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FARM HOUSEHOLD PRODUCTION: DEMAND FOR WIFE'S LABOR, CAPITAL SERVICES AND THE CAPITAL-LABOR RATIO

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The new home economics does not deal directly with household production in the common sense of the term. Most empirical studies have concentrated on labor supply aspects of time allocation and most researchers have not distinguished between leisure and work at home. Gronau (1977) and Wales and Woodland (1977), however, are exceptions. The possible distinction between leisure and household labor becomes important when nonwage (or non-income related) time is the focus of analysis.[1/] Leisure appears to be relatively human time intensive compared to basic household production. Also, resources allocated to basic household production may change with economic growth, especially if employment and wage opportunities for women improve (Becker 1981). Empirical evidence on capital-labor substitution in the household sector is scarce, compared to the market sector. The single published empirical study of capital-labor ratios in household production is by Bryant (1976). His study has several deficiencies, including the definitions of capital as the current dollar value of the stock of consumer durables and of home time as all nonincome related time.[2/]

The objective of this paper is to present a model of household resource allocation and econometric evidence on the determinants of absolute and relative factor intensities in household production. The households that we model have a self-employed farm business and the possibility of market wage work. Demand functions for wife's leisure, wife's household labor, capital services from household appliances and housing, and the household capital-labor ratio are fitted to micro-household data from a 1977 survey.

Our econometric results show wives' household labor reacts significantly differently from their leisure to economic forces; household capital services

Prepared for AAEA meetings, Logan, Utah, Aug 1-4, 1982 and husbands' and wives' household labor are substitutes in production; and a rise in wives' wage reduces the quantity of their household labor demanded, shifts rightward the demand for household capital services and raises the household capital-labor ratio. Thus, rising real wage opportunities for women can be expected to increase the relative capital intensity of household production. Wives' general training (schooling) has no significant direct effect on the demand for their household labor, capital services or the capital-labor ratio. All effects of schooling are indirect through the wage-labor demand function and probability of wage work. In contrast, wives' home-specific vocational training is a substitute for their household labor and household capital services.

Considerable attention has been given by economists to the substitution of market goods, including maid services, nursery schools, and schools in general, for parents' time in raising children, but very little attention has been given to nonhuman capital substitution possibilities. Our results show that the presence of young children in a household shifts the demand curve rightward for both wife's household labor and capital services but lowers the household capital-labor ratio. Thus, young children are shown to be relatively intensive in mother's household time, as succinctly argued by Becker (1981). The rightward shift in the demand for wife's household labor and household capital services is smaller for children age 6 and older, and they have no significant effect on the household capital-labor ratio.

Section one presents a theoretical model of household resource allocation. Section two contains a discussion of the data set, the econometric model and empirical definitions of the variables. The results are presented in section three, and section four contains conclusions.

I. A Theoretical Model of Household Resource Allocation

The households that we model have a self-employed farm business, as well as the possibility of wage work. This business changes the model from the standard ones applied to wage earning households, as in Koster (1966), Ashenfelter and Heckman (1974) and Kneisner (1976). [3/] Other published models of farm household behavior, e.g., by Rosenzweig (1980) and Huffman (1980), model working time of farm husbands and wives outside the household. They aggregate leisure time and household working time into "nonmarket time" and ignore household production. Bryant (1976) and Evenson (1978) have presented models where leisure time and household work are treated separately, but they have assumed that farm and household production are nonjoint. In our model, we assume that household production is an important activity (and similar to farm production) and that farm and household production may be joint.

Pollak and Wachter (1975) have argued that household production itself seems likely to be joint and that this jointness should be taken into account in deriving theoretical and empirical models of household behavior. For farm households, the possibilities for joint production are much greater than for wage earning households. For example, farm output of meat, dairy, poultry, fruit and vegetables may be an input into household production. The wife's household time may simultaneously be spent preparing dinner and listening to farm market and weather information. Farm records can be prepared while supervising children, and farm and household inputs can be purchased on the same trip to town. Finally, children may work on the farm while they are growing up.

The decision unit in our model is assumed to be the single-family farm household. To explain resource allocation, farm households are assumed to behave as if they attempt to maximize household utility subject to constraints on human time, income, and a joint farm-household production function. The household utility function is assumed to be a monotone twice-continuously differentiable, strictly concave function:

$$(1)\quad U = U(Y_H, T_L),\ U_q \geq 0,\ q = Y_H,\ T_L,$$

where Y_H is household output, or home goods, and T_L is a vector representing the leisure time of the husband (T_{1L}) and wife (T_{2L}).[4/] To simplify the analysis, the allocation of human time endowments of two adults, the husband and wife, are considered as choices. Husband's and wife's time are assumed to be heterogeneous (Becker 1981, Ch. 2) and are accounted for separately in the household's time constraint. The vector of time endowments is assumed to be allocated to four uses:

$$(2)\quad T = T_F + T_W + T_H + T_L$$

where T_F is farm labor, T_W is market (nonfarm) wage labor, T_H is household labor, and T_L is leisure. Household labor is considered to be work, and it does not include time allocated to recreation, vacations, and charitable or civic activities. Time allocated to the latter activities is included in leisure time.

The technology of joint farm-household production is represented by the twice continuously differentiable, strictly concave asymmetric transformation function:

$$(3)\quad Y_F = G(Y_H, T_H, T_F, X, \gamma) \geq 0,\ G_{Y_H} < 0,\ G_q \geq 0,\ q = T_H,\ T_F,\ X,$$

where Y_F is net farm output for sale and Y_H is home goods, T_H is the vector of husband's and wife's household labor, T_F is a vector of husband's and wife's farm labor, X is a vector of purchased inputs for household and farm production, and γ is a vector of environmental and fixed inputs. Purchased inputs may include labor services, domestic services and (or) hired farm labor. Because of human capital differences (e.g., education, experience, entrepreneurial capacity), purchased labor services are not assumed to be perfect substitutes for adult family labor.[5/] The environmental inputs are characteristics that affect the efficiency of transforming inputs into outputs. The variables include weather, age (experience) and education of husband and wife, number (stock) of children at home and fixed factors.

The household receives income from off-farm wage work of the husband and wife, sale of net farm output and other nonfarm nonwage income and it is spent on purchased inputs for household and farm production:

$$(4) \quad W\,T_W + P_F Y_F + V - P_X\,X \geq 0$$

where W is a vector of market wage rates for the husband and wife. We assume spouses' market wage rates are exogenous to their current labor supply decisions and that market hours are flexible.[6/] The price P_F is the exogenous price of farm output, V is nonfarm nonwage income, and P_X is a vector of exogenous input prices.[7/] If some of husband's and wife's time are allocated to market labor, then equations (2) and (4) can be combined into a net full-income constraint:

$$(5) \quad R = W\,T + P_F Y_F + V - W(T_F + T_H + T_L) - P_X X \geq 0.$$

The Lagrangean equation for maximization of household utility (1), subject to the transformation function (3) and full income (5) is:

$$(6) \quad \psi = U(Y_H,\ T_L) + \lambda_1[Y_F - G(Y_H,\ T_H,\ T_F,\ X,\ \gamma)]$$
$$+ \lambda_2[WT + P_F Y_F + V - W(T_F + T_H + T_L) - P_X X].$$

If only interior solutions for choice variables are considered, necessary conditions for each household are:

(7) $\frac{\partial\psi}{\partial T_L} = U_{T_L} - \lambda_2 W = 0$

(8) $\frac{\partial\psi}{\partial T_H} = -\lambda_1 G_{T_H} - \lambda_2 W = 0$

(9) $\frac{\partial\psi}{\partial T_F} = -\lambda_1 G_{T_F} - \lambda_2 W = 0$

(10) $\frac{\partial\psi}{\partial X} = -\lambda_1 G_X - \lambda_2 P_X = 0$

(11) $\frac{\partial\psi}{\partial Y_H} = U_{Y_H} - \lambda_1 G_{Y_H} = 0$

(12) $\frac{\partial\psi}{\partial Y_F} = \lambda_1 + \lambda_2 P_F = 0$

(13) $\frac{\partial\psi}{\partial \lambda_1} = Y_F - G(Y_H, T_H, T_F, X, \gamma) = 0$

(14) $\frac{\partial\psi}{\partial \lambda_2} = WT + P_F Y_F + V - W(T_F + T_H + T_L) - P_X X = 0.$

Equations (7), (8), and (9) imply optimal allocations where marginal values of wife's (husband's) time allocated to leisure, household labor, and farm labor are equal to her (his) market wage rate. Equation (10) implies that the marginal value of a unit of purchased farm or household input X equals its price. Equations (11) and (12) give conditions for optimal output of home goods and farm output. Output rates are such that the marginal value of Y_H in consumption equals its marginal cost, value of foregone farm output, and the price of farm output equals its marginal cost. Equation (13) insures being on the transformation function. Net full income received is maximized in this optimizing process and equation (14) insures that net full-income received is expended.

It is well known that models of optimizing households are useful for suggesting the parameters that should explain choices. Assuming elements of γ are not household choice variables, equations (7)-(14) give a set of structural equations that can be solved (locally) for household decision rules, the demand and supply equations:

$$(15) \quad \Omega = \Omega(W, P_F, P_X, V, \gamma), \; \Omega = T_L, T_H, T_F, T_W, X, Y_F.$$ [8]

If some optimal choices are at corners rather than interior solutions, equation (15) as well as some of equations (7)-(14) must be modified. This will occur, for example, when the wife (husband) has zero hours of wage work. Corner solutions are addressed in the discussion of the empirical model.

