{ij} & \forall\ i\neq j,\ h=k,\ r=0 \\ 0 & \forall\ i\neq j,\ h\neq k,\ r=0 \\ 0 & \forall\ i\neq j,\ h=k,\ r\neq 0 \end{cases}$$

(iii) $$\underset{\sim}{U} \sim N\left(0,\ \Sigma_{\phi}\otimes I_{HT}\right) \qquad \phi = S,\ R,\ \text{or}\ W;$$

(iv) $$\Sigma_{\phi} = \begin{bmatrix} \sigma_{11} & \cdots & \sigma_{1\Phi} \\ \vdots & & \\ \sigma_{\Phi 1} & \cdots & \sigma_{\Phi\Phi} \end{bmatrix} \qquad \begin{matrix} \phi = S,\ R,\ \text{or}\ W \\ \Phi = M,\ F,\ \text{or}\ N. \end{matrix}$$

There are two important features concerning the estimation of both the production and consumption sides of the household model specified by this study. First, the estimating equations are represented by a system of equations where the dependent variable is a share variable such that the sum of the dependent variables across equations is unity, while the error terms are contemporaneously correlated across equations. Second, the data set is in the form of a time-series of cross-sections with some households experiencing missing observations. Each of these features has certain repercussions with respect to the estimation process.

The first problem with respect to the linear dependency resulting from the "share" nature of the dependent variables is easily avoided by simply deleting an arbitrary equation.[4] Furthermore, the assumption of nonzero cross-equation error correlations implied by a "share" approach suggests a joint generalized linear system of equations framework for estimation. However, even this step may be simplified to equation by equation OLS estimation since the exogenous variables are the same for each equation (Johnston, 1984; Kmenta, 1971).

As concerns the second problem listed above, the method of dealing with the "panel" nature of the data combines the approaches of Kmenta (1971, pp. 508-14) and Johnston (1984, pp. 396-407). On the production side only one major approach is adopted, that of "fixed effects" over households where the panel data are adjusted with respect to cross-sectional units by adding zero-one dummy variables over the individual households. A quasi-Durbin-Watson test, d^* (see Schnepf, 1988), similar to that of Savin and Whites' d' test (1978) was used to test for first-order autocorrelation, but otherwise possible effects over time are ignored.

On the consumption side the panel data are "corrected" (or normalized) with respect to time by assuming, testing for, and then correcting for first-order autocorrelation using the traditional Cochrane-Orchut procedure on an equation by equation basis. The assumption was made that all households are homogeneous with respect to their consumption behavior such that no correction is made for across household heterogeneity. Given the simple OLS regression format, Johnston (1984) has shown that the Cochrane-Orcutt procedure of correcting for first-order autocorrelation produces consistent and asymptotically efficient parameter estimates.[5] The small number of years available to any household (ten years or less) precludes the possibility of correcting for heterogeneity by estimating individual household variances in order to transform the data set.

The missing observations are essentially ignored in the estimation process, particularly with respect to testing for and correcting first-order autocorrelation where the quasi-DW statistic, d^*, and the autocorrelation estimator simply skip over any missing years and treat the first available trailing year as though it were a one-period lag (see Schnepf, 1988).

EMPIRICAL RESULTS

Due to the volume of empirical results produced from this study and considering the consumption oriented focus, none of the production elasticity results and only the more relevant of the consumption and linking elasticity results are reported here. See Schnepf (1988) for the complete empirical results.

On the whole the results for the price variables were disappointing in the budget share equations. The own- and cross-price elasticities were uniformly elastic, although only a few of the coefficients were significantly different from zero as judged by their t-statistics. This is perhaps partially due to the highly aggregated nature of the expenditure categories and the predominantly cross-sectional nature of the data set. However, it is probably also attributable to the lack of farm level price data. The CPI Minneapolis/St.Paul may not accurately represent rural southern Minnesota prices, particularly the housing and transportation indexes. As a result the price elasticities are not reported here. Perhaps worth mentioning is the unrestricted leisure own-price elasticity of -0.61 (significant at the 1% level) which implies a gross household labor supply elasticity of 1.72.[6]

The full income and adult equivalent elasticities are given in Table 3. For the "restricted" results, the homogeneity condition was imposed. With both the restricted and unrestricted results, seven out of the ten income elasticities are statistically significant, which suggests that full income is a key factor influencing household expenditures.[7] Recreation and capital are luxuries under both the unrestricted and restricted estimation frameworks with their values exceeding one in both instances. The transportation income elasticity was reported near unit elasticity in both cases. All other income elasticities appeared as necessities with values below one. The lowest values are for the food and clothing income elasticities as might be expected. However, even though food includes away-from-home expenditures, its estimated elasticity seems high.