It is well known that these neoclassical models provide relatively few comparative static results that can be compared directly to signs of estimated coefficients of the stochastic version of household demand and supply equations. The reason is that estimated price effects contain both pure price and pure income (and scale) effects, and at most only the sign of the pure price effect is known *a priori*.[9] For the sake of brevity, we present in equations (16a)-(17b) only selected comparative static results for leisure, household labor, and X_H, hereafter labeled household capital services, that are directly relevant to the empirical analysis:[10]

$$(16a) \quad \frac{\overset{+}{\partial T^*_{iL}}}{\partial V} = \frac{\overset{+}{\partial T_{iL}}}{\partial R}\,\frac{\overset{+}{\partial R}}{\partial V}, \quad i = 1, 2$$

$$(16b) \quad \frac{\overset{\pm}{\partial T^*_{iL}}}{\partial W_j} = \left.\frac{\overset{\mp}{\partial T_{iL}}}{\partial W_j}\right|_{\bar{U}} + \frac{\overset{+}{\partial T_{iL}}}{\partial R}\,\frac{\overset{+}{\partial R}}{\partial W_j}; \quad i, j = 1, 2$$

$$\text{(17a)} \quad \overset{+}{\frac{\partial \Omega^*}{\partial V}} = \overset{+}{\frac{\partial \Omega}{\partial Y_H}} \; \overset{+}{\frac{\partial Y_H}{\partial R}} \; \overset{+}{\frac{\partial R}{\partial V}}, \quad \Omega = T_{1H}, T_{2H}, X_H; \quad i = 1,2,$$

$$\text{(17b)} \quad \overset{\mp}{\frac{\partial \Omega^*}{\partial W_j}} = \overset{\mp}{\frac{\partial \Omega}{\partial W_j}}\Bigg|_{\bar{Y}} + \overset{+}{\frac{\partial \Omega}{\partial Y_H}}\Bigg|_{\bar{W}/P_X} \left\{ \overset{+}{\frac{\partial Y_H}{W_i}}\Bigg|_{\bar{U}} + \overset{+}{\frac{\partial Y_H}{\partial R}} \; \overset{+}{\frac{\partial R}{\partial W_j}} \right\}$$

$$\Omega = T_{1H}, T_{2H}, X_H, \quad i, j = 1,2,$$

where $\bar{U}$ denotes a given level of utility and $\bar{W}/P_X$ denotes given relative prices of inputs.

The predictions for the reaction of leisure to a change in other income and wage rates are standard ones. If wife's (husband's) leisure is a normal household consumption good, as most studies suggest (Keeley), then an increase in household other income (V) increases the quantity of her (his) leisure demanded. If wife's wage increases and she has positive off-farm wage hours, there is a pure substitution effect away from her leisure and a pure income effect toward her leisure. The higher wage increases real full-income and when her leisure is a normal good, the income effect of the higher wage tends to increase the quantity of her leisure demanded. The pure price and pure income effects pull in opposite directions.[11] A positive uncompensated own-wage effect is, therefore, evidence that leisure is a normal good and that the income effect dominates the substitution effect.

If husband's and wife's leisure are substitutes and his wage increases (he has positive off-farm wage hours), then the pure relative price and income effects reinforce each other on her leisure. Thus, a negative uncompensated cross-wage effect for leisure is evidence that husband's and wife's leisure are complements. The negative pure price effect of complements must outweigh the positive pure income effect.

Because of production, wife's (husband's) household labor responds differently to income and wage changes than does leisure. If home goods are normal consumption goods and household labor is a normal input (i.e., $\frac{\partial T_{iH}}{\partial Y_H} > 0$ holding W/P_X constant), then an increase in household other income increases the quantity of her (and his) household labor demanded. Although husband's time is not the focus of analysis here, his household labor might not be a normal input. It may be a rare example of an inferior input. Most time-budget studies report relatively few hours of household labor for husbands, and Gronau assumes these hours are zero (or predetermined).

The addition of (farm-) household production to our model permits additional substitution possibilities over a pure consumption model. First, a rise in the wife's wage rate causes substitution in production away from her household labor and toward other inputs, primary household capital services, holding the quantity of farm output and home goods constant $(\bar{Y})$.[12/] Second, substitution and income effects in consumption tend to increase the quantity demanded of her household labor. Home goods are less intensive in her time than is her leisure. Thus when her wage increases, the marginal cost of home goods decreases relative to her wage (price of leisure) and if husband's and wife's leisure are complements, there is a pure substitution effect in consumption toward home goods. Furthermore, real full income increases because her wage has risen. This increase also causes a pure income effect in consumption toward more of normal home goods. These substitution and income effects toward more home goods cause scale effects in production that increase the quantity demanded of her household labor. Thus, the net effect on wife's household labor of an increase in her wage is *a priori* ambiguous in direction. Models that ignore household production cannot make this prediction. Also, as the elasticity of substitution between wife's household labor and other inputs increases or as her hours of wage work decrease (provided T_{2W} remains positive), the likelihood of the substitution effect in production dominating the scale effect and the uncompensated wage elasticity of wife's household labor being negative increases. Alternatively, if there is fixed proportions in production and consumption (i.e., $\frac{\partial T_{iH}}{\partial W_j}\Big|_{\bar{Y}} = \frac{\partial Y_H}{\partial W_j}\Big|_{\bar{U}} = 0$), the uncompensated wage elasticity of wife's household labor will be positive.

In our data set, a large share of husbands report hours of household labor. A negative uncompensated effect of husband's wage on wife's household labor will indicate that husband's and wife's household labor are complements in production, but a positive relationship will be consistent with their household labor inputs being substitutes (including used in fixed proportions) or complements.

The effect on household capital services (X_H) demand of increasing other income is similar to predictions for household labor. The income effect depends on the income elasticity of home goods and the marginal input-output relationship between X_H and Y_H. Wage effects on household capital services are similar to cross-wage effects on household labor. Increasing the wife's (husband's) wage causes a pure substitution effect toward other inputs, holding $\bar{Y}$. If wife's household labor and capital services are substitutes, as we expect, then the substitution effect in production will reinforce the substitution and income effects in consumption, and cause a positive uncompensated relationship between wife's wage and the quantity of capital services demanded. Husband's household labor and capital services, however, might be complements. Evidence for this will occur as a negative effect of husband's wage on the demand for capital services.

The skills of wives (and husbands) and children at home may affect household behavior. An individual may have specific training or experience that enhances the efficiency of farm-household production but that has a negligible effect on off-farm wage offers (e.g., farm or home vocational training). Schooling, however, is general training. An increase in an individual's schooling can be expected to raise his (her) wage (labor demand curve) and to enhance the efficiency of production, i.e., increase one or both farm output and home goods. The effect of schooling on the wage can be analyzed as wage effects, equation (16b) and (17b). The gain in production efficiency from schooling (or nonmarket specific training) seems unlikely to be neutral in its effect on the shape and location of the transformation curve and on resource saving. Furthermore, enhanced production efficiency implies increased real income and consumption of home goods, which absorbs some or all of the saved resources. The net effect on the demand for leisure, household labor, and purchased household inputs is *a priori* ambiguous. Men and women have incentives to acquire different types of skills because of expected (actual) division of labor between household and income earning activities (Becker 1981, Ch. 2). Thus, we expect husband's and wife's schooling and vocational training to have different effects on the household's demand for these goods.

The presence of children can be expected to change the marginal rate of substitution between pairs of some inputs (Gronau 1977, Becker 1981 , Leibowitz 1972, Gramm 1975) and perhaps the marginal rate of transformation between outputs. For example, Becker (Ch. 2) suggests the presence of young children in the household may raise the marginal rate of substitution between wife's and husband's household labor in producing home goods, i.e.,

$$\frac{\partial[\frac{\partial Y_H}{\partial T_{2H}} / \frac{\partial Y_H}{\partial T_{1H}}]}{\partial K_1} > 0$$ where K_1 denotes the presence of young children. Young children exert a form of wife-household-labor-using bias to production technology relative to husband's household labor and perhaps to purchased household inputs. Part of the increase in wife's household labor is expected to come from reduced farm and market labor but some may also come from reduced leisure. Thus, the presence of young children may reduce both wife's income-related labor and leisure. The human-time intensity of children declines as they grow older, especially after entering school, and capital services may become more highly substitutable for parents' (wife's) household labor.

II. The Data, Estimation Technique, and Variables

In this section, the data set and the empirical specification of the model and of the variables used to investigate farm household demand for wife's leisure, wife's household labor and household capital services are discussed.

A. The data set

The data are from an area probability sample of the population of all Iowa farms having gross sales in 1976 of at least $2,500 (Hoiberg and Huffman, 1978.[13/] The data were collected by personal interviews of 933 households. The survey provides information on a wide variety of household and farm characteristics, including the annual hours of house work, farm work, and wage work for husbands and wives; the ownership and usage of household appliances; and the characteristics of housing. Table 1 presents information on the frequency distribution of husband's and wife's time. Iowa farm husbands and wives show a traditional division of labor or specialization of tasks between husbands and wives (Becker, 1981, Ch. 2). Iowa farm wives allocate most of their time to house work and husbands allocate most of their time to farm work. Sixty-five percent of the wives reported positive annual hours of farm work, and 83 percent of the husbands reported positive annual hours of house work. Off-farm wage work participation rates are 25 percent for husbands and 27 percent for wives.

Our survey data have major advantages over alternative available data sets. First, the survey asked specifically about the allocation of time to house work, farm work and wage work, rather than to only farm work and off-farm work. Second, the survey asked specifically about off-farm wage hours, rather than aggregating off-farm wage and off-farm self-employment days together, which is the method of the U.S. Census of Agriculture. Third, the survey asked about characteristics of housing and ownership of household appliances. Fourth, the Iowa survey data are from a random sample of a broadly defined population of farm households. Other farm household samples are of low income (and otherwise not randomly selected) households e.g., the farm households of the Rural Income Maintenance Experiment.

B. The econometric model

A general empirical model is proposed that can be fitted to data for all farm households. By using the whole sample, we can explain a broader range of behavior, minimize the problems of sample selection

Table 1. Distribution of Annual Hours of Work for Husbands and Wives of Iowa Farm Households, 1976

Annual hours	Wife household work	Husband on-farm work
1-999	33 (3.54)	102 (10.93)
1,000-1,999	226 (24.22)	159 (17.04)
2,000-2,499	146 (15.65)	111 (11.90)
2,500-2,999	186 (19.94)	164 (17.58)
3,000-3,499	89 (9.54)	151 (16.18)
3,500-3,999	64 (6.86)	125 (13.40)
4,000 or more	86 (9.22)	104 (11.15)
None or no response	103 (11.04)	17 (1.82)

Annual hours	Wife		Husband	
	on-farm work	off-farm work	off-farm work	household work
1-249	195 (20.90)	44 (4.72)	47 (5.04)	473 (50.70)
250-499	102 (10.93)	32 (3.43)	25 (2.68)	161 (17.26)
500-999	115 (12.33)	48 (5.14)	32 (3.43)	99 (10.61)
1,000-1,999	118 (12.65)	78 (8.36)	64 (6.86)	30 (3.22)
2,000-2,499	19 (2.04)	29 (3.11)	45 (4.82)	3 (0.32)
2,500 or more	14 (1.50)	4 (0.43)	13 (1.39)	3 (0.32)
None or no response	370 (39.66)	698 (74.81)	707 (75.78)	164 (17.58)

The numbers in parentheses are relative frequencies. There are 933 households in the survey and 78 of these households did not have a wife present.

bias, and provide empirical results that can be generalized with confidence. Our approach is in contrast to Bryant's (1976). He grouped farm households by whether the husband or wife reported farm work and (or) off-farm work, and then he fitted household capital-labor ratio equations to each of these groups separately.[14/] The problem is that households are not randomly assigned to each of these groups (Heckman 1979). Both variables observed by the researcher and variables known to respondents but unknown to the research determine the allocation of households among the groups. Thus, the empirical results from Bryant's grouped data are difficult to interpret and generalizations are with much trepidation. We construct an econometric model that permits us to utilize the whole sample to fit household demand equations for wife's leisure, wife's household labor, and household capital services.

Consider the econometric model:

$$(18)\text{-}(20) \quad T_{2j} = \beta_1^j \, \ell nW_1 + \beta_2^j \, \ell nW_2 + Z_3\beta_3^j + \varepsilon_{2j}, \; j = L,H,W,$$

$$(21) \quad X_H = \gamma_1 \, \ell nW_1 + \gamma_2 \ell nW_2 + Z_3\gamma_3 + \varepsilon_X,$$

$$(22) \quad T_{1W} = \delta_1 \, \ell nW_1 + \delta_2 \, \ell nW_2 + Z_3\delta_3 + \varepsilon_{1W},$$

$$(23)\text{-}(24) \quad \ell nW_k^o = Z_k\alpha_k + \mu_k, \; k = 1,2,$$

$$\left.\begin{array}{l} (25) \quad I_{1i} = \begin{cases} 1 \text{ iff } \nu_{1i} > Z_i\beta_1^* \\ 0 \text{ iff } \nu_{1i} \leq Z_i\beta_1^* \end{cases} \\ (26) \quad I_{2i} = \begin{cases} 1 \text{ iff } \nu_{2i} > Z_i\beta_2^* \\ 0 \text{ iff } \nu_{2i} \leq Z_i\beta_2^* \end{cases} \end{array}\right\} \; i = \text{household index}$$

(27) $\ell n W_1^o = Z_1 \alpha_1^* + \eta_1 (1 - Z_i \hat{\beta}_1^*) + \mu_1^*$,

(28) $\ell n W_2^o = Z_2 \alpha_2^* + \eta_2 (1 - Z_i \hat{\beta}_2^*) + \mu_2^*$,

where ε_{2L}, ε_{2H}, ε_{2W}, ε_X, ε_{1W}, μ_1, μ_2, ν_1, ν_2, μ_1^*, μ_2^* are vectors of random disturbance terms. When this econometric model is applied to the whole population, all disturbance terms in the basic equations (18)-(26) are assumed to have zero mean values, except ε_{iW} because T_{iW} is truncated at zero. Equations (18)-(22) are the household demand equations for wife's leisure (T_{2L}) and household labor (T_{2H}) and supply of wife's wage labor (T_{2W}). Equation (21) is the household demand equation for household capital services, and equation (22) is the household's supply of husband's wage labor (T_{1W}). The vector Z_3 in these demand and supply equations contains nonwage explanatory variables, including household asset income; age, schooling, and nonmarket vocational training of the husband and wife; number of children at home; and characteristics associated with the farm.

Equations (23)-(24) are the market wage-offer or labor demand equations faced by the husband and wife, respectively, regardless of whether they decide to supply off-farm wage labor; Z_k is a vector of personal and market characteristics that determines the individual's market wage, e.g., schooling, experience, market vocational training, geographic region. Wage data are available, however, only for husbands and wives that choose to participate in off-farm wage work, or when the individual's market wage offer exceeds her or his reservation wage. A market wage rate is observed for the wife in the i-th household if her market participation index I_{2i} of equation (26) equals one which occurs when the random disturbance ν_{2i} exceeds the systematic relationship $Z_i \beta_2^*$, where Z_i

contains the unduplicated set of explanatory variables contained in the vectors Z_1, Z_2, and Z_3.[15/] Likewise for the husband, a market wage rate is observed for him if his market participation index equals one which occurs when the random disturbance ν_{1i} is greater than $Z_i\beta_1^*$. Thus, wage data are missing for husbands and wives who do not participate in market work.

One approach to this missing data problem is to fit the wage equations (23)-(24) to observations on wage rates and characteristics of market-labor participants, and employ the fitted equations to impute wage rates for both participants and nonparticipants. The problem with this approach is market-work participation is not assigned randomly to husbands and wives, respectively (Heckman 1979). For the subset of individuals with observed wage rates, the expected value of the disturbance terms in the wage equations is nonzero, i.e., $E(\mu_{ki}/\nu_{ki} > Z_i\beta_k^*) \neq 0$, because the disturbance term ν_{2i} (ν_{1i}) of the market participation equation is a linear function of μ_{1i}, μ_{2i}, and $\varepsilon_{2Wi}(\varepsilon_{1Wi})$; it is in general correlated with the disturbance term μ_{2i} (μ_{1i}) of the wage-offer equation. The probability of a wife (husband) being included in the subsample of wives (husbands) with observed wage earnings differs across individuals. To correct this problem, we follow Olsen (1980) and modify the market-wage or labor demand equations by adding the predicted probability of an individual not participating in market work as a regressor, equations (27)-(28). The disturbance term of these equations is assumed to have a zero mean. The estimate of these equations with $(1 - Z_i\hat{\beta}_k^*)$ set equal to zero is employed to predict market-wage offers for both participants and nonparticipants.

In some studies of market-labor supply of farm household members, the land input has been treated as exogenous or as a fixed input, e.g., Rosenzweig (1977, 1980). This is a dubious assumption, however, when an active land-rental market exists and a significant share of farmland is leased on short-term arrangements. For our sample, more than 45 percent of the farmland is leased and most contracts are annual. Furthermore, a larger farming area and (or) livestock enterprises are activities for employing larger amounts of household labor on the farm. Current values of these variables seem likely to be correlated with the unobserved variables captured in some or all of the disturbances of the household demand and supply equations (18)-(22). In this study, the land input and presence of a dairy enterprise are treated as endogenous variables. These variables are regressed on a set of instruments, Z_{31} and Z_{32}:

$$\text{(29)} \quad \text{LAND} = Z_{31}\phi_{31} + \varepsilon_{31}$$

$$\text{(30)} \quad \text{D(DAIRY)} = \begin{Bmatrix} 1 \text{ if dairy enterprise present} \\ 0 \text{ otherwise} \end{Bmatrix} = Z_{32}\phi_{32} + \varepsilon_{32}$$

where ε_{31} and ε_{32} are zero mean error terms, and predicted values replace actual values in equations (18)-(22).

Slope coefficients of wage variables in household demand and supply equations are permitted to be different for market-labor nonparticipants than for participants. We have assumed that a wife's (husband's) market wage equals her (his) reservation wage if she (he) participates in market work. For nonparticipants, the modified wage equations provide good estimates of the wife's (husband's) market-wage offer, but because she (he) is a nonparticipant, her (his) market-wage offer is less than her (his) reservation wage. To proceed, we permit the coefficients of wife's and husband's wage-offer variables in the fitted household labor, leisure and capital service equations to be different depending on the outcome of the respective individual's market-participation decision. Because market work status is a household choice, the new variables are not created by multiplying the predicted wage by a dummy variable equaling 1 for a nonparticipant and 0 otherwise. Instead, we employ predicted values of the dummy, defined as $(1 - Z_i\hat{\beta}_j^*)$ for nonparticipants and $Z_i\hat{\beta}_j^*$ for participants, e.g., $\hat{D}_{2i} \times \widehat{\ln W}_{2i}^o$ where for nonparticipating wives $\hat{D}_{2i} = 1 - Z_i\hat{\beta}_2^*$ and for participating wives $\hat{D}_{2i} = Z_i\hat{\beta}_2^*$.

This completes the development of the econometric model so that the household demand equations can be fitted to the whole sample. In summary, the equations to be estimated in this paper and the sequence of estimating them are the LAND and D(DAIRY) equations, (29) and (30); the reduced-form market-work participation equations, (25) and (26), where LAND and D(DAIRY) are deleted from Z and replaced by the variables represented in Z_{31} and Z_{32} that do not duplicate variables already present in Z; the modified market wage equation, (27) and (28); and the following quasi-reduced form specification of wife's leisure, wife's household labor, and household capital service demand equations:

$$(31)\quad J = \beta_1^J \widehat{\ln W_1^o} + \beta_{11}^J \left(\hat{D}_1 \times \widehat{\ln W_1^o}\right) + \beta_2^J \widehat{\ln W_2^o} + \beta_{21}^J (\hat{D}_2 \times \widehat{\ln W_2^o})$$

$$+ \beta_{31}^J \widehat{D(DAIRY)} + \beta_{32}^J \widehat{LAND} + Z_{33}\beta_3^J + \varepsilon_J,\ J = T_{2L}, T_{2H}, X_H, X_H/T_{2H},$$

and a household capital-labor ratio demand equation, where Z_{33} is Z_3 with LAND and D(DAIRY) deleted. The equations are estiamted by least squares, ordinary and multiple stage with instrumental variables. These estimators are statistically consistent.[16/]

C. The variables

The sample households for this paper are the Iowa survey farm households in which a husband and wife are present and in which complete data on relevant variables are reported. Husbands and wives were asked by interviewers to give retrospective information for a calendar year on the amount of time that they spent working on their farm, working off their farm for a wage, and working around the house. See Table 2 for the exact definition of these and other variables used in this study and Table 3 for sample means. As an aid in recalling this information, the calendar year was split into four seasons, and each respondent was asked first to give the number of days that they worked during a season and the average number of hours worked per day. Because working time was to be allocated to three broadly defined nonoverlapping categories,

Table 2. A Summary of Empirical Definitions of Variables

Variable	Definition
Endogenous household	
T_{iH}	Household labor--work around the house, including food preparation, care of children, cleaning house, shopping, house maintenance, yard and garden work, in annual hours.
T_{iW}	Market labor--work off the farm for a wage or salary, in annual hours. It excludes work at a nonfarm self-employed business and custom or contract work on another farm.
T_{iF}	Farm-labor--work on the farm including chores, caring for livestock, repairing buildings and equipment, keeping records, field work, buying and selling, and custom and contract work performed for other farmers.
T_{iL}	Leisure--the residual of 6205 hours less the reported hours of farm labor, household labor, and off-farm labor, in annual hours.
X_H	Household capital services--the annual rental value on 20 primary (non-recreational) household appliances and housing, in 1976 dollars per year.
LAND	Farmland input--the number of acres owned and operated plus acres rented in and operated. This is one measure of farm size.
D(DAIRY)	Dairy activity--a 1-0 dummy variable, taking the value of 1 if the farm reports a dairy livestock activity, and 0 otherwise.
I_i	Market work status--a 1-0 dummy variable, taking value of 1 if individual reports positive annual hours of off-farm wage work, and 0 otherwise.
Exogenous household	
W_i^o	Market wage-annual wage and salary income from off-farm work divided by annual hours of off-farm work, dollars per hour.
AG_i	Age--individual's reported age in years.
ED_i	Education--years of formal schooling completed. It includes elementary, intermediate, high school, and college years but does not include vocational training obtained in a business or trade school.
EX_i	Experience--post-schooling experience defined as age-education-6, in years. This is approximately a measure of work experience at all types of work, not just wage or farm work experience.
$D(MVT_i)$	Market specific vocational training--a 1-0 dummy variable, taking the value of 1 if an individual obtained market oriented vocational training in high school or later, and 0 otherwise.
$D(HVT_i)$	Home specific vocational training--a 1-0 dummy variable, taking the value of 1 if an individual obtained home oriented vocational training in high school or college (i.e., home economics in high school or college degrees in home economics), and a 0 otherwise.[a/]
$D(FVT_i)$	Farm specific vocational training--a 1-0 dummy variable, taking the value of 1 if an individual obtained farm oriented vocational training in high school or college (i.e., high school vocational agriculture or college degree in an agricultural curriculum), and zero otherwise.