Under the unrestricted estimation four of the adult equivalent elasticities were statistically significant: housing, other goods & services, donations, and leisure. An increase in the household adult equivalent measure is associated with decreases in the consumption expenditure for housing, other goods & services, and donations, and with an increase in the value of household leisure time. The latter effect is understandable since parental childcare and housekeeping are included in the household leisure time category and would obviously increase with increasing family size as proxied by the adult equivalent measure. On the other hand, increasing household adult equivalents appear to squeeze household resources such that expenditures on housing (maintenance and upkeep), other goods & services, and donations are diminished.

Farm Household Linking Elasticities

The final step in the estimation process is to obtain the elasticities that link exogenous variables from the variable profit function with the consumption expenditures derived from the AIDS model. The "linking" elasticities are calculated using all of the available coefficient estimates irregardless of their statistical significance, since these "linking" elasticities involve summations across net output equation coefficient estimates for a particular net output price or fixed asset variable. As a result, no measure of statistical significance is presented for these values.

The results for the elasticities of consumption expenditures with respect to a change in a net output price are presented in table 4. The effects are so small that net output price changes would appear to have no noticeable impact on household consumption expenditures. On the other hand, table 5 shows that the matrix of elasticities of consumption expenditures with respect to a change in the value of a fixed input were inelastic, but not negligible. A change in the value of household land holdings has the greatest impact on consumption expenditures from among the four fixed asset categories identified here, while a change in the value of household on-farm labor time has the smallest overall impact. With respect to individual expenditure categories, household expenditures on capital items appear to have the largest response to fixed asset value changes. This is understandable since both capital expenditures,which include savings and financial investments, and the purchases and value of farm assets can be expected to increase during economically prosperous times and decrease during hard times.

Alternate Specification of Consumption Side

As a whole, the estimation results from the initial ten expenditure category specification of the consumption side were disappointing. This was most particularly true of the price elasticities where very few were statistically significant and most of the calculated elasticity values appeared to be excessively large. Previous work, although generally dependent on more aggregated data, has for the most part produced elasticity estimates that are far less elastic.

Examination of the consumption price descriptive statistics (table 2) reveals that the ratios of standard deviations to means were relatively large for the prices of the three variables: donations, capital, and leisure. These three prices could be introducing substantial error into the model, particularly the estimated wage rate since it fails to account for the varying amounts of human capital at the household level. This potential error is made more acute by the fact that leisure time accounts for the majority of the mean household budget with a mean budget share value of 0.67 or 67% of total household expenditures. Thus, the majority of full income expenditure was subject to several restrictive assumptions and could have introduced and magnified unknown biases into the modelling effort.

In an attempt to gauge this problem the AIDS model was re-estimated using only seven of the original ten categories. Donations, capital, and leisure time were removed and instead treated as "predetermined" expenditures. To accomodate the new specification it must be assumed that donations, capital expenditures and expenditures on leisure time are made prior to any other allocations, such that C(p,U) now only represents the minimum cost of achieving a given level of utility from the remaining seven expenditure categories. Stated in terms of equations (9) and (10) this is:

$$C(p,\bar{U}) = Y^{*}(q;T,A,E,D) - p_L \cdot X_L - p_D \cdot X_D - p_K \cdot X_K \qquad (18)$$

where $C(p,\bar{U}) = \underset{\{X\}}{\text{MIN}} \left\{ \sum_{i=1}^{7} p_i X_i : U(X) \geq \bar{U} \right\}$, and X = 7x1 vector of expenditure categories.