Table 2. Continued

$D(FRAISED_i)$ Raised on a farm--a 1-0 dummy variable, taking the value of 1 if individual was raised on a farm, and 0 otherwise.

$D(H_i)$ Health status--a health status rating reported by the wife for the individual. It takes a value of 1, if a poor health status was reported by the wife for the individual, and 0 otherwise.

K_ℓ, ℓ=1-3 Children--the age specific number of children in the household. The age groups are (1) < 6 years, (2) 6-11 years, and (3) 12-18.

V_F Permanent farm income--an estimate of the permanent cash rental on the household's equity in farmland.

V_0 Permanent other income--an estimate of the flow of income from the net value of nonfarm assets of the household (stocks, bonds, a nonfarm business). It does not include transfer or welfare payments.

MCITY Miles to city--the distance in miles from the farmstead to the nearest city with a population of 10,000 or more.

D(WEST) Geographical region--a 1-0 dummy variable, taking value of 1 if household located in western half of state, and 0 otherwise.

RAINF Average annual rainfall--the 20 year average annual precipitation for U.S. Weather Bureau station closest to the farm.

$D(DGD_q)$, q=1-5 Growing-season dummy variables. The normal crop growing season is measured as average growing-degree-days accumulated between spring and fall dates of ≤ 50% frost probability. The q-th dummy takes value of 1 if normal growing season for farm falls in q-th growing-degree-day interval, and 0 otherwise.

Other variables

RENT House rental--the household's estimate of the monthly rental for their house.

HAGE Age of house--the age of the farm house, in years.

ROOMS Rooms in house--total number of rooms in the farm household, excluding bathrooms, hallways and enclosed porches.

$D(HC_r)$, r=1-4 Other housing characteristics--a dummy variable taking the value of 1 if the house has automatic central heat, central air conditioning, attached garage, or is a mobile home, respectively, and 0 otherwise.

MSMSA Miles to SMSA--the distance in miles from the farmstead to the nearest Standard Metropolitan Statistical Area.

[a/] Market specific vocational training is training in: business courses (09), LPN-nursing (13), lab. technician (17), teaching (22), being medical or legal secretary (23), accounting (24), computers (45), business-personnel, marketing, sales (53), professional-lawyer, M.D., veterinarian (57).

Table 3. Summary Statistics of Variables

Variables	Mean		Standard deviation	
Endogenous household				
Wife's: Household labor (hr/yr)	2,298.0		1,266.0	
Wage labor (hr/yr)	262.6		585.5	
Farm labor (hr/yr)	416.1		629.8	
Leisure (hr/yr)	3,228.3		1,047.0	
Participation in wage labor	0.28	(0.26)[1/]		
Husband's: Household labor (hr/yr)	243.2		327.7	
Wage labor (hr/yr)	285.3		666.9	
Farm labor (hr/yr)	2,601.6		1,066.7	
Leisure (hr/yr)	3,074.9			
Participation in wage labor	0.25	(0.28)		
Household capital services ($/yr)	2,213.2		599.6	
Farmland input (acre yrs/yr)	333.5	(341.5)	256.3	(70.0)
Dairy activity	0.34	(0.29)	(0.48)	(0.16)
Exogenous household				
Wage offer: Husband ($/hr)	5.80	(3.97)	2.9	
Wife ($/hr)	5.10	(4.35)	14.5	
Age: Husband (yrs)	47.8		13.3	
Wife (yrs)	45.3		12.8	
Education: Husband (yrs)	11.3		2.2	
Wife (yrs)	12.7		1.7	
Experience: Husband (yrs)	30.5			
Wife (yrs)	26.6			
Market-specific voc. training: Husband	0.08		0.28	
Wife	.23		0.48	
Home-specific voc. training: Wife	0.72		0.45	
Farm-specific voc. training: Husband	0.29		0.45	
Farm-raised: Husband	0.93			
Poor health status: Husband	0.11			
Wife	0.12			
Number of children: Under age 6	0.26		0.59	
age 6-11	0.50		0.85	
age 12-18	0.73		1.07	
Asset income: permanent farm ($/yr)	10,923.3		13,573.7	
other income ($/yr)	690.1		2,936.6	
Miles to city	27.9		14.5	
Other variables				
House rental ($/mo)	144.3	(142.7)		
House age (yrs)	57.7			
Rooms in house	7.1			
House has: automatic central heat	0.83			
central air conditioning	0.19			
attached garage	0.09			
House is mobile home	0.01			
Miles to nearest SMSA	45.1		22.2	

1/ Numbers from predicted values in parentheses.

the time seems to be allocated fairly accurately to each category by the respondents.

Leisure time is defined as a residual. For a spouse, leisure is defined as 6205 hours less total annual reported hours for farm work, off-farm work for a wage, and house work for each individual. In arriving at 6205 annual hours of available time, personal-care time of 7 hours per day (2555 annual hours) was first subtracted from the maximum total hours of 8760. The reason for deducting time for personal care is that personal-care time seems to be insensitive to changes in socio-economic variables (Ghez and Becker 1975).[17/]

The empirical definition of basic household capital services is the annual rental value of the services from household appliances and housing. The Iowa survey listed twenty primary nonrecreational household appliances to which respondents were to indicate ownership.[18/] Capital services from these household appliances are derived as:

$$(29) \quad X_H^A = \sum_{i=1}^{20} P_i \, (r + d_i)$$

where P_i = market price of i-th durable good when "new" indexed to 1976 = 100, r = rate of interest, and d_i = depreciation rate of i-th durable good. Market prices of new durable goods are derived as average prices from Sears and Montgomery Ward catalogs of the appropriate year. Average ages of appliances were not established in the survey, so a uniform age distribution was assumed based on expected lifespans of appliances (K. Tippett 1978). For example, an automatic clothes washer has an expected lifespan of 11 years, average age of 6 years, and the appropriate catalog year was 1970. Because of relatively larger search costs for farm households, as opposed to urban dwellers, catalog prices seem warranted. The rate of interest is set at 0.082. The estimated rate of depreciation is a simple straight-line rate based on the expected useful lifespans, the reciprocal of the expected lifespan (see Appendix A).[19/]

Two potential sources of error exist in the estimated annual value of the stream of services from household durables. First, if the actual lifespans vary from the expected, a decrease in the lifespan increases the annual value of capital services, all else constant. Second, the value of the annual services of a durable good varies directly with the market price of the good, all else constant. If the average price estimated from the catalogs exceeds (understates) the actual prices paid by farm families for new appliances, then annual service estimates exceed (understate) the actual value of capital services.

Housing is included in our capital service measure because some characteristics of housing seem likely to be substitutes for household labor, i.e., automatic central heat, running hot and cold water, indoor plumbing, and others to be complements, i.e., larger size and number of rooms. Households were asked to provide an estimate of the monthly rental for their house. However, very few of the households actually pay a cash rental. Most own their own house or rent a farm that includes a house. Thus, about 50 households could not provide an estimate of a monthly rental, but they did provide data on the characteristics of their house. To avoid losing these observations, we chose to fit the reported rental rates to the characteristics of the house in a hedonic regression (Kain and Quigley 1970, Ball 1973), and then employ the predicted values from this regression equation as the monthly housing rental for all households.[20/] Our measure of household capital services is the imputed annual rental on the 20 household appliances and on housing.

Two estimates of the farm-family household asset income are derived from the survey data. They are permanent nonfarm nonwage income and permanent farm income. The permanent nonfarm nonwage income, hereafter called permanent other income, is an estimate of a flow of income from the net value of the nonfarm assets of the household (stocks, bonds, nonfarm business). It does not include transfer payments and welfare assistance. Permanent farm income is an estimate of the permanent cash rental on the household's equity in farmland. This permanent farm-income measure does not include returns to livestock and farm machinery.[21/]

III. The Parameter Estimates

In this section, our model of household resource allocation is tested against the Iowa micro-data set. In completing the set of variables in the equations to be estimated, five equations are identified by selectively restricting some coefficients to being zero. Table 4 presents estimates of the LAND, D(DAIRY), and husband's and wife's market-participation equations. The estimated wage equations are displayed in the text and the estimates of wife's household labor, wife's leisure, household capital services and household capital-labor ratio equations are reported in Table 5.

A. Instrumental variables

The instruments for explaining the land input and probability of a dairy enterprise are personal characteristics of the husband and locational and weather characteristics associated with the farm.[22/] Increasing husband's age has a positive but diminishing marginal effect on the land input and on the probability of a dairy enterprise. The inverted "U" shape is, however, much stronger statistically for the land input than for dairy.[23/] More schooling by husbands lowers significantly the probability of a dairy enterprise. Farms where husbands have farm-specific vocational training employ a larger land input and have a higher probability of a dairy enterprise. These coefficients are statistically different from zero at the 10 percent level. The husband being farm raised increases the land input by 86 acres, which is an economically large effect and is statistically significant. Being farm raised reflects a myriad of early farming experience and family background effects, including raising the probability of being able to lease and inherit land from parents. Farms located farther from a city have higher probabilities of a dairy enterprise and larger land area. The effect of a distance to a city on the land input diminishes as distance increases, but both effects of distance are not significantly different from zero at conventional levels.

Weather variables, normal annual rainfall and length of crop-growing season, have significant effects on the land input. The growing-season variables also have a statistically significant effect on the probability of a dairy enterprise.