This new seven category specification was estimated using the autoregressive correction procedure described earlier. The overall results were improved even though the estimation still did not produce many statistically significant price variables. However, the general magnitude of the price elasticities was much more in line with expectations. The full income variable tends once again to dominate consumption behavior, although under this new specification the household adult equivalent variable plays a much greater role.

All of the original elasticities were again estimated. Table 6 presents the full income and adult equivalent elasticities. Now the full income elasticities are significant for all six of the estimated equations (recall that the recreation equations' coefficients are solved as residuals from the other six equations), while five of the six adult equivalent elasticities are significant. The calculated elasticities are also more in line with a priori expectations than those from the earlier ten category specification. The restricted expenditure elasticity for food and clothing are now .471 and .537 respectively, versus .829 and .831 previously. Housing, transportation, and recreation expenditures appear as luxuries now with the rest of the expenditure categories being necessities.

Finally, the new "linking" elasticities that measure the effect of production side decisions on consumption side behavior were derived. Again the very small estimated values suggest no discernible effect on consumption expenditures due to net output prices, while changes in the values of fixed assets again appear important, as shown in table 7. As before, land values play the largest role from among the fixed assets categories. Housing, transportation, and recreation expenditures are the most influenced by changes in land values with the elasticity of transportation expenditures with respect to a change in land values near unity at 0.957; while housing and recreation expenditures have elasticities of 0.728 and 0.627, respectively.

CONCLUSIONS

This study demonstrates the potential richness of the results that can be obtained with agricultural household models. The analysis also clearly reveals the complexity of the empirical application for U.S. farms and the very extensive data requirements. The results for a sample of southern

Minnesota farms suggest that farm household consumption behavior is strongly affected by income. Consumption expenditures are affected by changes in fixed asset values through the household's full income.

Households appear to maintain a level of consumption in line with their perception of "permanent or long-run" income. The household's ability to secure debt during the low income years as measured by its asset values, as well as off-farm wage opportunities, influence this perception. As a result, changes in net-output prices that are perceived as short-term have little impact on the household's consumption behavior, whereas changes in asset values can have a major impact.

In the early 1980's, Minnesota, along with many other agricultural areas in the U.S., experienced dramatically falling land values, low commodity prices, and an increasing debt burden. The estimated average value per acre of Minnesota farmland reached an all time high of $1,310 in 1981, but then fell every year between 1981 and 1986 (Hagen and Raup, 1987). The 1986 average value was only $515. This dramatic decline in rural land values has undermined farm-household debt/asset ratios; thus greatly limiting credit availability and causing severe cash flow problems. Substantial reductions in consumption expenditures followed as farm households adjusted their expectations with respect to long-run income downward. The decline in farm family consumer spending has been, in turn, a major factor spreading the depression through the retail sector to the general rural economy.

In light of the problems with incorporating household leisure time into the analysis, the need for better data is apparent. Such data would necessarily have to be at a household level and include off-farm wage rates, when relevant. Better information with respect to the allocation of household time, particularly on a per member basis, as well as individual specific off-farm wages, when available, would greatly enhance the labor supply - leisure demand analysis. Furthermore, leisure presently includes the time used in household "production", i.e., domestic chores such as cooking, cleaning, and child care. These activites should be included in a separate production category in household models.

In addition, this study suggests that the dynamics underlying the operations of a Minnesota farm are sufficient to probably render the static form of the agricultural household model not fully adequate. Further theoretical developments that formally address capital budgeting procedures, long-run income expectations, and financial constraints within the framework of a dynamic agricultural household model are still lacking. Certain dynamic aspects of farm production that are not dealt with in this study are on-farm commodity storage decisions and livestock feeding from produced versus purchased grain. In addition, farm asset purchase decisions do not enter the model's static framework as choice variables. Such asset decisions affect the farm production activities undertaken. A number of studies address these issues separately. The next step is to incorporate them into a household modeling framework.

Finally, further empirical application of agricultural household models to U.S. farms will require the collection of the necessary extensive data on production, consumption, financial, time allocation, and labor market activities for farm household. Although the data from the Southeastern and Southwestern Minnesota Farm Management Associations proved inadequate in several respects, it represents some of the most complete information on combined farm household production and consumption activities available. The U.S. Department of Agriculture should be encouraged to fund first a small pilot survey and then, hopefully, a nationally representative, multi-year survey of U.S. farms to collect the requisite data.

FOOTNOTES

1 Includes personal care items and education expenses.

2 Includes stocks, bonds, and other capital purchases, nonfarm real estate, life insurance payments and savings.

3 The dollar figures in tables 1 and 2 are in nominal terms averaged across households and years, unless indicated otherwise. Conversion to real terms was not necessary, since the estimation on both the production and consumption side was with share equations.

4 Although the estimated coefficients do not vary with the deletion of an arbitrary equation, their t-statistics may vary.

5 Berndt and Saving (1975) show that, with respect to estimation and hypothesis testing in singular equation systems with autoregressive disturbances, the aggregation property of the dependent variable shares imposes restrictions on the parameters of the autoregressive process, i.e., $\rho_i = \rho_j = \rho$ for all i and j. Otherwise the specification of the model is conditional on the equation deleted. However, in this study the estimated autocorrelation terms varied so substantially over equations that when a common overall ρ estimate was used it failed to correct for autocorrelation, and for many of the equations actually worsened the results.

6 This was calculated with X_L and $T-X_L$ evaluated at their data means of 10,598 and 3,754, respectively.

7 The calculation of each particular elasticity requires the use of different parameter estimates; therefore, an elasticity is marked as significant at a particular level if the parameter estimate required for its calculation was significant at that level of significance.

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Table 1. Production Data Descriptive Statistics

Variable	Mean	Std Dev.
Value of Net Outputs (dollars per year)		
Q1	84149.36	64496.69
Q2	131712.11	131089.29
Q3	-85324.96	99828.86
Q4	-38170.55	17839.54
Q5	-11252.34	13225.53
Q6	-5347.14	6958.93
Profit	75766.48	46319.83
Net Output Profit Shares		
S1	1.334	1.433
S2	2.035	2.581
S3	-1.435	2.365
S4	-0.658	0.558
S5	-0.196	0.341
S6	-0.080	0.118
Net Output Prices[a]		
q1	70.94	12.97
q2	88.82	10.37
q3	83.08	14.92
q4	81.66	10.69
q5	57.44	9.19
q6	35.91	3.71
Household Characteristics		
A5 (number of persons)	3.95	1.53
A6 (age in years)	45.16	11.44
A7[a]	1.04	0.09
Value of Fixed Inputs (dollars)[a]		
AB	427.46	337.48
AL	1968.84	1983.88
AM	371.65	218.13
AQ	160.36	125.26
Fixed Input Shares		
RB	0.175	0.123
RL	0.547	0.257
RM	0.193	0.172
RQ	0.085	0.080

Number of observations: 483

[a]See Schnepf (1988) for a description of these variables.

Table 2: Consumption Data Descriptive Statistics

Variable	Mean	Std. Dev.
Expenditures (dollars per year)		
XF	3549.32	1455.37
XM	2188.15	1476.97
XC	1254.22	814.37
XH	4194.21	6642.81
XT	1987.84	3482.45
XR	919.15	1110.50
XO	1128.33	1013.94
XD	2600.70	2262.25
XK	10261.87	26063.33
XL	58040.53	31657.64
Full Income		
(dollars per year)	86124.32	42855.38
Adult Equivalents	3.12	1.13
Total Hh Time	14352.53	4655.95
(hours per year)		
Labor hours	3754.40	2603.16
On-farm hours	2977.06	2353.24
Off-Farm hours	777.34	1352.84
Leisure hours	10598.12	5098.72
Value of Time (dollars per year)		
Total	77695.21	30534.35
On-Farm	15650.61	12383.46
Off-Farm	4004.07	6994.22
Wages (dollars per hour)		
Nominal	5.42	1.15
Real	1.97	0.21
Relative Price Indexes		
Food	0.966	0.058
Medical	1.033	0.096
Clothing	0.652	0.077
Housing	1.118	0.080
Transportation	0.911	0.032
Recreation	0.894	0.053
Other	0.924	0.053
Marginal Tax		
Rate (percent)	12.40	9.30
Intermediate Term Interest Rate		
(percent per year)	6.63	4.56