The estimated coefficients in columns (3) and (4) of Table 4 are employed to generate sex-specific probabilities of market work.[24/] The results for training, family size and distance to nearest city are of particular interest. Wives, as well as husbands, who have more general training or schooling have higher (significant) probabilities of participating in market work. The magnitudes are 2.6 and 2.2 percent per year for wives and husbands, respectively. Although additional husband's schooling increases his wife's probability of wage work, the coefficient is not statistically significant, but additional wife's schooling significantly reduces her husband's probability of wage work. The positive own-effect of wife's schooling is consistent with findings for U.S. nonfarm married women, e.g., Bowen and Finegan (1969), Schultz (1980), Cogan (1980), Heckman (1980), but the positive effect of husband's schooling on wife's participation is different. The evidence is indirect, however, because husband's schooling is not generally included as a regressor in equations explaining wage-work participation of nonfarm married women, e.g., Bowen and Finegan (1969), Schultz (1980), Cogan (1980), Heckman (1980). Increasing husband's schooling raises his wage, and studies have shown that a higher husband's wage reduces the probability of wage-work for U.S. nonfarm married women (Schultz (1980), Cogan (1980), Heckman (1980)).

The results for specific vocational training are new and seem plausible. If a husband has market-specific vocational training, his probability of market work is significantly higher. Husband's market vocational training also reduces his wife's probability of wage work. A wife's market specific vocational training, however, has no significant effect on her or her husband's probability of market work. If a wife has home-specific vocational training, she is less likely to participate in wage work, but her husband is more likely to participate. Similarly, if a husband has farm-specific vocational training, his probability of wage work is reduced and his wife's probability is increased. These results for different types of specific vocational training seem to be broadly consistent with household choices regarding market-nonmarket participation being determined by relative vocational-skill advantage.

Young children have a surprisingly similar negative effect on husband's and wife's wage-work participation.[25] Increasing the number of children under age 6 reduces the probability of wife's and husband's wage work by similar (and significant) percentages, 11 and 7 percent per child, respectively. The effect on wife's participation is similar to responses of U.S. nonfarm married women (Bowen and Finegan 1962, Cogan 1980, Heckman 1980), but in contrast, labor-supply decisions of nonfarm married men seem to be relatively insensitive to the presence of young children (DaVanzo, DeTray, and Greenberg 1976). Children ages 6-11 reduce wife's market participation probability, but children ages 12-18 have no significant effect. Children ages 12-18 increase husband's probability of wage work (approaches statistical significance).[26]

For a given market wage, fixed costs associated with commuting to work can be expected to reduce the probability of market-labor participation (Huffman 1975, Cogan 1980). Thus, we expect and find the distance from the farm to the nearest city (with population ≥ 10,000) to be a significant determinant of market-work probabilities. Increasing the distance reduces the probability of wife's and husband's wage work. The negative effect of distance, perhaps surprisingly, is larger for husbands than for wives, but for both sexes the marginal effect of distance diminishes as distance becomes larger.[27/]

For nonfarm married women, the effect of asset income on labor force participation is not generally different from zero, e.g., Schultz (1980), Heckman (1980). For Iowa farm households, increasing farm asset income significantly reduces both wife's and husband's probability of wage work. Other asset income, however, has a positive but not significant effect on wage work participation of both sexes.[28/] Additional results are: Wife's poor health status lowers her probability of wage work (-21%) and raises the probability of her husband's participation by 25 percent. Husband's poor health status has no significant affect on either sexes' probability of participation. Husbands who are farm raised have a lower probability of market work (-12%) and their wives also have lower probability of participation (-10%).

Following Mincer (1974) and Heckman and Pollachek (1974), the natural logarithm of the sex-specific hourly wage rates (or market labor demand functions) are assumed to depend on the individual's personal characteristics--schooling attainment, experience

Table 4. OLS Regression Equations Explaining the Size of the Farmland Input and Probabilities of a Dairy Enterprise, of Husband's Wage Work, and of Wife's Wage Work--Iowa Farm Households (standard errors in parentheses)

Exogenous variables	Choice Variable:			
	LAND (1)	D(DAIRY) (2)	I_1 (3)	I_2 (4)
Intercept	-455.77	0.653	0.643	-0.238
AG_1	19.02	0.0098	-0.015	-0.0004
	(5.01)	(0.0089)	(0.010)	(0.011)
AG_1^2	-0.227	-0.0002	-0.00001	0.00006
	(0.052	(0.00009)	(0.00009)	(0.0001)
AG_2			0.011	0.0025
			(0.004)	(0.004)
ED_1		-0.020	0.022	0.010
		(0.008)	(0.009)	(.009)
ED_2			-0.036	0.026
			(0.011)	(0.011)
$D(MVT_1)$			0.098	-0.080
			(0.061)	(0.064)
$D(MVT_2)$			0.042	-0.004
			(0.041)	(0.042)
$D(FVT_1)$	30.90	0.057	-0.053	0.038
	(21.28)	(0.039)	(0.037)	(0.038)
$D(HVT_2)$			0.063	-0.030
			(0.038)	(0.039)
$D(H_1)$			0.047	-0.048
			(0.135)	(0.141)
$D(H_2)$			0.249	-0.206
			(0.121)	(0.127)
$D(FRAISED_1)$	86.46		-0.122	-0.095
	(37.12)		(0.061)	(0.064)
V_F			-0.011	-0.008
			(0.004)	(0.004)
V_O			0.006	0.002
			(0.005)	(0.005)
K_1			-0.071	-0.108
			(0.030)	(0.031)
K_2			0.009	-0.060
			(0.019)	(0.020)
K_3			0.021	-0.003
			(0.015)	(0.016)
MCITY	2.51	0.0012	-0.014	-0.011
	(2.41)	(0.0012)	(0.004)	(0.004)
$MCITY^2$	-0.043		0.0002	0.0002
	(0.037)		(0.0006)	(0.00006)
RAINF	8.61		0.012	0.020
	(4.63)		(0.009)	(0.009)
$D(DGD_1)$	60.93	-0.208	0.014	0.019
	(31.41)	(0.056)	(0.052)	(0.055)
$D(DGD_2)$	44.22	-0.158	-0.039	0.097
	(29.57)	(0.048)	(0.048)	(0.051)
$D(DGD_3)$	90.04	-0.259	-0.041	0.031
	(28.07)	(0.049)	(0.048)	(0.051)
$D(DGD_4)$	76.38	-0.285	-0.060	0.079
	(36.15)	(0.064)	(0.060)	(0.063)
$D(DGD_5)$	101.09	-0.236	-0.137	-0.058
	(44.09)	(0.077)	(0.074)	(0.078)
D(WEST)			0.030	0.069
			(0.040)	(0.042)
R^2	0.07	0.10	0.14	0.12
s^2/n	255.2/733	0.45/733	0.41/733	0.43/733
F	4.81	8.05	4.59	3.88

(quadratic), and completion of market-specific vocational training--a regional variable, and sample-selection correction term. Post-schooling experience is defined as an individual's age - schooling - 6 and is exogenous. Market-specific vocational training obtained in high school or later is represented by a dichotomous variable, taking a value of 1 for completion and 0 otherwise. The rational for including a geographical variable is that sufficient geographical immobility exists that differences in density of industralization between the eastern and western sections of the state can be expected to affect wage offers (or labor demand).

The estimates of the modified wage equations (standard errors in parentheses) for the husband and wife, respectively, are:

$$\ell n\ W_1^o = 1.428 + \underset{(0.023)}{0.055}\ ED_1 + \underset{(0.013)}{0.029}\ EX_1 - \underset{(0.002)}{0.0006}\ EX_1^2 - \underset{(0.134)}{0.134}\ D(MVT_1)$$

$$- \underset{(0.085)}{0.116}\ R(WEST) - \underset{(0.324)}{0.963}\ (1-Z\hat{\beta}_1^*);\ R^2 = 0.19,\ n = 153,$$

$$\ell n\ W_2^o = -0.033 + \underset{(0.048)}{0.089}\ ED_2 + \underset{(0.027)}{0.057}\ EX_2 - \underset{(0.0005)}{0.0011}\ EX_2^2 - \underset{(0.179)}{0.247}\ D(MVT_2)$$

$$- \underset{(0.155)}{0.288}\ D(WEST) - \underset{(0.633)}{0.374}\ (1 - Z\hat{\beta}_2^*),\ R^2 = 0.08,\ n = 171.$$ [29]

The estimated coefficients of schooling and experience are similar to estimates for nonfarm married males (DaVanzo, et al.) and females (Heckman 1980). One difference is that a year of wife's schooling seems to be more effective in raising her wage rate than husband's schooling is in raising his wage rate.[30] The coefficient of wife's schooling is about 50 percent larger than the coefficient of husband's schooling. Few studies have estimated wage equations for both white nonfarm married males and females from the same data set using similar control variables. Schultz (1980) is an exception. He presents results for white married males and females. At low levels of schooling (0-8 years), he finds that the coefficient of wife's schooling in her ℓn wage equation is smaller than the coefficient of husband's schooling in his wage equation. For high school and college years, the ordering of sex schooling coefficients is reversed.[31] Increasing husband's and wife's experience have the typical positive but diminishing marginal effect on their respective wage rates.

The estimated coefficients of the market-specific vocational training dummy are negative. These results are opposite expectations based upon a hypothesis of skill enhancement, but to the extent that most vocational training was obtained in high school (or college), it was at the expense of more general training. Thus our results for schooling and market vocational training, when taken together, suggest that market-specific vocational training is less valuable in raising wage rates than general schooling.[32] The coefficients for market-specific vocational training are, however, not significantly different from zero at the 5 percent level. Wage rates appear to be lower in the western section of the state than in the eastern section, especially for females. Sample selectivity is having a statistically significant effect on wage offers of husbands but not of wives. Husband's with high probabilities of wage work have higher wage offers than husbands with low participation probabilities, other wage equation regressors constant. Unobserved factors that affect women's wage offers, e.g., taste for wage work appear to be randomly assigned across them.[33/]

Estimates of the household demand equations for wife's household labor, household capital services, household capital-labor ratio, and wife's leisure are displayed in Table 5. Variables added to complete the empirical specification of these quasi-reduced form equations are husband's and wife's ages, schooling attainment, and health status dummies; wife's home-specific vocational training dummy; two asset income variables; and number of children at home in three age categories. The equations are fitted by ordinary least squares with instrumental variables for LAND, D(DAIRY), $\ell n\ W_1^o$. and $\ell n\ W_2^o$. The instruments are the predicted values of these variables obtained from the equations reported in Table 4 and the text. The slope coefficients of the wage variables are permitted to differ depending on the predicted probability of the individual's wage-work participation outcome.

B. Wife's household labor

In the demand equation for wife's household labor, all coefficients have plausible signs and the coefficients for own-wage and age-specific numbers of children are significantly different from zero. The coefficients of the two asset income variables are positive, suggesting that wife's household labor is a "normal good" and a rightward shift in the demand for wife's household labor as asset income increases. Although we showed in the theoretical model that the wife's wage coefficient could be of

Table 5. Estimated Household Demand Equations: Wife's household Labor, Household Capital Services, Household Capital-Labor Ratio and Wife's Leisure: Iowa Farm Households, 1976. (Standard errors in parentheses)[1/]

Variables	Wife's household labor	Household capital services	Household capital-labor ratio	Wife's leisure
$\widehat{\ln W_1^o}$	329.21	597.13	0.195	-536.64
	(497.83)	(282.56)	(0.303)	(488.70)
$\widehat{\ln W_2^o}$	-631.75	321.18	0.606	116.93
	(236.33)	(134.14)	(0.144)	(232.00)
$\widehat{D}_1 \times \widehat{\ln W_1^o}$	149.89	-186.56	-0.041	25.68
	(127.57)	(72.41)	(0.078)	(125.23)
$\widehat{D}_2 \times \widehat{\ln W_2^o}$	525.01	-25.73	-0.350	389.50
	(122.27)	(69.40)	(0.074)	(120.03)
$\ln V_F$	2.87	22.46	0.004	8.86
	(10.32)	(5.85)	(0.006)	(10.13)
$\ln V_o$	6.93	8.72	-0.005	14.50
	(11.18)	(6.35)	(0.007)	(10.98)
ED_1	-40.70	-22.09	0.034	59.79
	(51.87)	(29.44)	(0.032)	(50.92)
ED_2	11.73	14.13	-0.012	6.55
	(27.65)	(15.70)	(0.016)	(27.15)
$D(HVT_2)$	-84.28	-63.27	-0.004	13.99
	(91.44)	(51.90)	(0.06)	(89.76)
$D(H_1)$	-234.88	-393.67	-0.079	-231.38
	(326.26)	(185.18)	(0.199)	(320.27)
$D(H_2)$	-294.61	-95.96	-0.033	600.89
	(299.59)	(170.04)	(0.182)	(294.1)
K_1	429.84	94.99	-0.147	-314.71
	(74.98)	(42.56)	(0.046)	(73.60)
K_2	128.91	47.26	-0.016	-97.67
	(47.74)	(27.10)	(0.029)	(46.87)
K_3	45.18	28.41	-0.019	-14.46
	(37.25)	(21.14)	(0.023)	(36.57)
AG_1	4.47	10.26	-0.004	-15.15
	(19.46)	(11.04)	(0.012)	(19.10)
AG_2	3.02	0.53	-0.006	4.11
	(10.61)	(6.02)	(0.006)	(10.42)
$\widehat{LAND}$	0.633	-1.24	-0.001	-0.651
	(0.884)	(0.50)	(0.0005)	(0.867)
$\widehat{D(DAIRY)}$	-503.7	-325.61	-0.10	-390.4
	(419.6)	(328.13)	(0.26)	(412.0)
Intercept	2099.57	915.84	1.34	3285.15
R^2	0.14	0.12	0.08	0.14
s^2/n	1002.48/733	569.00/733	0.61/733	984.10/733
F	6.66	5.72	3.78	6.65

[1/] These are unadjusted standard errors from OLS regressions and should be applied cautiously. Asymptotic standard errors of the 2-stage least squares type (Johnston, p. 380-4) cannot be obtained because of the missing market wage data. When actual, rather than predicted, values of D_1, D_2, LAND and D(DAIRY) are used to obtain estimates of the error variance (s^2) of each equation, the standard errors of the coefficients are slightly larger.

either sign in the demand equation for her household labor, the coefficient is actually negative (elasticity of -0.28 at mean of T_{2H}) and significantly different from zero at the 1 percent level. Given a non-negative and probably positive income elasticity of wife's household labor, the negative own-wage elasticity implies a substitution in production away from wife's household labor toward other inputs as her wage increases. Furthermore, the results imply that home goods and wife's leisure are substitutes and that the elasticity of substitution in consumption between Y_H and T_{2L} and in production between T_{2H} and X_H are significantly different from zero, i.e., there is not fixed proportions in household consumption or production. Our results show that most, but not all, of the negative effect of wife's wage offer on the demand for her household labor is removed if she does not participate in wage work, i.e., let $\hat{D}_2 = 1$, then the coefficient of $\ln W_2^o$ is significantly reduced from -632 to -107.[34/] The positive coefficient of husband's wage is consistent with his household labor being a substitute for wife's labor in household production or with husband's and wife's household labor being complements in production and the positive scale effect dominating a negative cross wage effect. Gronau (1977), also, reports a negative own-wage coefficient for work at home by employed nonfarm married women and a positive but not significant effect of husband's wage on the demand for nonfarm wife's household labor.

The estimated coefficient of wife's schooling is positive and of her home-specific training dummy is negative, but neither is significant. Any release of labor because of enhanced efficiency must be consumed by increased demand for household labor caused by the rise in real income.

Thus, measured effects of wife's training on the amount of her household labor come indirectly through her wage rate (and predicted probability of wage work). Wives with a poor health status tend to allocate (0.8 hours per day) less to household labor than wives in good health.

Increasing the predicted probability of a dairy farming enterprise, other things equal, reduces wife's hours of household labor (approaches statistical significance). At a probability of 1.0, the implied reduction in household labor is 1.4 hours per day. In contrast, the coefficient of (predicted) LAND is positive, but not significant.

In contrast to wife's schooling coefficient, the coefficient of husband's school attainment is negative, but it also is not statistically significant. Husband's schooling does have other generally weak indirect effects on wife's household labor through his wage offer, probability of dairy enterprise and probability of wage work. A husband's poor health status tends to reduce his wife's household labor. The magnitude is similar to the negative effect of her poor health. Our results suggest a slight increase in wife's household labor as she or her husband become older, other things equal. The relatively large standard errors of these age coefficients, however, suggest no significant pure age effect on the demand for wife's household labor. Life-cycle, cohort and other age or age-difference related effects on wife's household labor are associated with the predicted wage rates, land, and probabilities of a dairy enterprise and of wage work.

The age-specific number of children have positive and significant effects on the demand for wife's household labor as expected. Also, we hypothesized in the theoretical model, the youngest children (< age 6) cause the largest increase in wife's household labor, an average of 430 hours per year per child, and the magnitude of the increase diminishes systematically for successively older age groups. Our results are similar to those of Gronau (1977) and Leibowitz (1972) and consistent with results from nonfarm female labor-supply studies, e.g., Cogan (1980), Heckman (1980). Gronau finds that the number of children age 17 or less has a positive and significant effect on wife's work at home and children of school age reduce the amount of work at home. Our results, however, suggest more clearly the dramatic difference in the average rightward shift in the demand for wife's household labor caused by number of children at home of different ages.

C. Household capital services[35/]

In the demand equation for household capital services, asset income, wage rates and family size are strong determinants. Household capital services are a "normal" good; both asset income variables have positive coefficients and the coefficient of farm asset income is significantly different from zero at the 1 percent level. Given these positive asset income elasticities, the positive wage coefficients imply that household capital services are substitutes for both husband's and wife's household labor. With the husband's wage coefficient being almost twice wife's wage coefficient (elasticities of 0.27 and 0.14, respectively), the results also imply that household capital services are more highly substitutible for husband's than for wife's household time. These results are consistent with expectations and are subjectively appealing. The coefficient of husband's predicted wage, but not of wife's, is lowered significantly when the husband (wife) does not participate in wage work.

Wife's general training and her home-specific vocation training have opposite effects on the demand for capital services. Additional schooling shifts the demand rightward, but home-specific vocational training shifts the demand leftward. Thus, home-specific vocational training appears to substitute for household capital services. These conclusions, however, have wide confidence intervals. Poor health status by both the husband and wife reduce the demand for capital services, and the reduction is statistically significant for husband's poor health. He appears to spend additional time in household labor and this time substitutes for capital services.

The estimated coefficient of LAND and probability of a dairy enterprise is negative and for land is significant. Although increasing these variables raise the relative productivity of farm labor, there is no indication that it shifts the demand for household capital rightward. There is apparently expanded farm investment opportunities that are financially more attractive than household capital goods. The estimated coefficient for husband's schooling is negative and for husband's and wife's age are positive but none is significantly different from zero.

Additional children at each age shift the demand for household capital services rightward. Similar to the effect of age-specific number of children on wife's household labor, the shift in demand for capital services is largest (and significantly different from zero) for additional children under age 6. Additional children in each successively older age group cause about a 55 percent smaller shift in demand than each child in the preceding age group. Furthermore, the t-ratios decline for the coefficients of number of children of older ages. Thus, young children cause the largest and strongest rightward shift in the demand for basic household capital services.[36/]

D. The household capital-labor ratio

Given the household capital-labor ratio is not a simple linear function of its two components, capital services and wife's household labor, and Bryant (1976) has reported equations explaining household capital-labor ratios, reporting and discussing a capital-labor ratio equation is not a redundant exercise. Farm asset or permanent income has a positive (approaches statistically significant) coefficient, but the coefficient of other income is negative and statistically significant. Thus, the effect of asset income on the capital-labor ratio depends on its source. Wife's wage has a positive and statistically significant effect on the capital-labor ratio. For wage-work participants, the elasticity of X_H/T_H with respect to wife's wage at sample mean values is 0.61. For women who are not market-work participants, our results suggest the elasticity is reduced by about 42 percent. Bryant, using a different measure of household capital and wife's work at home, also found a positive effect of wife's wage on the household capital-labor ratio in low income farm households.[37/] Wife's age, schooling, home-specific vocational training and health status do not have significant effects on the household capital-labor ratio, other things equal. Our results for wife's schooling are in contrast to Bryant's (1976) finding of a positive and significant effect for wives who work for a wage, but he makes no attempt to control for sample selection bias.

Increasing the (predicted) LAND input or probability of a dairy enterprise reduces the household capital-labor ratio, other things equal. The reduction is statistically significant for land. Husband's wage, schooling, age and health status do not have significant direct effects on the household capital-labor ratio. Consistent with hypotheses stated by Gronau (1977) and Becker (1981), children under age 6 are not only absolutely but relatively wife household-labor intensive. Additional young children significantly reduce the household capital-labor ratio. Household nonhuman capital services are relatively poor substitutes for mother's household time when young children are present in the household. Older children, however, have no significant effect on the household capital-labor ratio.[38/]

E. Wife's leisure

The demand for wife's leisure reacts quite differently than the demand for her household labor. Comparing signs of variables in the two equations, two-thirds of them are different, although all differences seem unlikely to be statistically significant.[39/] However, the null hypothesis that coefficients of the corresponding variables in the wife's household labor and wife's leisure equations are all jointly equal, except for the intercepts, is rejected. Minus 733 time the natural logarithm of the likelihood ratio for this test is 202.[40/] The critical value of the χ^2 test statistic with 18 degrees of freedom at the 5 percent significance level is 28.9. Thus, wife's leisure and her hours of household labor react differently to economic variables.