Number of Observations: 518

Table 3: Elasticities of Consumption Expenditures with Respect to Full Income and Adult Equivalents[a]

	UNRESTRICTED		RESTRICT
	FULL INCOME	ADULT EQUIV.	FULL INCOME
FOOD	0.826*	0.113	0.829*
MEDICAL	0.836*	0.097	0.840*
CLOTHING	0.827*	0.057	0.831*
HOUSING	0.914	-0.214*	0.946
TRANSPRT	0.981	-0.256	1.011
RECREATION	1.152	-1.404	1.013
OTH_GDS	0.848*	-0.367*	0.864*
DONATIONS	0.840*	-0.526*	0.886*
CAPITAL	1.741*	-1.107	1.757*
LEISURE	0.944*	0.214*	0.937*

[a]Significance levels are: * = 1% and † = 5%.

Table 4: Elasticities of Consumption Expenditures with Respect to Net Output Prices

	q1	q3	q4	q5	q9
FOOD	1.6E-009	3.1E-010	-9.2E-010	-7.6E-010	-1.0E-010
MEDICAL	1.6E-009	3.1E-010	-9.4E-010	-7.7E-010	-1.0E-010
CLOTHING	1.6E-009	3.1E-010	-9.3E-010	-7.6E-010	-1.0E-010
HOUSING	1.9E-009	3.5E-010	-1.1E-009	-8.6E-010	-1.2E-010
TRANSPRT	2.0E-009	3.7E-010	-1.1E-009	-9.2E-010	-1.2E-010
RECREAT	2.0E-009	3.7E-010	-1.1E-009	-9.2E-010	-1.2E-010
OTH_GDS	1.7E-009	3.2E-010	-9.6E-010	-7.9E-010	-1.1E-010
DONATION	1.7E-009	3.3E-010	-9.9E-010	-8.1E-010	-1.1E-010
CAPITAL	3.4E-009	6.5E-010	-2.0E-009	-1.6E-009	-2.2E-010
LEISURE	1.8E-009	3.5E-010	-1.0E-009	-8.6E-010	-1.2E-010

Table 5: Elasticities of Consumption Expenditures with Respect to the Value of Fixed Inputs Homogeneity Restricted

	BLDGS	LAND	MCH/EQUIP	HH LAB
FOOD	0.128	0.399	0.141	0.062
MEDICAL	0.129	0.404	0.143	0.063
CLOTHING	0.128	0.400	0.141	0.062
HOUSING	0.146	0.455	0.161	0.071
TRANSPRT	0.156	0.487	0.172	0.076
RECREAT	0.156	0.488	0.172	0.076
OTH_GDS	0.133	0.416	0.147	0.065
DONATION	0.137	0.426	0.150	0.066
CAPITAL	0.271	0.846	0.298	0.132
LEISURE	0.144	0.451	0.159	0.070

Table 6: Elasticities of Consumption Expenditures with Respect to Full Income and Adult Equivalents[a]

	UNRESTRICTED		RESTRICTED
	FULL INCOME	ADULT EQUIV.	FULL INCOME
FOOD	0.428*	0.993*	0.471*
MEDICAL	0.659*	0.723*	0.674*
CLOTHING	0.531*	0.697†	0.537*
HOUSING	1.557*	-0.922*	1.512*
TRANSPRT	2.012*	-1.472†	1.989*
RECREATION	1.295	-1.228	1.302
OTH-GDS	0.563*	0.590	0.559*

[a]Significance levels are: * = 1% and † = 5%.

Table 7: Elasticities of Consumption Expenditures with Respect to the Value of Fixed Inputs Homogeneity Restricted

	BLDGS	LAND	MCH/EQUIP	HH LAB
FOOD	0.073	0.227	0.080	0.035
MEDICAL	0.104	0.325	0.114	0.051
CLOTHING	0.083	0.258	0.091	0.040
HOUSING	0.233	0.728	0.257	0.113
TRANSPRT	0.307	0.957	0.338	0.149
RECREAT	0.201	0.627	0.221	0.098
OTH_GDS	0.086	0.269	0.095	0.042