The coefficients from wife's leisure and household labor demand equations can be used to explain changes in wife's labor outside the household, combined wage and farm labor. Wife's wage coefficient in her leisure equation is positive, opposite in sign and smaller than its coefficient in her household labor equation. Thus, for wives who participate in wage work, increasing their wage causes a net increase in their labor outside the household. In contrast, for nonwage wives, the combined wage-slope coefficient in the leisure equation is larger than for wage workers and more than offsets the small negative combined wage coefficient in the household labor equation. Thus, increasing non-participant's wage offers appears to reduce their labor outside the household. As seen from our theoretical model, the positive coefficient of wife's wage suggests that the pure substitution effect reducing leisure demanded as her wage rises is being more than offset by a large positive income effect. The income elasticity of demand for wife's leisure is positive; her leisure is a normal good. Furthermore, the positive estimated coefficients for the two asset income variables in the leisure equation agree with this conclusion. Given the positive asset income coefficients in wife's household labor equation, a rise in asset income tends to reduce wife's labor outside the household. Wife's schooling and home-specific vocational training variables have positive coefficients but they are not significant.

Although husband's and wife's poor health status have similar negative effects (-0.6 hour per day) on wife's household labor, wife's poor health status increases her leisure (or nonlabor hours about 2 hours per day) and therefore implies a reduction in labor outside the household. In contrast, husband's poor health status tends to reduce wife's leisure (-0.6 hours per day), so her income related labor increases (1.2 hours per day). Thus, when a wife has poor health status, she transfers hours from household labor and farm or (and) wage labor to hours for convalescing (here labeled leisure), but when her husband has poor health status, she transfers hours from household labor and leisure to income related labor.

Although husband's and wife's household labor might be substitutes, their leisure appear to be complements. Assuming a positive income elasticity for wife's leisure, the estimated coefficient of husband's wage in her leisure equation can be negative, only if the compensated wage effect is negative, i.e., husband's and wife's leisure are complements. Furthermore, the slope coefficient of husband's wage is not changed significantly by his nonwage work participation.

Increasing the probability of a dairy enterprise reduces wife's leisure, just as it reduces her household labor. At a probability of 1.0 for a dairy enterprise, the point estimate is that a total of 2.5 hours per day of her time is transferred from household labor and leisure to work outside the household and probably to farm labor. The confidence interval is, however, relatively wide on this conclusion. Additional LAND tends to reduce wife's leisure and the hours appear to be transferred to household labor, leaving work outside the household unaffected. Increasing husband's schooling increases wife's leisure, which is in contrast to its negative (but not significant) effect on wife's household labor, and therefore tends to reduce her labor outside the household. The coefficients of husband's and wife's age variables are negative and positive, respectively, in wife's leisure equation, but they are not significant.

There is some empirical evidence and much speculation in the literature about which categories of time are reduced to provide time for child care. Our results show that additional children significantly reduce wife's leisure. The largest reduction is for children under age 6, an average of -315 hours per child-year, and the size of the reduction diminishes for children in each successively older age group. Even children in the oldest age group cause a small, but not significant, reduction in wife's leisure. Comparing the effects of children on wife's leisure to their effects on her household labor, three-fourths of the increase in hours of her household labor caused by additional children under age 12 is transferred from her leisure and the other one-fourth is from farm and (or) wage labor. Thus, for Iowa farm households, the main effect young children have on time utilization is to reduce wife's leisure and, to a much lesser extent, to reduce her income related labor. Although additional children age 6-11 cause both a larger reduction in wife's leisure and larger increase in her household labor than children age 12-18, the point estimate is that additional children in both age groups have the same negative effect on her income related labor, -30 hours per child-year. Thus, the distinction between wife's household labor and leisure has permitted us to gain new information about the sources of time associated with raising children.

IV. Conclusions

This study has presented econometric estimates of equations explaining absolute and relative factor intensities in farm household production. The need to explore household production indirectly through factor demand functions is caused by the unmeasurable nature of home goods. It does appear, however, that the value added by the household sector in developed countries like the United States exceeds 30 percent of market output and in developing countries it is much larger. Thus, resource allocation in the household sector seems to be an economically important issue. Our theoretical and econometric analyses have been of farm households where resource allocation issues are more complex than in most nonfarm households. Although farm households are less than 5 percent of all U.S. households, our approach is applicable to developing countries where farm households are in the majority and some of our empirical results can be generalized to nonfarm households.

We have successfully extended the empirical analysis of household production to the demand for two inputs, wife's household labor and household capital services. We have shown for wage-work wives that the reaction to a rise in their wage rate is to reduce the quantity of their household labor demanded, shift rightward the demand for household capital services, and raise the household capital-labor ratio. Thus, rising real wage opportunities for women can be expected to increase the relative capital intensity of household production, other things equal. Wives' general training (schooling) has no significant direct effect on the demand for their household labor, capital services or the capital-labor ratio. The effects are all indirect through their (predicted) wage rate (and probability of wage work). In contrast, wives' home-specific vocational training tends to reduce the demand for their household labor and capital services.

Considerable attention has been given by economists to the possible substitution of maids, nursery schools, and schools in general for parents' time in raising children. We have presented econometric evidence showing that young children (under age 6) shift the demand curve rightward for wife's household labor and for household-capital services and lower the household capital-labor ratio. Thus, household capital services appear to be relatively poor substitutes for mother's household time in caring for young children. The rightward shift in the demand for wife's household labor and household capital services is smaller for children age 6 and older, and they have no significant effect on the household capital-labor ratio. Thus, for older children, household capital services appear to be better substitutes for mother's household time.

Generally declining family sizes, other things equal, can be expected to reduce the demand for household capital goods of the basic production type -- basic durables and housing. Also, our results suggest that reduction of farm family size would transfer most (about 75 percent) of wife's time released from household labor to their leisure time.

Our analysis has shown that household production is time intensive relative to farm production. The capital-labor ratio is 10 times larger for farm than for household production. This suggests that there are dramatic differences in the two types of production technologies and that it has been much easier to substitute capital for labor in farm production than in household production over the past 30 years when the relative price of human time has risen dramatically. International and secular comparisons of household and farm capital-labor ratios are left for future research.

FOOTNOTES

*The authors are Associate Professor of Economics, Iowa State University and Assistant Professor of Economics, St. Cloud State University, respectively. Helpful comments were received on an earlier draft from Randall J. Olsen, Ken Wolpin and other participants in the Labor and Population Workshop, Yale University, and participants in the Applications of Economics and Agricultural Economics Workshops, University of Chicago.

1/ Household labor may be defined generally as work around the house, e.g., meal and food preparation, house maintenance, child care, lawn care and gardening.

2/ Households purchase capital goods primarily to acquire their services. The value of the stream of services from a capital good is measured in a well functioning rental market by its (annual) rental, or in its absence, the rental can be represented as a function of the rate of interest, rate of depreciation, and the original purchase price of the durable good. The depreciation rate differs across new goods of different types because of differences in the expected useful lifespans. Goods of a given type also have different ages and hence differ in the quantity of remaining services. Thus, even if one assumes the same interhousehold opportunity cost of capital, the value of the stream of services from household capital goods will not be the same fixed proportion of the current value of the stock for all households.

3/ It has similarities to Wales' (1973) model for self-employed business proprietors, and our model can be applied to any household with a self-employed income generating business.

4/ Two characteristics distinguish leisure activities from farm and household production. First, market labor services are less substitutible for husband's and wife's leisure time in producing leisure activities than are market labor services for husband's and wife's labor in farm and household production. Second, leisure activities are relatively more time (and less capital) intensive than farm and household production for given relative input prices. For example, in our study area the farm nonhuman capital services (from land, machinery and equipment, buildings and breeding stock) in 1976 prices - farm labor (operator and hired) ratio is about $10.50 per hour, and the household nonhuman capital service (from household appliances and housing) in 1976 prices - household labor (wives and husbands) ratio is $0.87 per hour. We do not have data on the capital-labor ratio in leisure activities, but we claim it is significantly lower. We make the simplifying assumption that the leisure activities of a designated individual, say the wife, requires only her time. Our results in this section depend, however, only on wife's and husband's leisure being relatively more intensive in their time than household and farm production are in their respective farm and household labor. Our view is that T_{1L}, T_{2L}, and Y_H are each composite goods (Berndt and Christensen), and husband's and wife's leisure can be complements in consumption.

5/ For households that do not have a self-employed business, equation (3) becomes an implicit production function for home goods. An implication of the productive household model and the conditions for weak separability of a function is that aggregating leisure time and household labor into a single composite consumption good called nonmarket time, as is common in models of labor supply in nonproductive consuming households, is improper aggregation. The reason is that the marginal rate of substitution between leisure and household labor is not in general independent of the consumption or employment of purchased household inputs. The utility function is not weakly separable in the group of goods containing leisure and household labor and other goods. The issue of proper aggregation of leisure and household time is nontrivial when these components of time are the center of analysis.

6/ These are simplifications that will ease the burden of the econometric model. We, also, ignore income and excise taxes (Rosen 1976, Nakamura and Nakamura 1981) for the same reason.

7/ Only a small share of our sample households report purchases of domestic services, and about 60 percent report hired farm labor.

8/ Some researchers, for example, Rosenzweig and Wolpin (1980), Fleisher and Rhodes (1979), and DeTray (1973), consider a household's completed family size (total number of children) to be a choice variable. Our approach seems to be consistent with completed family size being endogenous, provided the age distribution of a household's children is random. Other researchers, e.g., Heckman (1979, 1980), Gronau (1973, 1977), Cogan (1980), Gramm (1975), continue to treat the number of children as exogenous.

9/ Furthermore, data concerning nonlabor income are generally of such poor quality that their estimated coefficients are unreliable for estimating compensated wage and price effects (Kniesner 1976).

10/ A complete set of comparative static results is available from the authors upon request. Addition of (farm and household) production to the activities of a household changes the magnitude of the marginal effect of the wage rate on full-income received from that of a pure earning and consuming household model. The budget constraint for our producing household is a strictly concave function, opposed to being a weakly concave function for a standard pure earning and consuming household, and $\partial R/\partial\Omega = T_{W_i} + P_F \frac{\partial Y_F^*}{\partial\Omega}$, $\Omega = W_1, W_2$.

11/ If wife's leisure is an inferior good, then the predicted own-wage effect on her leisure is unambiguously negative.

12/ Substitutes and complements in production are defined analogous to the use of these terms for consumption.

13/ The survey was sponsored by the Iowa Agriculture and Home Economics Experiment Station and directed by the Statistics Laboratory, Iowa State University.

14/ Gronau (1977) also grouped nonfarm households by whether the wife reported wage work and then fitted leisure and house work equations to each of the groups separately.

15/ We define the wife's reservetion wage at $T_{2W} = 0$ and assume that she participates in off-farm wage work if her market offer wage exceeds her reservation wage. To obtain her reservation wage, take equation (20) and substitute equation (23) for ℓnW_i° to obtain:

$$T_{2W} = \beta_1^W[Z_1\ \alpha_1 + \mu_1] + \beta_2^W\ \ell nW_2 + Z_3\beta_3^W + \varepsilon_{2W}.$$

Now set T_{2W} equal to zero and solve for ℓnW_2, the wife's reservation wage:

$$\ell nW_2^R = -\frac{1}{\beta_2^W}\ [Z_1\alpha_1^W + Z_3\beta_3^W + \varepsilon_{2W} + \beta_1^W\mu_1].$$

The wife participates in off-farm wage work if $\ell nW_2^\circ > \ell nW_2^R$, or if

$$Z_2\alpha_2 + \mu_2 > -\frac{1}{\beta_2^W}[Z_1\alpha_1\beta_1^W + Z_3\beta_3^W + \varepsilon_{2W} + \beta_1^W\mu_1.$$

Grouping random disturbance terms, we have

$$\nu_2 = \mu_2 + \frac{1}{\beta_2^W}\varepsilon_{2W} + \frac{\beta_1^W}{\beta_2^W}\mu_1 > -\frac{1}{\beta_2^W}[Z_1\alpha_1\beta_1^W + Z_2\alpha_2\beta_2^W + Z_3\beta_3^W] = Z\beta_2^*$$

Because Z_1, Z_2, and Z_3 may contain overlapping variables, Z contains the set of unduplicated variables and β_2^* is a vector of coefficients associated with Z. Likewise, the husband participates in off-farm work if

$$\nu_1 = \mu_1 + \frac{1}{\gamma_1}\varepsilon_{1W} + \frac{\beta_2^W}{\gamma_1}\mu_2 > -\frac{1}{\gamma_1}[Z_2\alpha_2\gamma_1 + Z_1\alpha_1\gamma_1 + Z_3\gamma_3] = Z\beta_1^*.$$

Thus, the participation decisions of the husband and wife are determined by the same set of variables (Z).

16/ A major advantage of our suggested estimation procedure is its low computational cost. Its main disadvantage is lack of statistical efficiency. A one-step fully efficient maximum-likelihood estimation procedure of the type suggested by Heckman (1974) has prohibitive computation costs. This led Heckman (1979) to suggest a less costly, consistent but less efficient three-step estimation procedure where the probit estimation procedure is employed to predict work participation probabilities. These probabilities are transformed into Mill's ratios and added to the wage equation to correct for sample selection bias. The wage equations are estimated by generalized least squares, and predicted wage rates are utilized as instruments in the hours of work equations. Olsen's (1980) OLS procedure for sample selectivity correction has a much lower computer cost than probit, and both estimation procedures yield unbiased predictors. Thus, we have chosen to apply a low cost many-step least-squares estimation procedure.

17/ Gronau (1977) also defines leisure residually. A residual measure of leisure has the disadvantage of including hours allocated to some activities that are not widely viewed as leisure, e.g., time spent convalescing, commuting, working in a nonfarm self-employed business. Although our measure of leisure is not perfect, we believe that it contains useful information.

18/ Leisure or recreation oriented durables such as televisions, stereos, musical instruments, bicycles and sports equipment were not included. Our measure of capital does not include some basic household durable goods. No information was collected about household furnishings, clothing and some small household power tools, so they are not included in our capital service measure.

19/ The easiest and not unreasonable assumption is that the quality of services does not deteriorate with age of a durable good and that the service flow is constant over the lifespan of it. The good then falls apart and disintegrates costlessly at the end of its expected lifespan. In this case, the conversion from stock to flow is relatively simple. Assuming constant real "new" price of the good, the rental rate for services is just interest plus depreciation (1/expected life in years) multiplied by the new price of the durable good. The interest rate is the Production Credit Association average interest rate paid by borrowers in 1976.

20/ The estimate of the housing rental equation (t-ratios in parentheses) is:

$$HRENT = \underset{(8.73)}{213.88} - \underset{(-6.66)}{1.832}HAGE + \underset{(3.80)}{0.009}HAGE^2 + \underset{(2.97)}{16.76}ROOM - \underset{(-1.66)}{0.517}ROOM^2$$

$$- \underset{(-6.86)}{3.12}MCITY + \underset{(4.71)}{0.039}MCITY^2 - \underset{(-5.69)}{2.06}MSMSA + \underset{(4.49)}{0.015}MSMA^2$$

$$+ \underset{(3.98)}{20.42}D(HC_1) + \underset{(2.30)}{11.87}D(HC_2) + \underset{(3.10)}{16.7}D(HC_3) - \underset{(-4.16)}{80.6}D(HC_4),\ N = 766,\ R^2 = 0.475.$$

21/ Owned farmland comprises more than 86 percent of Iowa farm sector wealth on January 1, 1977 (U.S. Department of Agriculture, 1978). Our measure of permanent farm income appears to have a large exogenous component because Iowa farmland prices appreciated at a compound annual average rate of 19.4 percent during the six years 1970-76, which dramatically exceeds the 3.3 percent annual average appreciated rate for the previous 20 years.

22/ We have ignored heteroscedasticity in the disturbance term of the dairy equation, but the OLS estimator remains unbiased. Standard errors should be interpreted with caution because of the binomial distribution of the disturbance term.

23/ Other things equal, our results suggest that the land input peaks when the husband is a relatively young 42 years of age.

24/ Because both participations equations contain the exact same set of regressors, there is no potential gain in statistical efficiency from considering intra-household cross-equation correlation of random disturbance terms. We have also ignored heteroscedasticity in fitting these equation, but the estimator remains unbiased. Standard errors should be interpreted with caution because of the non-normal distribution of the disturbance terms in these equations.

25/ In empirical labor supply studies, the treatment of number of children in the household continues to be mixed. Economists studying human fertility consider children as choice variables, and when they conduct labor supply studies, children are generally excluded from the set of explanatory variables, e.g., Schultz (1980). Rosenzweig (1980), however, reports some market supply equations with number of young children included as regressors and some without. Labor economists (other than fertility researchers) have included and continue to include number of children as exogenous variables in female labor supply and time allocation studies, e.g., Leibowitz (1972), Gramm (1973), Gronau (1973 and 1977), Cogan (1981), Nakamura and Nakamura (1981), and Heckman (1979, 1980). Because the labor intensity of children of different ages seems to differ, there is no middle ground between the two positions. Statistical identification of more than one equation for number of children is difficult.

26/ For white not self-employed wage earning males, DaVanzo, DeTray and Greenberg (1976) have found that increasing the number of older children at home increases their weeks worked per year.

27/ The depressing effect of distance on wife's participation rate is consistent with Schultz's (1980) finding of a significantly lower wage-work participation rate for U.S. white married women who have a farm residence.

28/ Keeley (1981) discusses the sources of problems with asset income variables.

29/ These standard errors are correct for the null hypothesis of no sample selectivity. Otherwise they should be interpreted with caution.

30/ These coefficients measure the percentage change of the wage rate associated with a marginal change in schooling, other things equal. If male wage rates exceed female wage rates, then a larger percentage change may be associated with a smaller absolute change.

31/ Schultz (1980), however, makes no attempt to test for sample selectivity. It is ignored.

32/ Obtaining market oriented-vocational training might be highly associated with ability. Thus, these coefficients should be interpreted with caution.

33/ The evidence for sample selectivity in wage equations for nonfarm women is mixed. Gronau (1974) and Nakamura and Nakamura (1981) find evidence of selectivity bias, but in contrast Heckman (1979, 1980) and Cogan (1980) do not. The importance of the issue is, when sample selectivity is not present, wage equations fitted directly to data for working women can be used to impute offer wage rates for women who do not work.

34/ The size of this coefficient and others which permit wage-slope coefficients to change for nonparticipants are similar to those obtained by multiplying the predicted wage rate by actual (1-0) values of D_1 and D_2.

36/ When the definition of household capital services is expanded to include automobile services, older children are more capital intensive then young children.

35/ About 76 percent of household capital services is housing rental.

37/ His measure of household capital excludes houses (and automobiles) but includes all appliances, furniture and furnishing, sporting equipment, lawn and garden tools, jewelry, dishes, etc. His measure of wife's household time includes leisure, household labor, and personal-care time (i.e., all time not spent at farm or off-farm work).

38/ See footnote 36.

39/ In contrast, Gronau's (1977) results for employed nonfarm married women showed only 3 of 9 estimated coefficients of variables in women's work at home and leisure equations having different signs.

40/ Applying the likelihood ratio principle of generating a test statistic for a system of equations, $-733 \ln\left|\hat{\Sigma}_{\omega}/\hat{\Sigma}_{\Omega}\right|$ is distributed asymptotic χ^2, where $\hat{\Sigma}_{\omega}$ and $\hat{\Sigma}_{\Omega}$ are estimates of the variance-covariance matrix of the error terms ε_{2T_H} and ε_{2L} in a two equation system under the restricted system associated with the null hypothesis and of the unrestricted system.

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Appendix A. Durable household goods included in appliance component of capital services.

Durable goods	Average age	Estimated life-span	Prices of new goods, adjusted to 1972
1. Automatic clothes washer	6	11	220
2. Wringer washer	10	20	150
3. Automatic dryer	7	13	210
4. Refrigerator	8	15	300
5. Stove	7	13	280
6. Freezer	8	20	190
7. Dishwasher	5	11	250
8. Microwave oven	3	13	450
9. Sewing machine	7	13	120
10. Lawn mower	6	15	80
11a. Garden tractor or tiller < 3.5 H.P.	7	15	190
11b. Garden tractor or tiller ≥ 3.5 H.P.	7	15	250
12. Electric fry pan	5	10	23.50
13. Electric mixer	5	10	20
14. Electric blender	5	10	23.50
15. Toaster	4	10	14.00
16. Electric can opener	5	10	13.50
17. Slow cooker (crockpot)	3	10	20
18. Electric iron	5	10	18
19. Electric hair dryer	4	10	17
20. Vacuum cleaner	6	12	145